CLASSIC PAPERS
N.L. DUTT

HUNDRED YEARS OF EXCELLENCE IN SUGARCANE RESEARCH
SBI 100 YEARS
1912 - 2012

Sugarcane Breeding Institute
Coimbatore
2012

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CLASSIC PAPERS ON SUGARCANE

NAND LALL DUTT

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CONTENT

Dr . Nand Lall Dutt - A Brief Biography

Dr. NAND LALL DUTT was a dedicated scientist, research leader and able administrator who served in sugarcane research for more than 30 years at Sugarcane Breeding Institute, Coimbatore. He joined the institute during 1926 under Sir. T. S. Venkataraman. He was a botanist, breeder and started the breeding of tropical thick cane varieties. Associated in the development of many promising varieties like Co 419, Co 421, Co 453, Co 658, Co 740, Co 1148 which revolutionized the sugarcane cultivation in tropical and subtropical sugarcane belt and significantly improved sugarcane production. He was specialized in taxonomy, cytogenetics and pollen biology. He standardized the technique for pollen germination which helped the sugarcane breeders in to stream line the crossing programme in breeding for thick cane varieties. Influence of female parents in seed set was established by him through series of experiments. One of his significant achievements was on induction / delaying / advancing of flowering in the parents to for synchronize the desired male and female parents in crossing programme through photoperiod manipulation.

He was a prolific scientific writer and possessed in depth knowledge about the varieties. His famous book on "Coimbatore cane in cultivation" was a treasure hunt containing full account of morphological descriptors and agronomic characters of 34 varieties under cultivation. It was of great use to the sugarcane workers and sugarcane growers a descriptive account of the varieties so that they may be correctly identified in the field and the seed material may be kept pure. The cultivator benefited through the right selection of sugarcane which would best responds to the local conditions of soil and climate.

Dr. N. L. Dutt was a dedicated worker, keen observer and intelligently interpreted the observations into useful results. After working in different capacities for long time at Sugarcane breeding Institute, he was served as Director from 1950 to 1958 and retired from service.

Agricultural Journal of India 22:186-191 (1927)

PHYLLOTAXIS AND LEAF-OBLIQUENESS AS SEPARATION CHARACTERS IN SEEDLING CANES.

BY

NAND LALL DUTT, M.Sc.,

Second Cane-breeding Officer, Imperial Sugarcane Station, Coimbatore.

I. Introductory.

Increasing attention has been paid to cross-breeding work in sugarcane since the nineties of the last century when it was resorted to in Java, chiefly for obtaining disease-resistant types. Cross-bred canes have multiplied from that period onwards, and Java, India, Barbados and other cane producing countries have now their own improved seedling canes to replace the older types.

It is in certain cases rather difficult to distinguish from one another seedlings which are similar in appearance, and as the seedlings have ultimately to go to the cultivator, an easy means of identification is of great importance. But in the case of vegetatively reproduced crops like the sugarcane, the floral characters are often not available and one is forced to depend entirely on the vegetative characters. Vegetative characters which in other plants might be overlooked, often serve to separate one set of canes from another. Characters based on the measurement of parts or the relative proportion of one part to another (*e.g.*, leaf-sheath lamina, etc.) are good in their way, but their utility in the field for separating allied canes is rather limited. Definite and easily distinguishable morphological characters would seem to be desirable as guides to identification.

Attempts to provide keys for identifying grasses by their vegetative characters have previously been made by M'Alpine,[1] Ward,[2] Percival[3] and Lyman Carrier.[4]

While studying the morphological characters of seedlings and varieties, it was observed that the arrangement of leaves on the shoot and the asymmetry or inequality in width between the two halves of the lamina (on either side of the midrib) are two characters in regard to which the seedlings or the varieties of sugarcane differ among themselves. These characters are easily noticed in the field and while not of absolute classificatory value, are yet of use chiefly as additional confirmatory characters in identifying closely allied seedlings or varieties.

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[1] M'Alpine, A. N. How to know grasses by the leaves. *Standard Cyclopedia of Modern Agri.*, Vol. VI, p. 153, 1890.

[2] Ward, H. M. *Grasses*, pp. 39 to 61, Cambridge, 1901.

[3] Percival, John. *Agricultural Botany*, pp. 560 to 563, London, 1918.

[4] Carrier, Lyman. The identification of grasses by their vegetative means. *U. S. Dept. of Agri. Bull.* 461, 1917.

II. Phyllotaxis.

The leaf arrangement in grasses is typically distichous, the angular divergence between two successful leaves being 180°. This typical arrangement was found to be absent in some seedlings and varieties under study. Co. 205, Co. 210 and Co. 304 among seedlings and Katha and Saretha (Partabgarh) among varieties are some of the instances showing a disturbed phyllotaxis (*i.e.*, leaves not typically distichous). The top of the leaf-sheath of the alternate leaves shifts about a quarter of the circumference so that the angular divergence between the two orthostichies comes to be about 90°. This results in a crowding together of the leaves on one side, presenting a vacant appearance on the other. The place of origin of the leaf-sheath, however, remains in the usual distichous position. This has been termed as disturbed phyllotaxis (Pl. XXX, fig. 2a and Pl. XXXI, fig. 3a). In Pl. XXX, fig. 2b and in Pl. XXXI, fig. 3b, one row of leaves is on the right and the other on the left showing the typical distichous arrangement. In fig. 2a on Pl. XXX, the second row instead of being on the right and in fig. 3a on Pl. XXXI on the left, faces the observer. The lower three laminas have been cut to show the arrangement.

For comparison the phyllotaxes of the following grasses were also studied :— *Arundo Donax* L., elephant-grass (*Pennisetum purpureum* Schum.) and guinea-grass (*Panicum maximum* Jacq.). The shoots examined were from the same clump which was carefully washed before dissection. The relative proportions of disturbed to distichously arranged shoots per clump or row in each case are :—

	Head row No.	Disturbed arrangement	Distichous arrangement
Guinea-grass	1st clump	23	30
	2nd clump	41	50
Elephant-grass	..	11	21

Fig. 1a on Plate XXX shows a portion of clump of *Arundo Donax* L. In the shoots on the right and left the leaves are distichously arranged, while in the central shoot both the distichous and the disturbed arrangements are present. Fig. 1b separately shows this shoot and it may be noticed that four orthostichies arise as a result of the irregularity of the leaf arrangement, if the whole shoot is taken into account. From among the grasses observed, *Arundo Donax* L. stands by itself in this respect. There are, however, only two rows of leaves giving the two-ranked arrangement in any particular portion of the shoot.

For sugarcanes, Co. 281 and Co. 210 show striking differences in phyllotaxis. Two-month and six-month crops have been studied in both the seedlings to find

out indications of differences, if any, between the younger and the older stages of the plant in relation to leaf arrangement. The relative proportions of the disturbed and distichously arranged shoots are :—

	Disturbed	Distichous	Total disturbed	Total distichous
Co. 281—				
2 months	5	141	15	297
6 months	10	156		
Co. 210—				
2 months	174	29	551	53
6 months	377	24		

It will be noticed that a small percentage of disturbed arrangement shoots in Co. 281 and distichously arranged shoots in Co. 210 are met with. This brings out the fact that phyllotaxis is not an absolute character ; nevertheless the presence in a majority of cases of a particular type of leaf arrangement in a seedling or a variety suffices for practical purposes to put it down as showing the disturbed or the distichous arrangement.

In thick tropical canes the typical distichous arrangement seems to be the rule. Out of thirty-seven varieties and seedlings examined for this purpose, only Vellai, J. 247 P. O. J. 2688 and P. O. J. 2690 were observed to show disturbed shoots and in each case the percentage was negligible.

III. Obliqueness of leaf.

It is perhaps generally known that in the sugarcane leaf the halves of the lamina on either side of the midrib are unequal in width. That this asymmetry or obliqueness is constant for a particular seedling or a variety is seen from the table below. It will also appear that seedlings and varieties differ as to the extent in the leaf in which obliqueness is noticed. All grades from oblique practically the entire length, oblique up to middle, oblique up to basal one-third, to more or less symmetrical leaves are met with. The measurements in the subjoined tables were made on leaves taken from the row of canes without any attempt at selecting any particular leaf. Table I gives the averages based on measurements of 195 leaves. Table II gives the actual measurements of ten leaves from two of the seedlings.

TABLE I.

Showing measurements of lamina halves in Co. 210 and Co. 281.

Seedling	Class value	Two-month crop						Class value	Six-month crop					
		BASE		MIDDLE		TOP			BASE		MIDDLE		TOP	
		Narrow half	Wide half	Narrow half	Wide half	Narrow half	Wide half		Narrow half	Wide half	Narrow half	Wide half	Narrow half	Wide half
Co. 210	c.m.							c.m.						
	0·50—0·60	..	..	..	..	11	5	0·80—0·90	37	..	..	..	1	1
	0·60—0·70	6	..	1	..	9	9	0·90—1·00	11	17	..	..	5	3
	0·70—0·80	13	2	4	..	4	10	1·00—1·10	14	15	..	..	3	2
	0·80—0·90	5	13	7	2	..	..	1·10—1·20	8	13	..	..	4	4
	0·90—1·00	1	6	7	7	..	..	1·20—1·30	..	19	6	1	20	9
	1·00—1·10	..	2	6	11	..	..	1·30—1·40	..	1	6	..	7	13
	1·10—1·20	..	2	..	4	..	..	1·40—1·50	..	4	20	4	14	12
	1·20—1·30	..	..	..	1	..	..	1·50—1·60	..	1	22	9	3	9
								1·60—1·70	..	..	9	16	1	5
								1·70—1·80	..	..	5	21	1	..
								1·80—1·90	..	..	2	14	..	1
								1·90—2·00	..	..	..	4	..	..
								2·00—2·10	..	..	..	..	..	..
								2·10—2·20	..	..	..	1	..	..
	Average	0·76	0·88	0·90	1·04	0·63	0·65	Average	0·95	1·10	1·51	1·71	1·23	1·30
Co. 281	c.m.							c.m.						
	0·50—0·60	10	..	..	..	4	2	0·70—0·80	5	1	..	..	..	..
	0·60—0·70	9	5	..	..	13	7	0·80—0·90	5	..	..	..	..	..
	0·70—0·80	6	13	9	6	6	13	0·90—1·00	14	3	..	..	1	..
	0·80—0·90	..	7	10	12	2	3	1·00—1·10	18	11	4	3	8	7
	0·90—1·00	..	..	5	6	..	..	1·10—1·20	18	23	5	5	4	5
	1·00—1·10	..	..	1	1	..	..	1·20—1·30	8	18	8	9	11	8
								1·30—1·40	7	12	6	4	13	10
								1·40—1·50	..	3	11	9	12	9
								1·50—1·60	..	3	12	15	5	7
								1·60—1·70	..	1	12	12	3	4
								1·70—1·80	..	..	8	6	2	2
								1·80—1·90	..	..	4	7	..	1
								1·90—2·00	..	..	4	3	..	..
								2·00—2·10	..	..	..	1	..	..
								2·10—2·20	..	..	1	1	..	..
	Average	0·64	0·75	0·80	0·84	0·72	0·77	Average	1·08	1·23	1·50	1·55	1·34	1·38

TABLE II.

Seedling	No.	Two-month crop						No.	Six-month crop					
		BASE		MIDDLE		TOP			BASE		MIDDLE		TOP	
		Right half	Left half	Right half	Left half	Right half	Left half		Right half	Left half	Right half	Left half	Right half	Left half
Co. 210	1	0·96	0·64	1·03	0·80	0·75	0·66	1	1·15	1·45	1·45	1·86	1·13	1·12
	2	0·95	0·79	1·13	0·98	0·77	0·67	2	1·25	0·97	1·73	1·55	1·35	1·24
	3	0·80	0·63	0·95	0·85	0·58	0·52	3	1·55	1·15	1·88	1·55	1·38	1·28
	4	0·81	0·95	1·08	1·18	0·69	0·75	4	1·03	0·87	1·73	1·53	1·18	1·07
	5	0·86	0·70	0·94	0·90	0·58	0·58	5	1·13	1·23	1·51	1·75	1·00	1·12
	6	0·90	0·78	1·05	0·90	0·71	0·70	6	1·00	1·15	1·58	1·62	1·00	1·00
	7	0·74	1·03	0·92	1·05	0·75	0·75	7	1·21	1·00	1·61	1·47	0·85	0·85
	8	0·98	0·80	1·10	1·04	0·72	0·73	8	1·22	1·09	1·90	1·75	1·40	1·40
	9	0·85	0·80	1·20	1·07	0·73	0·73	9	1·20	0·90	1·90	1·60	1·35	1·28
	10	0·84	0·64	0·90	0·78	0·70	0·64	10	1·26	1·12	1·82	1·61	1·51	1·39
Co. 281	1	0·61	0·70	0·71	0·75	0·68	0·70	1	1·38	1·30	1·85	1·90	0·96	1·01
	2	0·62	0·73	0·82	0·83	0·68	0·77	2	1·27	1·35	1·60	1·58	1·19	1·23
	3	0·84	0·56	0·85	0·80	0·80	0·70	3	1·10	1·19	1·70	1·70	1·57	1·57
	4	0·90	0·65	0·85	0·83	0·73	0·62	4	1·35	1·15	1·84	1·78	1·83	1·78
	5	0·55	0·69	0·78	0·78	0·60	0·65	5	1·20	1·35	1·80	1·80	1·50	1·55
	6	0·73	0·60	0·85	0·72	0·64	0·57	6	1·30	1·19	1·73	1·73	1·35	1·25
	7	0·75	0·72	0·82	0·82	0·59	0·46	7	0·84	1·00	1·40	1·43	1·37	1·35
	8	0·88	0·75	0·75	0·75	0·73	0·65	8	1·05	1·14	1·76	1·76	1·58	1·62
	9	0·65	0·78	0·90	0·95	0·70	0·70	9	1·25	1·14	1·92	1·92	1·50	1·56
	10	0·68	0·72	0·90	0·90	0·70	0·55	10	1·05	1·10	1·60	1·58	1·45	1·49

From the above table it is seen that Co. 210 is oblique throughout its whole length. A difference of about two millimeters at base and middle between the two halves in the two-month as well as the six-month crop is easily noticed by the naked eye. There is a difference at the top also but it is not appreciable. In Co. 281 the lamina halves are appreciably unequal in width at base. The difference at middle and top though noticeable when measured with calipers is not appreciable to the eye. Fig. 2 on Plate XXXI shows the symmetrical and asymmetrical leaves. It will be noticed that the eye perceives the difference in width between the two halves in Fig. 2*a* and Fig. 2*b*. The halves in Fig. 2*c* are practically symmetrical though not absolutely true to the calipers.

The measurements in the above tables have been supplied to provide the statistical basis for eye judgment. The eye very easily detects a difference, if there is any, between the widths of the two halves of the lamina, and it is possible to say without measuring whether a particular leaf is from Co. 210 or Co. 281 shoot. It cannot be denied that leaf-obliqueness like phyllotaxis is not an absolute character, but it is an easily recognizable one and as such is preferable to very minute and obscure characters. Very often it may happen that these two characters (leaf-obliqueness and phyllotaxis) are the same or not very different for the seedlings intended to be compared, but their value chiefly lies in being easily noticeable and as additional characters for identification.

My thanks are due to Mr. S. U. Khan, Superintendent, Central Farm, Coimbatore, for affording facilities for observations in guinea-grass. Botany Assistant M. P. Gourisankara Ayyar has been of great help in taking measurements.

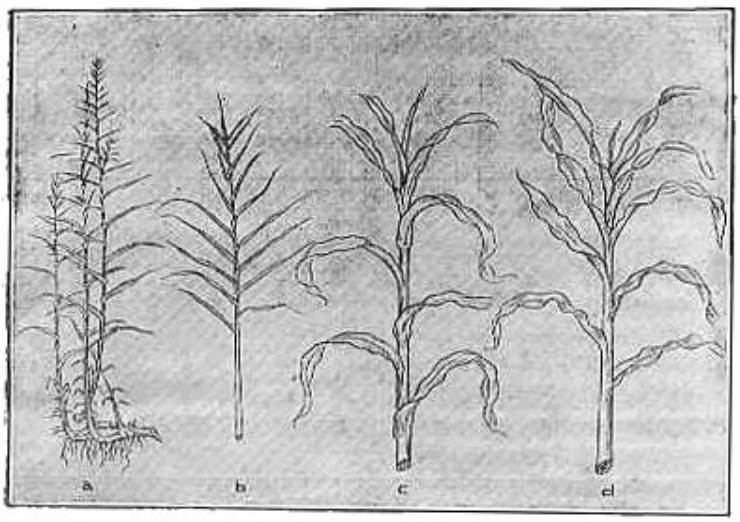

Fig. 1. (*a*) showing a portion of clump of *Arundo Donax*, L.
(*b*) central shoot of (*a*) shown separately.
(*c*) a shoot of sorghum showing disturbed phyllotaxis.
(*d*) another shoot of sorghum showing regular distichous arrangement.

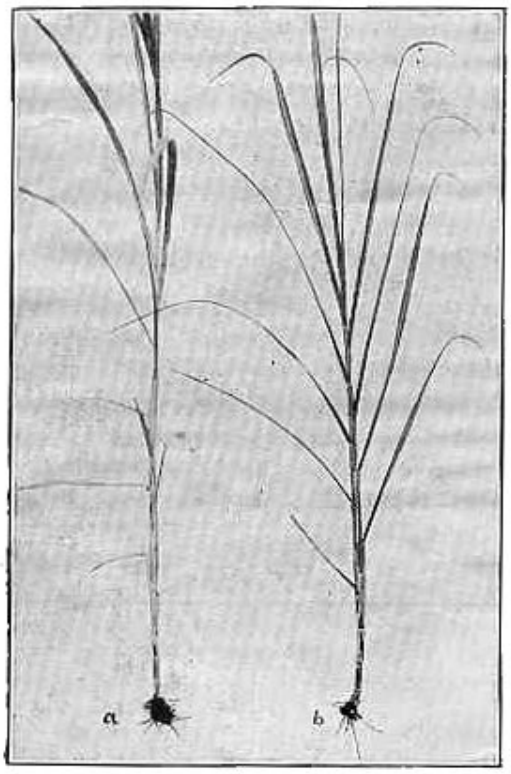

Fig. 2. (*a*) Co. 210 showing disturbed arrangement.
(*b*) Co. 281 showing typical distichous arrangement.

PLATE XXXI.

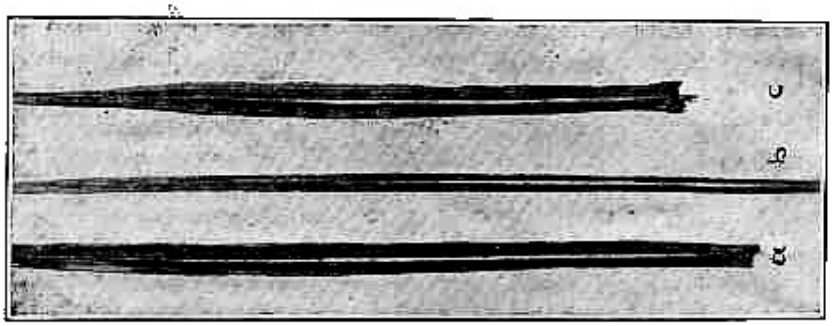

Fig. 2. *a*. P. O. J. 2690. Leaf asymmetrical.
b. Co. 210. Leaf asymmetrical.
c. B. 6308. Symmetrical leaf.

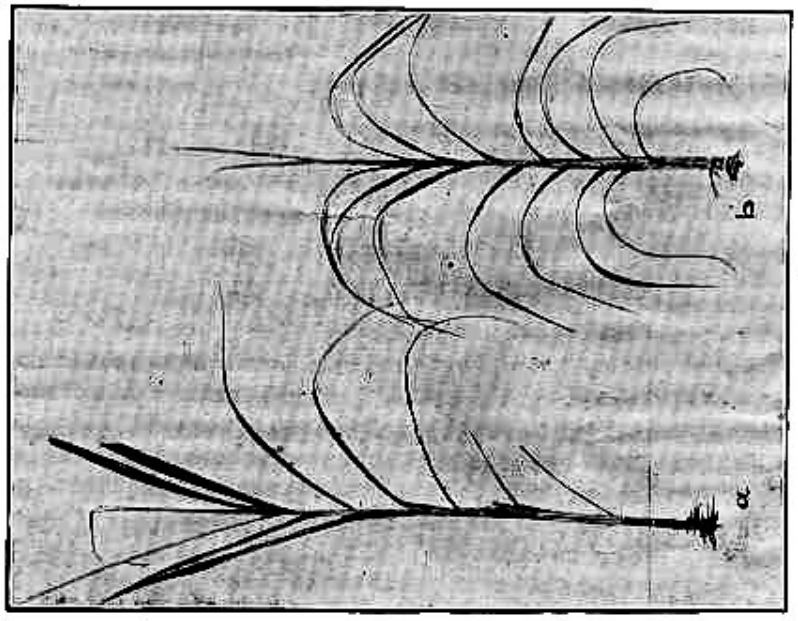

Fig. 1. *a*. P. O. J. 2688 showing disturbed arrangement.
b. B. 6308 showing typical distichous arrangement.

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STUDIES IN SUGARCANE POLLEN WITH SPECIAL REFERENCE TO LONGEVITY.

BY

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I. Introduction.

Sugarcane pollen studies have a direct bearing on the problems connected with sugarcane breeding, and engaged the attention of Wilbrink and Ledeboer,[1] Barber,[2] Venkatraman,[3] Calvino,[4] Cottrell-Dormer,[5] and more recently Weller[6] and Mercado.[7] Weller in his paper concludes that the "Methods for determining viability of sugarcane pollen have not been satisfactory because (1) they do not discriminate between viability and maturity, as, for example, the iodine method; (2) they are not adapted mechanically for securing counts in large numbers so that viability may be determined upon a quantitative basis, as, for example, the method of using the stigmatic surfaces of various plants such as *Hibiscus*, *Ipomea*, and *Datura*."

The importance of pollen viability tests to sugarcane breeding and the failure or partial success of the previous workers to germinate sugarcane pollen artificially, suggested the retrial of various culture media in the arrowing season 1926, and after some experimentation 26 per cent. sugar and 0·7 per cent. agar was found to be the most suitable culture medium. With this medium the pollen of some of the Barbados, Coimbatore, Demerara, Java and Mauritius varieties was successfully cultured under artificial conditions.[8] The data available from these viability

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[1] Wilbrink, G., and Ledeboer, F. De Geslach telijke Voortplanting Bij Het Suikerriet. *Archief Voor de Suikerindustrie*, Jaargang XIX, 1 Deel, 1911.

[2] Barber, C. A., Studies in Indian Sugarcanes, No. 2. *Mem. Dept. Agri. India, Bot. Series*, Vol. VIII, No. 3, p. 126, 1916.

Barber, C. A. A direct method of germinating sugarcane pollen grains. *International Sugar Journal*, Vol. XXVII, pp. 358-359, July 1924.

[3] Venkatraman, T. S. Germination and preservation of sugarcane pollen. *Agri. Jour. India*, Vol. XVII, pp. 127-132, March 1922.

[4] Calvino, E. M. Notas sobre la Fertilidad de las flores de la cana. *Chaparra Agricola*, Vol. I, No. 3, pp. 17-19, July 1924.

[5] Cottrell-Dormer, W. Studies on fertility of sugarcane flowers. *Planter and Sugar Manufacturer*, Vol. LXXIII, No. 20, pp. 389-391, Nov. 15, 1924.

[6] Weller, D. M. Progress Report of Sugarcane Pollen Studies. *Hawaiian Planters' Record*. Vol. XXX, No. 3, pp. 400-414, July 1926.

[7] Mercado, T. Study of flowering habits and flower characteristics of three sugarcane varieties. *Phillippine Agriculturist*, Vol. XV, No. 4, pp. 181-204, Sept. 1926.

[8] Dutt, N. L., and Ayyar, G. Ganapathi. Germination of sugarcane pollen in artificial culture media. *Agri. Jour. India*, Vol. XXIII, Part III, pp. 190-202, 1928.

tests have been helpful in shaping the hybridization programme at the Thick Cane Section of the Imperial Sugarcane Station, Coimbatore.

With a view to corroborating the results obtained in the 1926 season, but chiefly with the object of prolonging the viability of sugarcane pollen, the studies were continued in the 1927 and 1928 arrowing seasons.

II. The pollen grain.

The sugarcane pollen is yellow in colour and ellipsoidal to spherical in shape (Plate XXII, fig. 1). In the fresh and dry condition it varies in size from 38·25μ ×42·75μ to 67·5μ×72·0μ. It contains about 48 to 51 per cent. moisture. Fig. 4 (Plate XXII) shows the smoothness of the grain, and the presence of the single pore.

Such characters as the number of folds and germinal apertures of the pollen grain, and the character and arrangement of the papillæ on the surface, have been shown to be of classificatory value and indicative of phylogenetic relationship, by Gagnepain[1] for Geraniaceæ, Kohler[2] for Gentianaceæ, Urban[3] for Bignoniaceæ and Wodehouse[4] for Vernoniaceæ. These characters will not be helpful in the sugarcane, as in the pollen of all the varieties that were examined, the grains were smooth and with one germinal aperture.

Sugarcane varieties, however, differ in the amount of abortive pollen that they contain. This fact may be indicative of the hybrid origin of the variety or varieties containing abortive pollen, but is difficult to press into service for demarcating one variety from the other. Morphologically normal pollens range in dimension between 38 and 72μ when dry and fresh, and germination was noticed to take place irrespective of the size of the normal grain (Plate XXII, fig. 5). The aborted pollen is incapable of germination, and the percentage of such pollen in a variety will, to a certain extent, be a factor for its success or otherwise as a male parent.

III. The culture medium and moist chamber.

Tests made during the 1927 arrowing season showed that in the preparation of the culture medium, commercial white sugar could with advantage be substituted for chemically pure sucrose.[5] In 1928 the constituents of the culture medium were varied rather elaborately to study their effect on germination. It will be seen from Table I that ordinary white sugar and shred agar suit the artificial culture of sugarcane pollen best. It was further found that filtered rain water could take

[1] Gagnepain, F. Contribution a l etude du pollen des Geraniacees. *Bull. Soc. Hist. Nat.d' Autun*, XVI, 83, 1903.

[2] Kholer, A. Systematischer Wert der Pollenbeschaffenheit beiden Gentiaceen. Mitteilungan aus dem *Bot. Mus. der Universitat*, Zurich, XXV, 1905.

[3] Urban, I. Ueber Ranken und Pollen der Bignoniaceen. *Ber. Deutch. Bot. Ges*, XXXIV, 9, pp. 728-58, 1916.

[4] Wodehouse, R. P. The phylogenetic value of pollen grain characters. *Ann. Bot.*, Vol. XLII, pp. 891-934, 1928.

[5] Dutt, N. L. Pollen studies (Culture Medium). *Sci. Rep. Agri. Res. Inst. Pusa*, 1927-28, p. 139.

PLATE XXII.

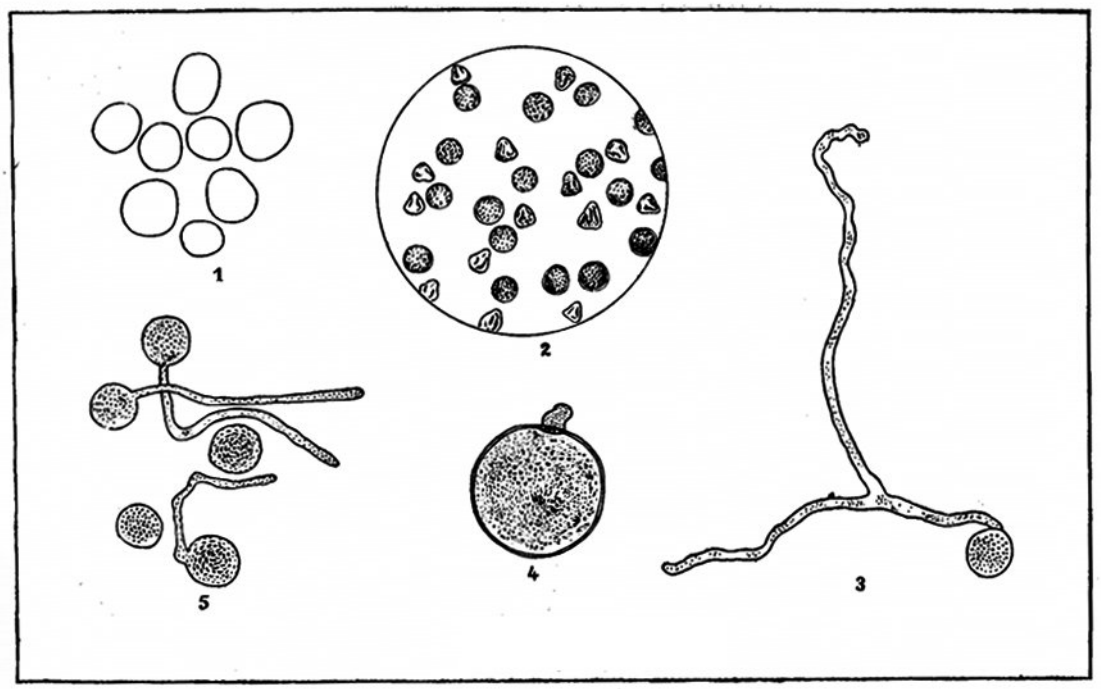

Fig. 1. P. O. J. 2696. Showing shape of fresh and dry pollen.
Fig. 2. Normal and aborted pollen in a mixture of pollen of some varieties.
Fig. 3. Co. 213. Bifurcation of the pollen tube.
Fig. 4. P. O. J. 2696 pollen enlarged showing the single pore.
Fig. 5. P. O. J. 2696. Germination takes place irrespective of the size of the pollen.

the place of distilled water and that germinations did result on the use of 19 days old filtered rain water as solvent in the medium.

TABLE I.

Pollen germination as effected by varying certain constituents of the culture medium.

Date	Name of variety	Nature of the* culture medium	Percentage of germinations	Length of pollen tubes	REMARKS
12th October 1928	Co. 243	26 per cent. sugar and 0·7 per cent. shred agar in distilled water.	12·86	long	In the preparation of the culture medium filtered rain water may be substituted for distilled water.
Ditto	Ditto	26 per cent. sugar and 0·7 per cent. shred agar in filtered rain water.	11·94	medium	
Ditto	Ditto	Distilled water alone	1·23	short	The longest pollen tube was 1029μ.
14th October 1928	Ditto	26 per cent. sugar and 0·7 per cent. shred agar in distilled water.	13·7	medium	Commercial sugar can be substituted for sucrose.
Ditto	Ditto	26 per cent. sucrose and 0·7 per cent. shred agar in distilled water.	12·17	short to medium.	
15th October 1928	Ditto	5 per cent. sugar and 0·7 per cent. shred agar in distilled water.	2·0	short	Sugarcane pollen germinates in quite a wide range of sugar concentrations.
Ditto	Ditto	10 per cent. sugar and 0·7 per cent. shred agar in distilled water.	2·6	short	
Ditto	Ditto	15 per cent. sugar and 0·7 per cent. shred agar in distilled water.	2·8	short	
Ditto	Ditto	20 per cent. sugar and 0·7 per cent. shred agar in distilled water.	13·4	medium	
Ditto	Ditto	26 per cent. sugar and 0·7 per cent. shred agar in distilled water.	12·0	long	
16th October 1928	Ditto	30 per cent. sugar and 0·7 per cent. shred agar in distilled water.	9·8	medium	
27th October 1928	P. O. J. 2696	35 per cent. sugar and 0·7 per cent. shred agar in distilled water.	only five germinations.	short	35 per cent. sugar and above do not suit artificial culture of sugarcane pollen.
Ditto	Ditto	40 per cent. sugar and 0·7 per cent. shred agar in distilled water.	only one germination.	short	

* Whatever the composition of the culture medium, 2 to 3 drops of it were placed at the bottom of the moist chamber and it was spread into a thin layer on the cover slip which after dusting the pollen was inverted at the top of the chamber.

TABLE I—*concld.*

Pollen germination as effected by varying certain constituents of the culture medium—concld.

Date	Name of variety	Nature of the * culture medium	Percentage of germinations	Length of pollen tubes	REMARKS
27th October 1927 .	P. O. J. 2696	45 per cent. sugar and 0·7 per cent. shred agar in distilled water.	no germination.		35 per cent. sugar and above do not suit artificial culture of sugarcane pollen.
Ditto .	Ditto .	50 per cent. sugar and 0·7 per cent. shred agar in distilled water.	no germination.		
18th October 1928 .	Co. 243 .	26 per cent. sugar and 0·7 per cent. shred agar in distilled water.	13·7	short . .	Addition of fresh potato juice helps the sugarcane pollen tube growth.
Ditto .	Ditto .	26 per cent. sugar and 0·7 per cent. shred agar fresh potato juice.	14·2	medium . .	2 drops of fresh potato juice in 10 c.c. of distilled water. One drop of this solution added to 2 c.c of normal culture medium.
19th October 1928 .	P. O. J. 2696	26 per cent. sugar and 0·7 per cent. shred agar fresh potato juice.	17·2	long . .	
Ditto .	Ditto .	26 per cent. sugar and 0·7 per cent. shred agar in distilled water.	16·8	long . .	

* Whatever the composition of the culture medium, 2 to 3 drops of it were placed at the bottom of the moist chamber and it was spread into a thin layer on the cover slip which after dusting the pollen was inverted at the top of the chamber.

As to the most suitable concentration of sugar in the culture medium, it will be seen from Table I that the results are in substantial agreement with those obtained in 1926. 26 per cent. sugar plus 0·7 per cent. agar gave best results though germinations are obtained even when mere distilled water alone is used, or with 5, 10, 15, 20, and 30 per cent. sugar solution plus 0·7 per cent. shred agar. The results with 35, 40, 45, and 50 per cent. sugar solutions were either insignificant or negative.

As a result of the 1926[1] work, it was stated that in order successfully to culture sugarcane pollen artificially, it was a necessary pre-requisite to have a glass ring, 7·5 mm. high and 17 mm. in diameter, vaselined at top and bottom to ensure a fairly air-proof moist chamber. The results detailed in Table II point to the fact that any sized moist chamber ranging from 1·2 cm. to 15 cm. in diameter and 0·5 cm. to 1·5 cm. in height could be used, and though germinations are obtained if the moist chamber be not air-proof, it would be an advantage to have it so. As the 1926 work indicated, it was further found advantageous to have the sugar agar

[1] *ibid.*

solutions spread into a thin film at the top of the moist chamber, instead of having it as a large hemispherical drop presumably because, as pointed out by Adams,[1] oxygen is more readily obtained by the dusted pollen grains in this way.

TABLE II.

Pollen germination as effected by the size and the air-proof condition of the moist chamber.

Date	Variety	Size of moist chamber		Vaselined or not	Nature of pollen tubes	Per cent. germination
		Diameter	Height			
17th October 1928	P. O. J. 2696	12 mm.	5 mm.	vaselined	medium to long	12·1
Ditto	Co. 243	17 mm.	7·5 mm.	vaselined	medium	12·6
Ditto	Ditto	,,	,,	un-vaselined	medium	11·3
Ditto	P. O. J. 2696	,,	,,	vaselined	medium	10·8
Ditto	Ditto	,,	,,	un-vaselined	medium	9·6
12th October 1928	Co. 243	15 cm.	1·5 cm.	vaselined	long	12·09
Ditto	Ditto	Control. *		vaselined	long	12·86
13th October 1928	Ditto	15 cm.	1·5 cm.	un-vaselined	medium to long	13·08
Ditto	Ditto	Control.		vaselined	long	13·17

* In the control the diameter of the moist chamber was 17 mm. and the height 7·5 mm.

IV. POLLEN TUBE GROWTH.

The time that the pollen tube will take to reach the ovary naturally varies according to the distance and the nature of the path which it has to traverse. That greater distance does not always entail greater interval between pollination and fertilization is brought out by the classical instances given by Hofmeister[2] and Schleiden.[3] In *Crocus* with a style 6 to 10 cm. long, the pollen tube covered the distance in one to three days and in *Arum* where the length of the style is only 2 to 3 mm. it took five days for the tube to do the distance; while according to Schleiden in *Cereus grandiflorus* having a style 9 inches long, only a few hours are required for the descent of the tube.

Though very long tubes under artificial culture are not on record, Brink,[4] Knight,[5] and Bobilioff-Preisser[6] working on *Scilla* and *Vinca minor* pollen, successfully

[1] Adams, J. On the germination of the pollen grains of apple and other fruit trees. *Bot. Gaz.*, Vol. LXI, pp. 131-147, 1916.

[2] Hofmeister, W. Neue Beitrage zur Kenntniss der Embryobildung der Phanerogamen. *Abhandl. Konigl Sachs. Gesell. Wiss.*, 6, 533-672, 1859.

[3] Schleiden, M. J. *Principles of Scientific Botany*, p. 407, 1849. (Gray's Botanical Text-book, by Goodale, Vol. II, p. 431, 1885.)

[4] Brink, R. A. The Physiology of Pollen. III. Growth *in vitro* and *in vivo*. *Amer. Jour. Bot.*, Vol. XI, pp. 351-364, 1924.

[5] Knight, L. J. Physiological aspects of self-sterility of the apple. *Proc. Amer. Soc. Hort. Sci.*, Vol. XIV, pp. 101-105, 1917.

[6] Bobilioff-Preisser, W. Zur physiologie des pollens. *Beih. Bot. Centralbl.* I, Vol. 34, 459-492, 1917.

secured pollen tubes *in vitro* long enough to effect fertilization if they were growing in the style of the plant. Sugarcane pollen was found to show very irregular growth when cultured artificially. A difficulty that was experienced in this direction was that quite a large number of pollen tubes taken up for measurement either bursted or stopped growth after an hour or so. It was therefore decided to look up the cultures only after the first hour had elapsed and then pitch upon the particular pollen tubes for growth measurements. The curves in Text-fig. 1 represents the

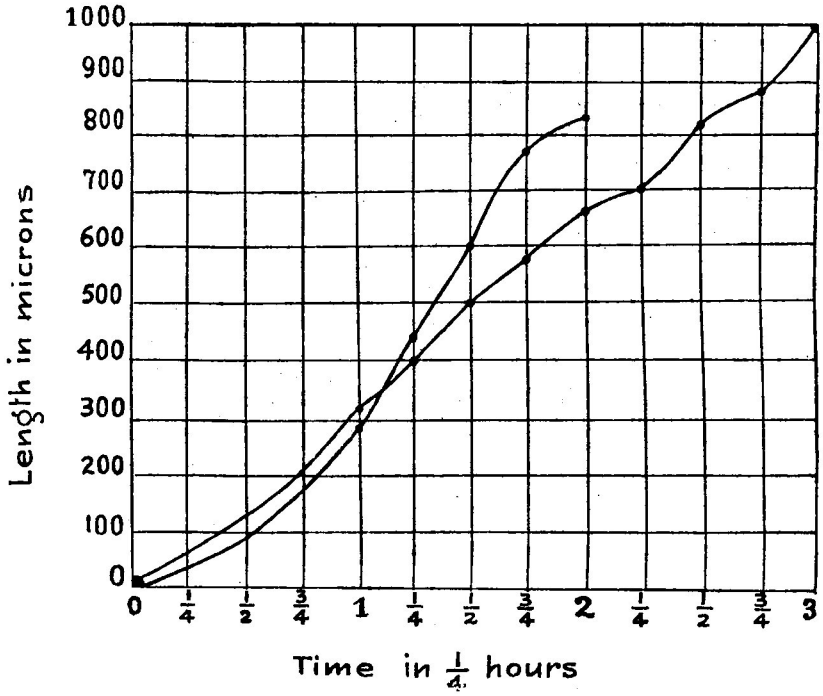

Fig. 1. Growth curves of pollen of P. O. J. 2696 cultured in 20% sugar +0·7% shred agar.

growth of two such tubes. Though the longer of the two tubes attained a length of 1000μ in 3 hours, it is not rare to find tubes measuring between 1500μ and 2000μ or more for the same period of time. The greatest length attained by a sugarcane pollen tube when grown artificially was by a pollen from P. O. J. 2696, which measured 2921 after 3 hours, and as pollen tubes have been met with, which attain that length or more after 3 hours growth in artificial culture, it might be said that the sugarcane pollen tube reaches the ovary in about 3 to 4 hours.

V. Pollen storage experiments.

The following experiments were conducted to ascertain the effect of exposing sugarcane pollen to various conditions, on its viability :—

(*a*) P. O. J. 2696 pollen, evenly spread in a watch glass and placed inside an oven, was subjected for 20 minutes to a series of temperatures ranging from [illegible]°C. to 45°C. It gave no germinations when cultured in the normal way. Negative results were obtained when it was similarly treated at 50°C. and 60°C.

(*b*) P. O. J. 2696 pollen exposed to a temperature of 12°C. for 3 hours yielded 14·32 per cent. germinations, the maximum length of the pollen tubes being 1268μ.

(*c*) P. O. J. 2696 pollen kept at 2°C. for 48 hours gave 0·4 per cent. germinations on culturing artificially.

(*d*) P. O. J. 2696 pollen when exposed to free atmosphere in the laboratory or to direct sunlight for more than an hour suffered in viability.

(*e*) Artificial cultures of P. O. J. 2696 pollen were subjected to temperatures ranging from 35°C. to 45°C. No germinations resulted. A second series was put at 12°C. and 14·32 per cent. germinations were obtained. On keeping another series at —2°C. the results were negative.

Weller's[1] attempts to germinate sugarcane pollen at atmospheric humidities controlled by sulphuric acid concentrations showed that, if exposed to relative humidities below 92 per cent., the sugarcane pollen grains shrivelled, evidently due to desiccation. This and the above experiments indicate that sugarcane pollen would keep best at moderately low temperatures (5° to 13° C.) and moderately high humidities. Knowlton[2] working with corn pollen also came to the same conclusion.

In 1927[3] sugarcane pollen was stored alive for 96 and 168 hours in partial vacuum and corked and paraffined glass tubes respectively, at temperatures varying from 9° to 13° C. The pollen inside the glass tube was, however, found to have caked. It was thought that the caking might be due to incomplete sealing of the tube or to fungus growth. In 1928, glass ampoules were therefore substituted for the glass tubes. The ampoule tip was broken to allow the pollen in, after which the tip was sealed with the help of a blow pipe over a flame. For keeping the pollen at low temperatures varying from 5° to 13° C., galvanized iron box of a pattern used by Sandsten,[4] was employed, the only difference being that a zinc rack to

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[1] *loc. cit.*

[2] Knowlton, H. E. Studies in pollen, with special reference to longevity. *Cornell Univ. Agri. Expt. Sta. Mem.* 52, pp. 751-793, 1922.

[3] Dutt, N. L. Longevity of sugarcane pollen. *Agri. Jour. India*, Vol. XXIII, Part VI, pp. 482-483, 1928.

[4] Sandsten, E. P. Some conditions which influence the germination and fertility of pollen. *Wisconsin Univ. Agri. Expt. Sta. Res. Bull.*, No. 4, 1909.

accommodate ampoules was placed inside the inner box. The results were discouraging as the pollen inside the ampoules if allowed to remain in that condition for more than two days caked and subsequently turned into viscid liquid.

The idea in sealing pollen in ampoules was that the CO_2 content inside the ampoule would increase in course of time and with the lessening of metabolic processes by keeping the ampoules at low temperature, it was thought that these two conditions would be favourable for prolonging the viability of sugarcane pollen.

The negative results with the above arrangement led to the keeping of pollen over 85 per cent. relative humidity, in an atmosphere of CO_2 and at low temperatures varying from 5°C. to 13°C. This was done in the following manner. A watch glass containing pollen was placed on wire gauze inside a desiccator which had at the bottom a mixture of H_2SO_4 and water mixed in a proportion[1] to maintain the atmosphere at 85 per cent. relative humidity. The desiccator was connected to a CO_2 generating apparatus, the gas being passed through two wash-bottles, the first one containing water and the second Con. H_2SO_4, the object being to get dry CO_2 free from acid. After CO_2 had passed into the desiccator for about half an hour replacing the air inside the desiccator, both the tubings were tightly clamped and disconnected. The desiccator was then removed and placed inside a zinc box surrounded by ice and kept at temperatures varying from 5°C. to 13°C.

By the time the above method of pollen storage was decided upon, the flowering period of most of the varieties was nearly over. The pollen of Maur. 131, which was then available, was stored in the above manner. On the 13th day the pollen was removed and cultured artificially. The germinations worked out to 0·9 per cent. It has to be mentioned that in the fresh condition before putting up for storage, this pollen gave only a few germinations. Owing to the unavailability of pollen as the season was almost over, the experiment could not be continued.

VI. Discussion of results.

Earlier work on sugarcane pollen by the writer showed that for artificial germination, sugarcane pollen is very sensitive to moisture and that the concentration of sugar in the medium, the size and air-proof nature of the moist chamber had to be very exact. The experiments reported under Section III of the present paper indicate that sugarcane pollen would grow over a comparatively wide range of sugar concentrations, or in distilled or filtered rain water alone; and that to secure germinations an air-proof moist chamber consisting of a glass ring 17 mm. in diameter and 7·5 mm. high properly vaselined at top and bottom, is not an absolute prerequisite. This is at variance with the impression that for artificial germination the pollen of grasses requires exact sugar concentration.

[1] Wilson, R. E. Humidity Control by means of sulphuric acid solutions, with critical compilation of vapour pressure data. *Jour. Ind. and Eng. Chemistry*, pp. 326-331, 1921.

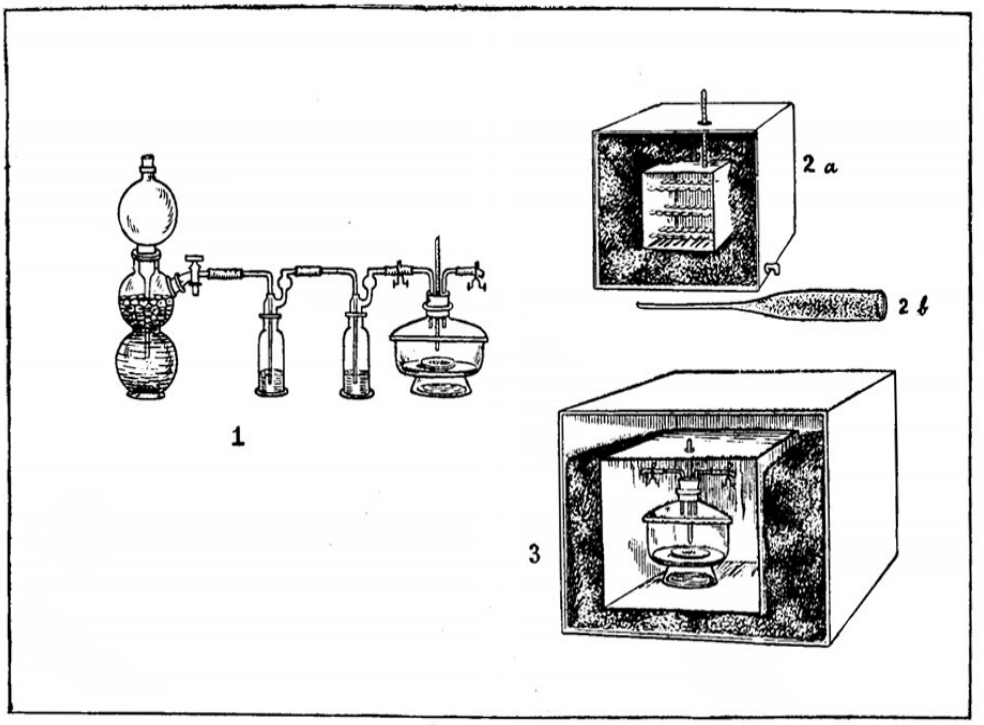

Fig. 1. Showing Kipp's apparatus for generating CO_2 and washbottles containing water and H_2SO_4. The desiccator contains pollen over a mixture of water and H_2SO_4 (85% relative humidity).
Fig. 2a. Zinc box containing ice. The inner box contains rack for ampoules.
Fig. 2b. Glass ampoule.
Fig. 3. The desiccator in fig. 1 placed inside the box containing ice.

Best germinations were secured when 26 per cent. sugar plus 0·7 per cent. shred agar was employed, but even the pollen of varieties which usually gave good germinations when cultured artificially with this medium, sometimes yielded negative or very inconsistent results, and it was at one time felt whether artificial germination was at all any use as a pollen viability test and whether it would not be best to rely upon fertilization tests alone. It is true that conditions under artificial culture do not approximate those found on the stigma or inside the style, but as the physiology of pollen germination is the same in both the cases, and inasmuch as pollen tubes, comparable in length to the length of the sugarcane pistils, have been secured *in vitro* this method of attacking the physiology of pollen may not be entirely without use.

That pollen tubes about 1029μ in length were secured by using distilled water indicates that, given the proper moisture in the stigma to start germination, there is enough reserve food material in the sugarcane pollen grain to carry the tube more than one-third way down the style.

The artificial culture of fresh Maur. 131 pollen yielded 5 per cent. germination in the 1926 season, 22 per cent. in 1927 and 2·1 per cent. in 1928. This once again brings out the fact that for artificial germination of sugarcane pollen it has not been possible to bring all the factors under control. Maur. 131 pollen, stored in an atmosphere of CO_2, over 85 per cent. relative humidity and at temperatures varying from 5°C. to 13°C. gave 0·9 per cent. germination when cultured artificially after 12 days' storage. Its fertilizing ability by dusting over a pollen sterile variety could not be tested as the flowering season was almost over. It is well known that the capacity to germinate under artificial conditions does not indicate that the same pollen will be capable of fertilizing the ovule, while, on the other hand, the pollen which failed to germinate artificially has been found to effect fertilization after a long time, suggesting that the fertilizing ability may outlast the power to germinate under artificial conditions.

VII. Summary.

(1) In the fresh and dry condition sugarcane pollen varies in size from 38·25μ × 42·75μ to 67·5μ × 72·0μ. It contains about 48 to 51 per cent. moisture.

(2) Sugarcane pollen was found to germinate in quite a wide range of sugar concentrations or distilled or filtered rain water alone. Filtered rain water could without detriment be substituted for distilled water as solvent in the medium. A definite sized ring and air-proof condition of the moist chamber are not absolute pre-requisites. Best germinations were, however, obtained by using 26 per cent. commercial sugar plus 0·7 shred agar.

(3) The maximum length attained by a sugarcane pollen tube under artificial culture was by a P. O. J. 2696 pollen, when the tube measured 2921μ after 3 hours, and as the sugarcane pistils measure less than this (between 1/12 and 1/10 of an

inch) it may be said that under favourable conditions the sugarcane pollen tube would reach the ovary in about 3 to 4 hours.

(4) Maur. 131 pollen was stored alive for 12 days over 85 per cent. relative humidity, in an atmosphere of CO_2, and at temperatures varying from 5°C. to 13°C.

The writer is indebted to Rao Bahadur T. S. Venkatraman B.A., I.A.S., Government Sugarcane Expert, for valuable suggestions. Sub-assistants K. Achuthan Nambiyar and T. R. Venkatraman helped in conducting the tests.

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A PRELIMINARY NOTE ON THE CHEMICAL COMPOSITION AND THE ENZYMES OF SUGARCANE POLLEN.

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I. Introductory.

The present preliminary study, which is based mainly on Paton's[1] work, was taken up with the idea that a knowledge of the chemical composition and enzymes of the sugarcane pollen will help in understanding its physiology.

II. Material and methods.

Portions of arrows were cut about one hour before the opening of the anthers and were brought to the laboratory with the base of the cut portion placed in a bottle containing water. As soon as the bulk of the anthers dehisced, the arrow portion was gently tapped and the pollen dust collected on a clean paper. Fresh pollen was collected every day, and the weighed quantity of pollen was ground with glass and taken up with distilled water and examined for the particular enzyme. Control was run in all cases with pollen that was either boiled or auto-claved.

For chemical analysis, the quantity of pollen available daily was very insufficient. The pollen had therefore to be stored for several days. Freshly collected pollen was first dried in a desiccator over H_2SO_4, and then in an oven at 60—70° C.

III. Experimental.

(*a*) *Enzymes.* (i) *Diastase.* 0·15 gm. of fresh pollen was ground with powdered glass and taken up with 10 c. c. of distilled water in a test tube. To this was added 10 drops of a 1 per cent. solution of starch and a few drops of toluol as a preservative. This was plugged with cotton and kept for 24 hours at the room temperature. The solution was then tested for reducing sugars and for starch.

[1] Paton, J. B. Pollen and Pollen Enzymes. *Amer. Jour. Bot.*, Vol. VIII, No. 10, pp. 471-501, 1921

A control was run on the same lines with boiled pollen. The control gave only a very faint reduction with the Fehling's solution, while the fresh pollen extract gave very copious reduction; the test for starch showed the absence of starch in fresh pollen, while the control contained starch.

(ii) *Invertase.* 0·15 gm. of fresh pollen in 10 c. c. of water +0·3 gm. of sugar + toluol as a preservative. A control was run with boiled pollen, and the solutions were tested for reducing sugars.

The fresh pollen extract showed almost complete reduction of the Fehling's solution (equal quantities of Fehling's and the extract were taken), while the control gave a very faint reduction.

(iii) *Lipase.* 0·15 gm. of fresh pollen+10 c. c. of water+2 c. c. of N/60 oxalic acid as an activator+2 c. c. of methyl acetate+toluol as a preservative. A control was run with auto-claved and boiled pollen. The solutions were kept for 24 hours at 38—40°C. and titrated against standard alkali (N/10 NaOH), using phenolphthalein as indicator—

Fresh pollen required	8·95 c. c. of standard alkali.
Control required	9·0 c. c. ,,

(iv) *Cytase.* 0·1 gm. of fresh pollen+0·3 gm. of pure cellulose (best Swedish filter paper that was repeatedly boiled with distilled water and washed until free from starch and sugars, was used)+2 c. c. of toluol and water to make 50 c. c. A control was run with auto-claved pollen and the solutions were kept at 38—40°C. for 24 hours and tested for reducing sugars.

There was only very faint reduction, when tested with the Fehling's solution, in both the control and the normal. Tests after 48 hours also gave the same result.

(v) *Proteolytic enzymes. Erepsin.* 0·05 gm. of fresh pollen in 10 c. c. of 1/10 per cent. peptone solution+0·1 gm. thymol. A control was run with auto-claved pollen. The solutions were tested with Gies Buiret reagent after 24 hours.

There was absolutely no colour difference between the control and the normal. The experiment was repeated with a 1 per cent. peptone solution with the same result.

(vi) *Trypsin.* Blood fibrin was prepared from fresh blood and after washing it completely with distilled water, was stained with 1 per cent. congo red, and auto-claved. This was used in the experiments.

10 c. c. of fresh pollen suspension (0·05 gm. in 100 c. c.)+blood fibrin+2 c. c. of N/10 Na_2CO_3 solution+1 mg. thymol. A control was run with auto-claved pollen. The colour of the solution and the nature of the fibrin after 24 hours was noted.

In the normal the solution was deeply coloured and the fibrin had slightly swelled and disintegrated, while in the control, there was slight colour, and the fibrin was the same as before.

(vii) *Pepsin.* 10 c. c. of pollen suspension (0·05 gm. in 100 c. c.)+blood fibrin +2 c. c. of 0·2 per cent. HCl+1 mg. of thymol. A control was run with auto-

claved pollen. The colour of the solution and the nature of the fibrin was noted after 24 hours. There was no colour in the control, while a slight pink colour had developed in the normal and the fibrin had swelled a little.

(viii) *Pectinase.* It was not possible to prepare pure pectin for the tests, so the dried (in a desiccator over H_2SO_4) pistils of *Datura* were used.

0·1 gm. of fresh pollen+0·1 gm. of *Datura* pistil dried in a desiccator and powdered+15 c. c. of water+4 c. c. of toluol. A control was run with boiled pollen and the solutions were quantitatively examined for reducing sugars, by Horne's[1] method.

10 c. c. of the normal pollen extract .	Consumed 2·7 c. c. of standard Fehling's solution (10 c. c. equivalent to 0·05 gm. of invert sugar).
10 c. c. of the control . . .	Consumed 2·6 c. c. of standard Fehling's solution.

(b) *Chemical analysis of sugarcane pollen.*

	Per cent.
Ash	4·84
Starch	16·25
Sugar.	19·49
Proteids	16·66
Ether extract	2·06
Amido compounds	6·26
(The percentages were calculated on dry pollen).	
Moisture	48·7 to 51·1

For moisture determination the pollen was dried in a desiccator till constant weight was obtained. Though as much as 80 per cent. of the moisture was given up in one day, it required about two months for the pollen to become completely dry.

IV. Conclusions and Summary.

Diastase and invertase are present in the sugarcane pollen, while lipase, cytase and erepsin are absent. Indications were obtained of the presence of pepsin and trypsin. The results about the presence of pectinase were not conclusive.

The chief constituents of the sugarcane pollen are carbohydrates (starch and sugar) and proteids. Water constitutes a fairly large part (about 48 to 51 per cent.).

[1] Horne, W. D. Rapid method of Glucose determination. *Louisiana Planter and Sugar Manufacturer*, Vol. LXXXI, No. 1, p. 1, 1928.

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A PRELIMINARY NOTE ON STIGMA RECEPTIVITY IN CERTAIN SUGARCANE VARIETIES.

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In a sugarcane arrow the opening of the flowers and hence the emergence of the stigmatic branches occupies a period sometimes as much as seven to eight days. For hybridization work the arrow will need to be pollinated each morning as fresh stigmas are exserted; and observations on stigma receptivity are likely to enable cross pollination to be done in one operation in the case of varieties whose duration of stigma receptivity is longer than the period of the opening of flowers in the whole arrow. The observations detailed in the present note represent stigma receptivity tests made during the 1929 arrowing season with the varieties POJ. 100, POJ. 2364 and Vellai and repeated again for confirmation during the 1930 season. During the latter season POJ. 2725 was also tested. The above varieties were selected for these tests as they have little or no pollen of their own.

Mercado [1926] working with the sugarcane varieties C. A. C 87, Badila, and Negros Purple states that "observations were made on the length of the time the stigmas remained fresh.....Just after the flowers opened, the fresh stigmas could be seen to have a 'syrupy secretion'.....After a time the stigmas lost the sticky secretion, causing their receptive power to cease". Observations on stigma receptivity have also been recorded for other crops, *e.g.*, Anthony and Harlan [1920] on barley; and Leding [1928] on date palm. Anthony and Harlan found that, on the sixth day, no pollinations brought about fertilization, and according to Leding there was a gradual decline to 23·2 percentage of fertilized blossoms in the date palm on the eleventh day. Weatherwax [1923] states that "the period of receptivity in the maize silks continues for two weeks or more, the silks continuing to elongate in the meantime if they are not pollenized".

For these tests the 'isolated' canes—artificially rooted according to the method developed at Coimbatore [Venkatraman and Thomas, 1926] were kept growing in

big earthen pots (height 16 in., diameter at top 18 in.) and located in separate sheds—each variety in a shed—quite separate from other such sheds and far away from the cane plots at the station to protect against unintended pollen. After making sure by careful examination that the stigmas were actually free from any pollen, the experiment was started. In the morning the flowers were emasculated bofore opening, and left undusted with pollen for the required period. The stigmas were then dusted with fresh pollen, and about two hours after dusting, stigmatic branches were removed, stained with cotton blue, and examined under the microscope for pollen germinations.

In the 1929 season fresh POJ. 2606 pollen was dusted on the stigmas of all the varieties under study, the dusting being done after emasculation on 2, 4, 8, 12, 24, 48 and 72 hours old stigmas. On examining under the microscope it was found that the dusted pollen had germinated in all the above-mentioned stigmas. Pollen was then dusted on seven days old stigmas of Vellai, and POJ. 100 ; and five days old stigmas of POJ. 2364, and on these also germinations were noticed. These tests were repeated during the 1930 season and the pollen was dusted on five or more days old stigmas. The results are detailed in the following table.

TABLE I.

Results of stigma receptivity tests, 1930.

Name of the variety	Date of emasculation	Date of dusting with fresh pollen	Name of the pollen parent	No. of stigma branches examined	Total No. of pollen grains on stigma branches	Total No. of germinations	Remarks
POJ. 2725	16th October 1930.	21st October 1930.	Co. 285 . .	8	720	354	
POJ. 2725	Ditto. .	24th October 1930.	*Saccharum spontaneum.*	10	477	280	Tips of stigmatic branches found drying. Lower portions receptive.
POJ. 2725	Ditto. .	27th October 1930.	Ditto.	8	808	27	Two branches completely dry. A third one just beginning to dry but receptive.
POJ. 2364	17th October 1930.	22nd October 1930.	Co. 285 . .	8	329	281	Three branches dry.
POJ. 2364	Ditto. .	24th October 1930.	*Saccharum spontaneum*	6	851	382	Two branches drying up in patches.

L A

Results of stigma receptivity tests 1930—contd.

Name of the variety	Date of emasculation	Date of dusting with fresh pollen	Name of the pollen parent	No. of stigmas branches examined	Total No. of pollen grains on stigma branches	Total No. of germinations	Remarks
POJ.2364	17th October 1930	27th October 1930.	Saccharum Spontaneum.	6	329	121	Two branches drying up in patches. A third one completely dry.
POJ. 100	1st November 1930.	9th November 1930.	B. 3412 . .	8	265	128	
Vellai .	27th October 1930.	1st November 1930.	Ditto .	6	720	322	
Vellai .	30th October 1930.	8th November 1930.	*Saacharum spontaneum*	12	48	27	Only one branch receptive. Others dry.

It will be seen from the above table that about thirty-four to forty-nine per cent. of the pollen dusted had germinated on five days old stigmas of Vellai, POJ. 2364, and POJ. 2725, and that on such stigmatic branches as had not completely dried, there were germinations on 8, 9, 10, and 11 days old stigmas of POJ. 100, Vellai, POJ. 2364, and POJ. 2725 respectively. Besides the above tests, a few flowers of the varieties Vellai, POJ. 2364, POJ. 2725 and B. 6308 were emasculated about twenty-four hours before opening and the stigmas were dusted with fresh pollen. The stigmatic branches were then examined under the microscope and it was noticed that the pollen dusted had germinated on the stigmas.

It has to be pointed out that in all the foregoing tests the observations were intended mainly to find out whether the stigmas were receptive to pollen germinations, that is to say, whether fresh and viable pollen, when dusted on the stigmas, would germinate. It is proposed to continue these observations during subsequent years to ascertain the length of time during which the flowers of the sugarcane remain receptive to fertilization.

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Indian Journal of Agricultural Sciences 2:47-50 (1932)

OBSERVATIONS ON MALE NUCLEI IN THE SUGARCANE

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(With Plates IX-XI.)

I. INTRODUCTION.

The germination of sugarcane pollen in artificial media has, of late, been extensively employed at the Imperial Sugarcane Breeding Station, Coimbatore, for ascertaining the male fertility of the varieties used in crossing. Fairly high percentages of germination have been obtained by this method in certain of the thick and thin types of canes [Dutt and Ayyar, 1928], as also in *Saccharum spontaneum* and *S. Narenga*. In some cultures the pollen tubes were long enough to reach the ovary if they were growing on the style of the plant [Dutt, 1929]. The artificial culture method has thus been quite successful in the percentages of germination and in the length attained by the pollen tubes; attempts were therefore made to see if the migration of the male nuclei takes place *in vitro*. For staining, Belling's [1921] aceto-carmine was used as this stain has been successfully employed by Brink [1924].

II. PRESENCE OF TWO MALE NUCLEI IN THE POLLEN GRAIN BEFORE SHEDDING.

The freshly shed pollen grains of the sugarcane varieties—Kaludai Boothan, Co. 213, Co. 285, D. 74, D. 131, D. 1135, E.K. 28, S.W. 111, P.O.J. 2696, P.O.J. 2878, Ges. Preanger, Maur. 131, N.G. 24 and *Saccharum spontaneum* (local and

Glaggah) were stained and were in all cases found to contain two male nuclei and one tube nucleus. The tube nucleus took the stain rather faintly, while the male nuclei were deeply stained.

To ascertain if the division of the generative nucleus takes place earlier than the time of the dehiscence of the anther, such flowers were taken as would open the next morning. The anthers were removed and teased in aceto-carmine. In all the varieties thus examined, two male nuclei were clearly stained. This would indicate that the generative nucleus divides into two male nuclei at least 24 hours before shedding. In Plate IX, fig. *g*, is shown a fairly early stage where the nucleus has not yet divided into tube and generative nuclei.

The shape of the male nuclei in the pollen grain varied from roughly spherical to spindle or crescent-shaped as shown in Plate IX, figs. *a* to *f*.

III. Migration of the nuclei into the pollen tube.

Different stages in the migration of the nuclei into the pollen tube were observed. In Plate X, fig. *a*, the pollen tube has been formed, but the nuclei have not yet migrated. A similar stage is shown in Plate X, fig. *b*, but on a stigmatic papilla. The migration has taken place in figs. *c* and *d*, but in the latter the tube nucleus has not been stained.

In several cultures, pollen grains were met with which had not germinated, but in which the nuclei were apparently normal. Brink [1924] records a similar experience in *Scilla*.

The male nuclei in the pollen tubes were mostly elongated in shape. In certain cases they were more or less spherical and in others somewhat spirally curved.

Four male nuclei were noticed in certain pollen tubes and in a few pollen grains of the variety B. 3412, C. A. C. 87 and P. O. J.1410. The different positions occupied by these nuclei are shown in Plate XI, figs. *b* to *e*. All the four nuclei stained deeply and were therefore most probably male nuclei. The tube nucleus was not clearly stained in either of these. The pollen grain in Plate XI, fig. *a*, however, shows the tube nucleus and four male nuclei. The shape of the nuclei in the pollen tube varied, as seen in Plate XI, figs. *b* to *e* from more or less spherical to somewhat vermiform.

IV. Discussion of results.

The division of the generative nucleus into two male nuclei inside the pollen grain prior to shedding, which was observed in all the fourteen sugarcane varieties

studied and in *Saccharum spontaneum*, would appear to be characteristic of quite a number of grasses, as this condition was met with by Golinski [1893] in *Triticum* and other grasses, and by Cannon [1900] in *Avena fatua*. Weatherwax [1923] noticed in maize that the mature pollen grain at the time of leaving the anther contains fully developed sperms, which are two small crescent-shaped cells with long attenuate ends. Percival [1921] mentions that the pollen grains of wheat germinate while still in the un-opened anther and possess two slender male gametes each of which is curved and pointed at one end. Artschwager, Brandes and Starrett [1929] have figured two male nuclei in the mature pollen grain of the sugarcane variety U.S. 1694.

In the sugarcane varieties studied by us, the form of the male nuclei in the pollen grain was not constant. It ranged from spherical to crescent or spindle-shaped. As the male nuclei migrated into the pollen tubes, they sometimes retained the spherical shape, but mostly became elongated. In a few instances they were observed to be spirally curved, but this shape was noticed only inside the pollen tubes and on no occasion inside the pollen grain.

The occurrence of four male nuclei is rather unusual though not unprecedented, as Coulter and Chamberlain [1909] mention this condition as having been observed by Strasburger [1884] as sometimes occurring in *Camassia Fraseri*, and Chauveaud [1892] found four or five bodies in the pollen tubes of *Vincetoxicum nigrum* and *V. medium*, which he thought might be interpreted as male nuclei and responsible for polyembryony. The four male nuclei have so far been observed by us only in three sugarcane varieties and the phenomenon will need to be studied more thoroughly before it can be said what its real significance is, but most probably as pointed out by Coulter and Chamberlain, it may have no further significance than that any active cell may be induced to divide by favourable conditions.

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EXPLANATION OF PLATES.

All the drawings have been made with a Camera Lucida, and at the level of the stage.

Plate IX. Figures *a* to *f* show the shape of the male nuclei in the pollen grains. Fig. *g* is an early stage of the male gametophyte where the nucleus has not yet divided into the tube and generative nuclei. The magnification of fig. *b* is 770 diameters; all other figures 380 diameters.

a. P.O.J. 2878 pollen grain, 24 hours before shedding.

b. P.O.J. 2696 pollen grain, 24 hours before shedding.

t. n. tube nucleus.

g. n. generative nuclei.

c. Co. 285 pollen grain just before shedding.

d & e. B. 3412 pollen grains growing *in vitro*.

f. Co. 285 pollen grain just before shedding.

g. Co. 243 pollen grains from an undehisced anther.

Plate X. Various stages in the migration of the male nuclei in the pollen tubes.

a. × 380. *Saccharum spontaneum* pollen *in vitro*.

b. × 380. *Saccharum spontaneum* pollen germinating on a stigmatic papilla.

c. × 240. B. 3412 pollen *in vitro*.

d × 380. Co. 285 pollen *in vitro*.

Plate XI. Four male nuclei in the pollen grain and pollen tubes of the variety B. 3412.

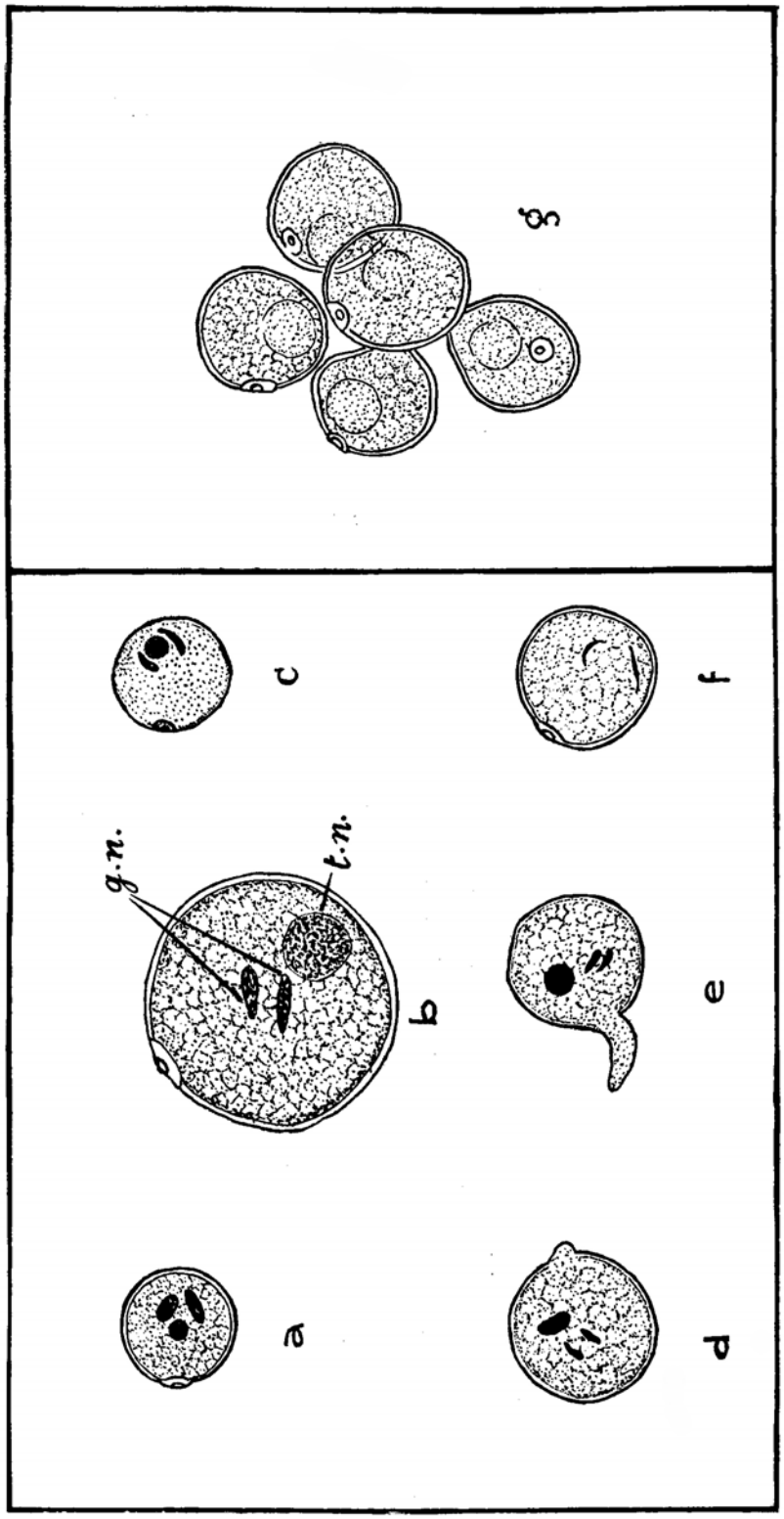
a. × 770. t. n. tube nucleus.

g. n. generative nuclei.

b. × 770. Four male nuclei in two pairs.

c. × 240. Two of the nuclei are somewhat spirally curved.

d. & e. × 240. Male nuclei in pairs. Note the relative distance between the first and the second pair of nuclei.


g.
a
b
g.n.
t.n.
c
d
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f

PLATE X.

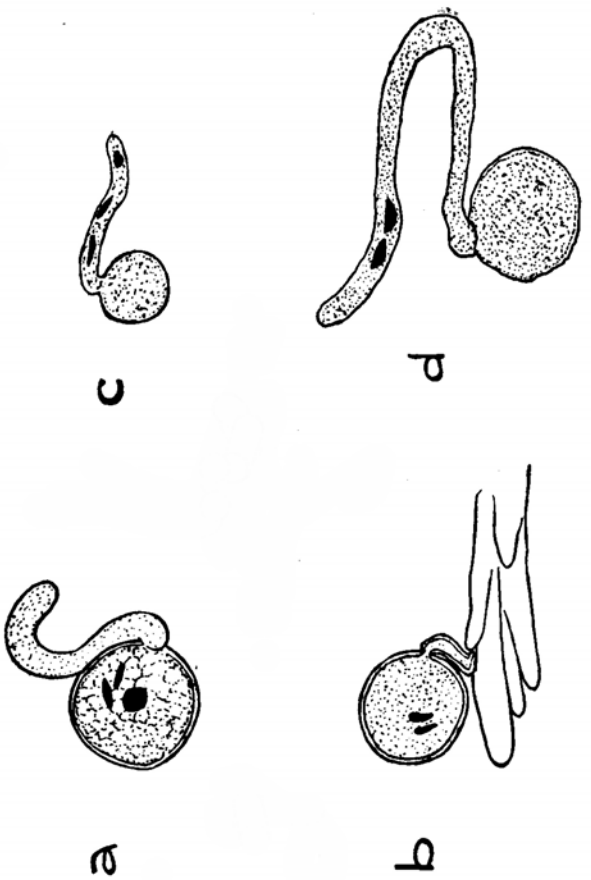
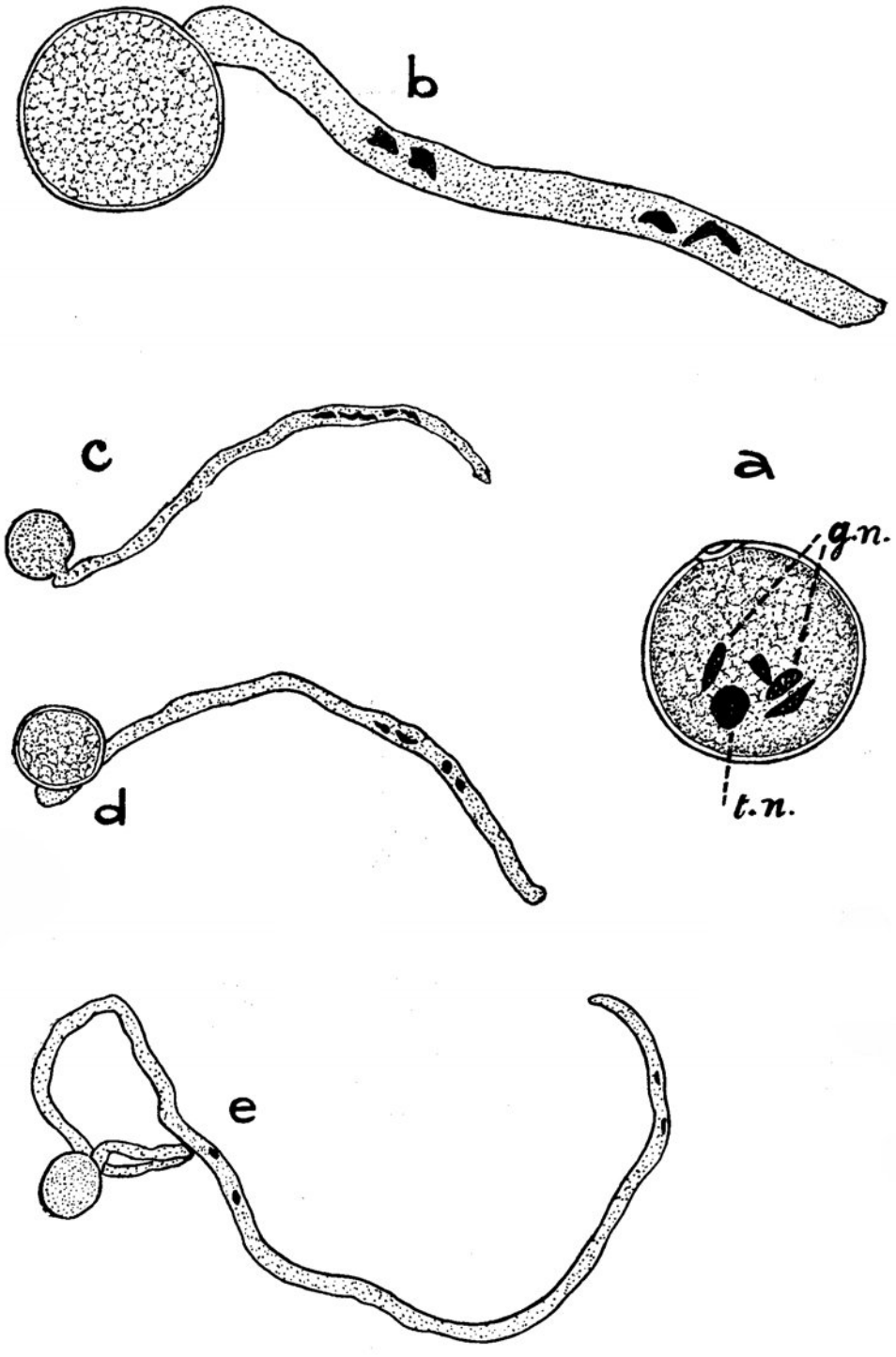


PLATE XI.



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OBSERVATIONS ON THE CYTOLOGY OF THE SUGARCANE.

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(With Plates V-VIII)

I. Introduction.

The cytology of Saccharum has received attention from Franck [1911], Kuwada [1915], and more recently from Bremer [1923]. In a comprehensive scheme of the study of anatomy, ontogeny and the cytology of the sugarcane, Artschwager, Brandes and Starrett [1929], have studied the varieties U. S. 875 and U. S. 1694, and have described in detail the development of the flower and seed in these varieties.

Bremer's [1923] outstanding work has thrown valuable light on the chromosome behaviour in the various forms of Saccharum and certain inter-varietal and inter-specific hybrids, as also on the taxonomic relationship of *Saccharum arundinaceum* and *S. munja*. During the arrowing season 1930-31 and 1931-32 a study of fertilization and embryogeny in the sugarcane was taken up and the results, as far as available, are reported in this paper. An attempt was also made to determine the chromosome number in the following varieties of *S. officinarum* grown in India, *viz.*, Vellai, Shamshara, Poovan, Chittan and Puri. Since meiosis was expected to be regular in it, *S. spontaneum* (Coimbatore) was included to serve as a control, and later on Co. 205 was added because of its interest as a seedling of a cross between *S. officinarum* and *S. spontaneum*.

II. Material and methods.

All the material was collected from the canes grown at the Thick Cane Area of the Imperial Sugarcane Station, Coimbatore, except Poovan which was collected from Kuniamuthur, a village about six miles away.

For fixing the flowers, arrows slightly before the 'flag' stage were selected. As the spikelets at the top of the arrows generally contained bright yellow anthers in which fully formed pollen grains were found, flowers from the lower portions of the arrows were taken. These contained pale yellow or whitish anthers which on staining with Belling's [1921] Acetocarmine were found to contain a large number of dividing pollen-mother cells. The best time for fixing the material was found to be between 9 and 11 A.M.

The following fixatives were tried:—(1) La Cour's [1929]. One per cent. chromic acid—90 c.c.; potassium bichromate—1 grm.; sodium sulphate—0·5 grm.; urea—1 grm.; 5 per cent. acetic acid—10 c.c.; 2 per cent. osmic acid—15 c.c.; distilled water—45 c.c., (2) Carnoy's [Lee, 1928]:—Chloroform—3 parts; absolute alcohol—6 parts; acetic acid—1 part, and (3) Allen's modification of Bouin's fluid [Lee, 1928]:—Picric acid (saturated solution)—75 c.c.; formaldehyde—25 c.c.; acetic acid—5 c.c.; chromic acid—1·5 grms.; urea—2 grms. The first and second fixatives were not found to be as satisfactory as the third, which was therefore employed for fixing most of the material for study.

The flowers were kept in the fixative for 24 hours and after washing in running water for the same period, were run up through the usual alcohol grades, cleared in xylol, and finally embedded in paraffin (54°C.). The callus hairs were removed from flowers as they were being run up through the alcohol grades and wherever ovaries had to be sectioned, the glumes also were removed to facilitate cutting. Sections of anthers were cut 8 to 12 μ thick and of ovaries 15 to 20 μ thick and stained with Heidenhain's Iron Alum Haematoxylin. To ensure the removal of all traces of picric acid before staining, slides were left for about half an hour in a saturated solution of lithium carbonate in 70 per cent. alcohol.

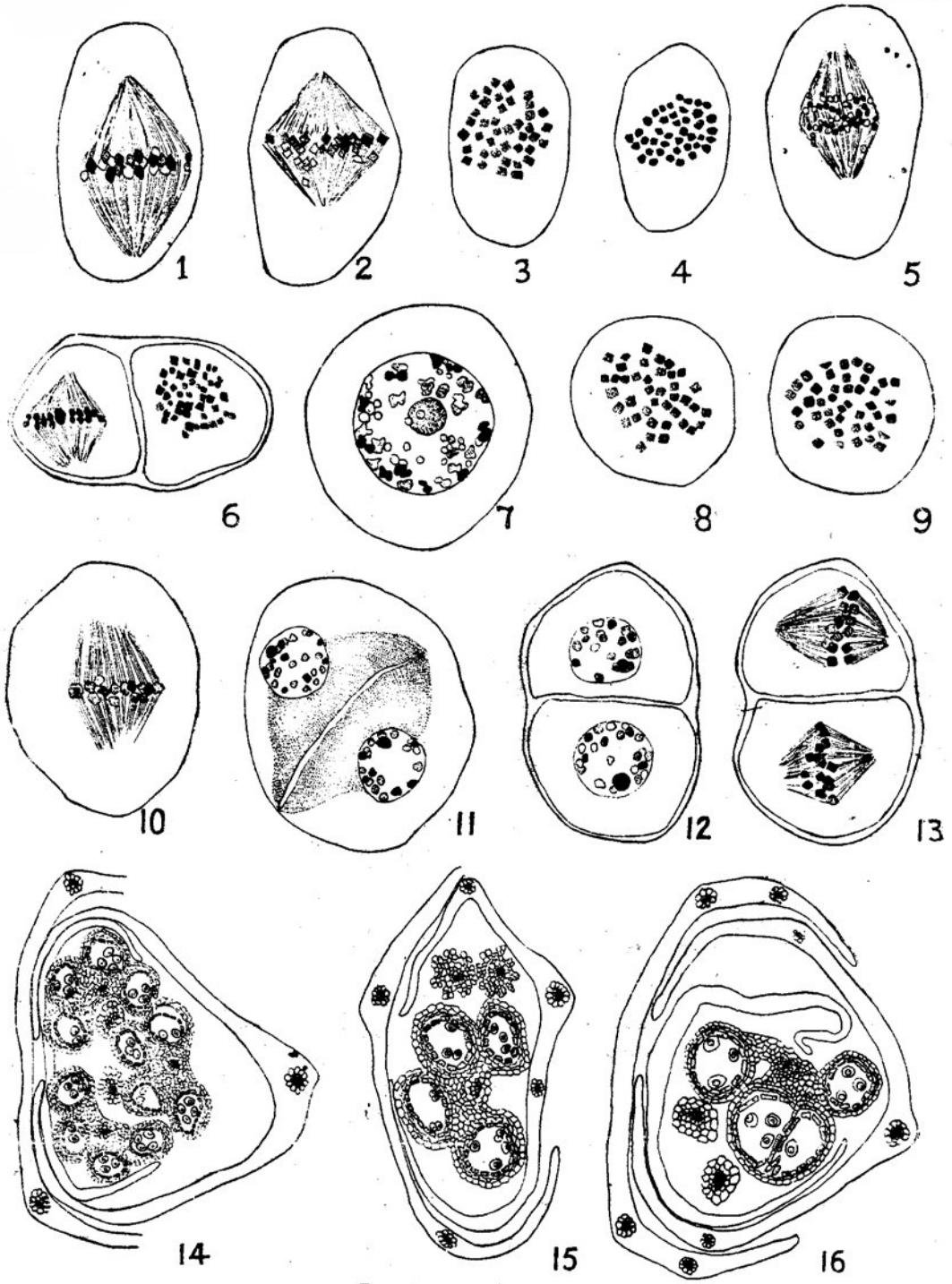
In order to corroborate the chromosome numbers obtained from microsporocytes, root tips were also fixed in some of the varieties. Sections were cut 8 to 10 μ thick and stained in Heidenhain's Iron Alum Haematoxylin.

III. Chromosome numbers.

(*a*) *Vellai*.—The morphological characters of Vellai were compared with the published botanical descriptions of Otaheite [Earle, 1928; Deerr, 1921; Rosenfeld, 1927], and it was found that they agreed in most respects. It was thought that a cytological study of Vellai might reveal features which will help in its identification.

Chromosome counts were made from polar views of the metaphase equatorial plates. One of these is represented in Plate V, figure 3, and forty chromosomes are seen, probably all bivalents. In Plate V, figure 4, are seen forty-one chromosomes, evidently due to irregularity in the heterotypic division. In not a few counts, the numbers 41 and 42 were encountered, but as in the majority of counts, the number

PLATE V.



(For explanation see page 54.)

was 40, it may be taken that the haploid number in Vellai is 40. This number could not be confirmed in counts of the bivalents at the diakinesis stage, as in the preparations examined suitable stages could not be found. In Plate V, figures 2 and 5, certain chromosomes are seen travelling in advance, while Plate V, figure 6 shows irregular homeotypic-division in one of the diads.

An examination of the somatic chromosomes as also of the bivalents in the diakinesis stage of the microsporocytes will need to be made before Vellai and Lahaina [Otaheite] could be compared satisfactorily.

(*b*) *Shamshara.*—This cane has been described by Woodhouse, Basu and Taylor [1915], and they consider it to be very similar to Benaresia Nepali. Earle [1928] in the annotated list of cane varieties mentions Shamshara as equal to Otaheite. Like the other Paunda canes, this cane is also probably an introduced tropical cane, but according to Deerr [1921] under the name Samsara has travelled out again from India as an Indian cane.

Chromosome counts were taken from diakinesis and also from equatorial plates. In Plate V, figure 7, are seen 33 pairs and 14 univalents at diakinesis. In Plate V, figure 8, 40 chromosomes are represented while Plate V, figure 9 shows 38 bivalents and 4 univalents. The heterotypic division of the microsporocytes would thus appear to be irregular while in Plate V, figure 13 is shown the side-views of the metaphases of the homeotypic divisions where, in one of the diads, the arrangement of the chromosomes is somewhat irregular.

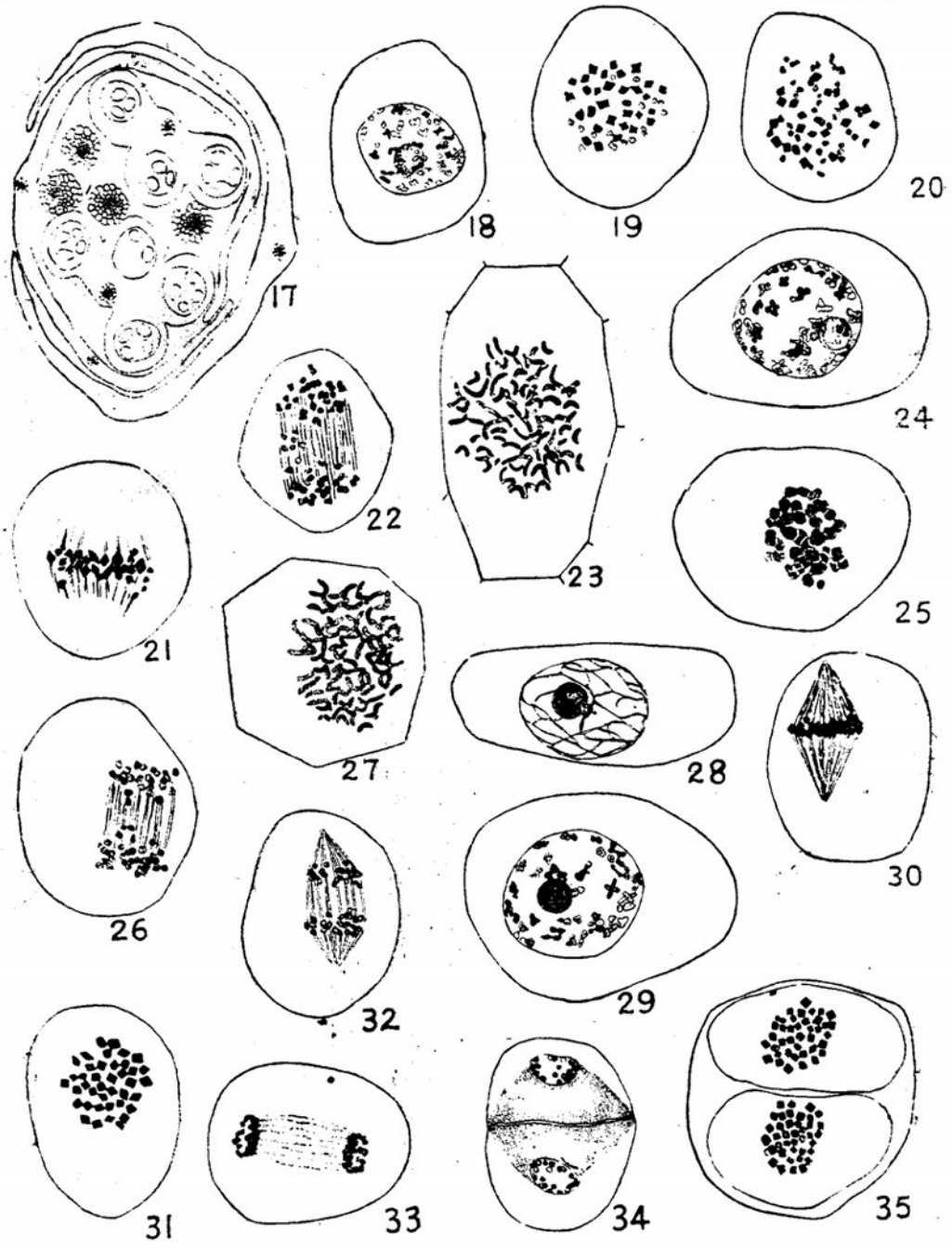
The suppression of one and sometimes two anthers was noticed to be a common occurrence in this variety. Plate V, figures 15 and 16 show these abnormalities, while a normal case is represented in Plate V, figure 14. Yet another abnormality which was sometimes met with is shown in Plate VI, figure 17 where two pairs of styles are seen.

From the above, it will be noted that Shamshara differs from Vellai in some respects. A few morphological differences were also noticed between the two. As diakinesis and a few other stages were not available in Vellai, it has not been possible to compare these two varieties in all cytological details.

(*c*) *Poovan.*—In morphological characters Poovan resembles Keli and Hottai Kabbu. These varieties are probably identical, but grown under different local names. Poovan also resembles Pundia in certain characters. As none of the above-mentioned varieties, with the exception of Poovan, flowered, their identification could not be confirmed by a cytological study of the flowers.

Chromosome counts were made from diakinesis and also from polar views of the equatorial plates. Poovan shows very irregular meiosis, in fact the most irregular of all the varieties examined. Lagging chromosomes were invariably met with in the metaphase and the anaphase while univalents were common in diaki-

PLATE VI.



(For explanation see page 55.)

nesis and polar views of metaphase. In Plate VI, figure 20, 23 bivalents and 39 univalents are seen, while Plate VI, figure 19, represents 33 bivalents and 13 univalents. Plate VI, figure 18 shows 34 gemini and 12 unpaired chromosomes in diakinesis.

The somatic chromosomes are represented in Plate VI, figure 23 and were found to be 78. As it was very difficult to make exact counts in root tips, reliance has to be placed mainly on the counts in meiosis. From the various counts the haploid chromosome number in Poovan would appear to be about 40.

(*d*) *Chittan.*—Barber [1916] in his classical work on Indian sugarcanes mentions that from the detailed morphological study of Chittan, Karun and Kaludai Boothan, it seemed probable that they are closely related to one another, there being some ground for supposing that Chittan, a striped cane, is the oldest and that Karun (Claret) and Kaludai Boothan (green with blush of pink) have at some time arisen as sports from it. With a view to study the cytology of these forms, spikelets in the desired stages of microsporogenesis, and root tips were fixed in Chittan and Kaludai Boothan. It was proposed to take up Karun later.

Counts could not be made from the polar views of metaphase plates, as the chromosomes were noticed to be very closely packed together. This closely packed nature of the chromosomes extended to practically all the stages, including homeotypic division. The prophases and diakinesis stages, however, were clear enough and the gemini could be distinctly traced in the latter. Plate VI, figure 24, shows 40 gemini in diakinesis while irregular anaphase is represented in Plate VI, figure 26. The somatic chromosomes are shown in Plate VI, figure 27. The haploid chromosome number in Chittan may be tentatively taken as about 40.

In the preparations of Kaludai Boothan also, the chromosomes were found to be closely packed together and no good diakinesis stages could be seen to enable the counting of chromosomes.

(*e*) *Puri.*—This cane has been described by Woodhouse, Basu and Taylor [1915]. Deerr [1928] grew Creole and Caliph's Cane alongside Puri, and after a very careful examination of their morphological characters came to the conclusion that they were identical in all respects. The main observations on the cytology of Puri are detailed below.

Chromosome counts were made from the diakinesis and also from the polar views of metaphase. Meiosis in Puri was found to be more regular than Vellai, Shamshara, Poovan and Chittan. In Plate VI, figure 31, forty bivalents are seen in the polar view of the metaphase of the microsporocyte, while 40 gemini are also seen in the diakinesis stage (Plate VI, figure 29). In Plate VI, figures 30 and 33, are shown the regular metaphase and telophase respectively, while Plate VI, figure 32 represents a more or less regular anaphase. In the preparations examined, no laggards were observed and similarly no univalents were seen either in the side or

polar views of the metaphase. The homeotypic division was also noticed to be regular (Plate VI, figure 35). In some sections darkly stained bodies probably chromatin granules were observed in the cytoplasm. These might be extruded chromatin.

The following has appeared in an abstract of Bremer's [1932] sixth paper on the cytology of sugarcane. "The cane known as Yellow Egyptian, thought to be the same as Creole, is discussed in a separate section; 81 was established as the somatic number with 39 bivalents and 3 univalents, at metaphase of the reduction division. This leads the author to regard this cane as a hybrid between the Mungo Indian cane with 41 and a noble cane with 40. The characteristic remains of the nucleolus referred to above was also observed here, a phenomenon which in *S. officinarum* is never observed. This affords further indication of the Indian and hybrid origin of the Creole cane."

In the preparations of Puri the present writers never came across the characteristic remains of the nucleolus which, according to Bremer [1923], is typical of the Indian sugarcanes. The only indications of chromatin in the cytoplasm were very small, darkly stained granules—smaller in size than gemini. These are of course in no way comparable in size to the long membranous body in the cytoplasm usually near one of the poles noticed and figured by Bremer [1923] in the Indian sugarcanes.

Creole could not be examined cytologically by the present writers, as it did not flower at Coimbatore.

(*f*) *Saccharum spontaneum* (*Coimbatore*).—Barber [1915] mentions *S. spontaneum* as a variable species in India. Hole [1911] also found that this species varied greatly according to its habitat, there being three oecological forms, *viz.*, (1) the most xerophilous form found on dry sandy soil, (2) the most hygrophilous form found in swamps and marshy places, and (3) a form intermediate between the first and second, usually found in loam. This difference in habitat was associated with a difference in growth. As there were numerous intermediate forms, Hole [1911] did not think it advisable to define these as different sub-species or varieties. Owing to the slight difference of the African forms—sub-species *aegyptiacum*, variety *aegyptiacum* from the Indian plants examined by him, Hole [1911] thought that a more complete knowledge of the African plant will prove *aegyptiacum* to be merely one of the several oecological forms.

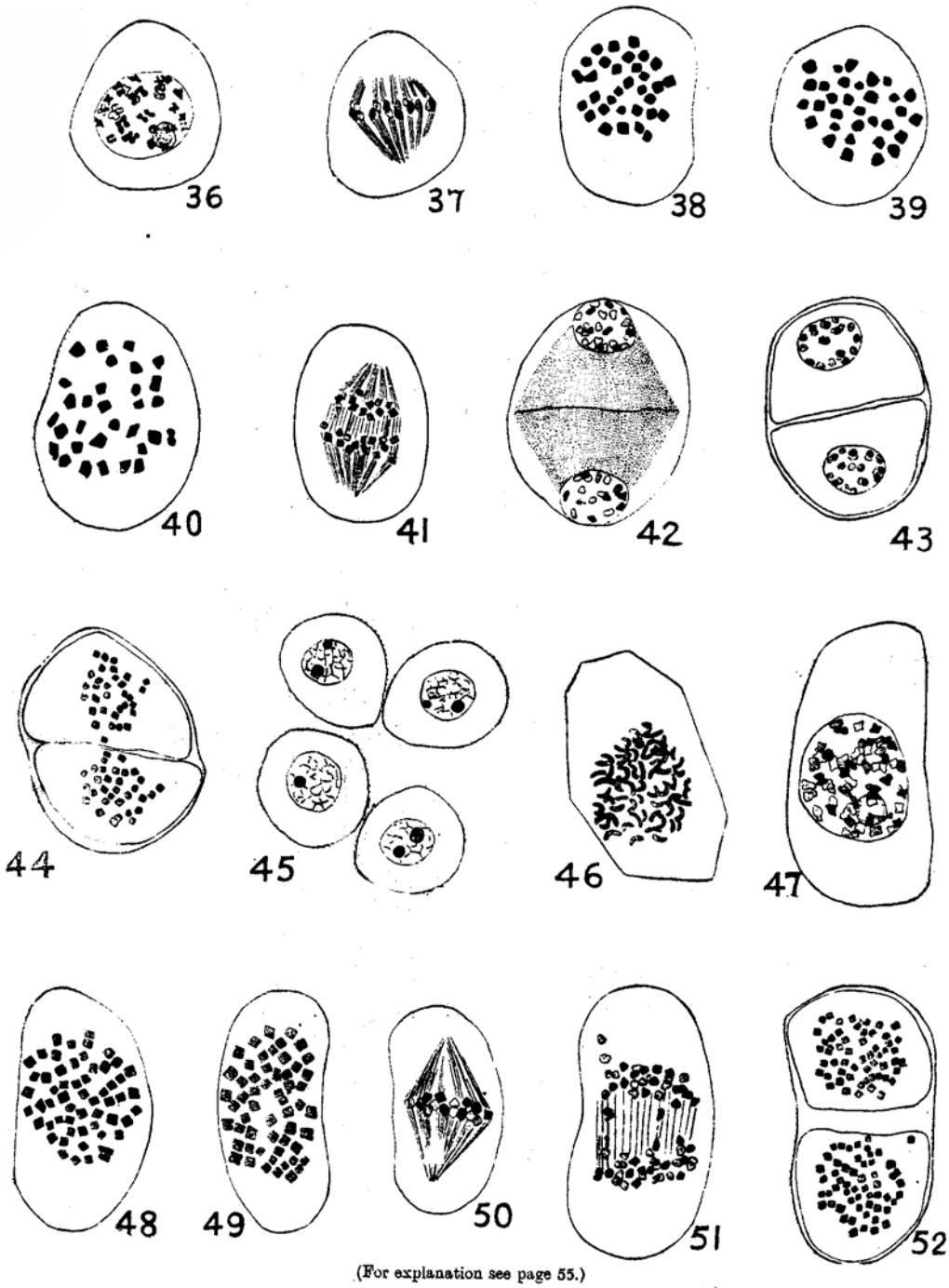
There seems to be little doubt, however, that at least certain of the forms of *S. spontaneum* differ from one another fundamentally. For instance, Bremer [1923 and 1925] who studied two of these forms cytologically, found that the Java *S. spontaneum* (Glagah) had 56 haploid chromosomes, while Glagah Tabongo—the *S. spontaneum* of North Celebes—had 40 haploid chromosomes. The collection at Coimbatore includes about nine forms and the variation in the quality of the juice

is from about 2 per cent. sucrose to as much as over 8 per cent. [Venkatraman, 1930].

S. spontaneum (Coimbatore) affords yet another example of a form with different chromosome number. The haploid chromosome number was found to be 32. Chromosome counts were made from the polar views of the equatorial plates and also from diakinesis. Meiosis was seen to be very regular. In Plate VII, figures 38, 39 and 40, are shown the polar views of the metaphase in which 32 chromosomes could be counted beyond any doubt. Similarly 32 pairs could also be counted at diakinesis (Plate VII, figure 36). In Plate VII, figures 37 and 41, are represented the side-views of metaphase and anaphase. The homeotypic division was also noticed to be regular, as seen in Plate VII, figure 44. Thirty-two chromosomes are seen in equatorial plates of each of the diads. The somatic number, as seen in Plate VII, figure 46, was found to be 64. The haploid chromosome number of *S. spontaneum* (Coimbatore) may therefore be taken as 32.

(*g*) *Co. 205.*—This seedling belongs to the F_1 progeny of the cross Vellai *S. spontaneum* [Venkatraman and Rao, 1928], and the writers were informed that the *S. spontaneum* employed was the Coimbatore form. Bremer [1923], while working on the cross between *S. officinarum* and the Java form of *S. spontaneum* found that the resulting seedlings had an increased chromosome number. For example, Kassoer which is supposed to be a cross between Black Cheribon and Glagah (Java) when examined cytologically was found to show 68 chromosomes and since Black Cheribon has 40 haploid chromosomes and Glagah 56, one would expect Kassoer to have 48 haploid chromosomes. But instead, it possesses 68. Obviously the diploid chromosome number 136 could be arrived at by a fusion of twice the haploid chromosome numbers of the female parent, *i.e.*, 2 (40), and the haploid number of the male parent, *i.e.*, 56 ; the alternative possibilities being that (1) the reduction division had failed to take place and (2) that during fertilization the *S. officinarum* chromosomes undergo longitudinal fission. Bremer [1923] thinks the latter explanation as the more probable one, because the division stages of the egg mother cell in *S. officinarum* observed by him, always pointed towards reduction division. A similar phenomenon of the increased chromosome number in seedlings was also found by him in the cross between *S. officinarum* and the Indian cane Chunnee. The following seedlings of this cross, *viz.*, P.O.J. 181, P.O.J. 213 and P.O.J. 920, were found to have chromosome numbers varying between 62 and 64, giving the diploid number of approximately 124 to 128 which is obtained by adding the diploid number in *S. officinarum*, *i.e.*, 2 (40), and the haploid number of Chunnee, *i.e.*, 46 to 48.

It seemed worth while to ascertain if the seedlings of *S. officinarum* and the Coimbatore form of *S. spontaneum* also had an increased chromosome number on



(For explanation see page 55.)

the same basis as Kassoer and P.O.J. 181, P.O.J. 213 and P.O.J. 920. Chromosome counts of Co. 205 were made from polar views of the metaphase and also from diakinesis. The metaphase plates in Plate VII, figures 48 and 49, show the 56 number very clearly and similarly Plate VII, figure 47, shows 56 pairs at diakinesis. In Plate VII, figure 50, is represented the side-view of the metaphase. While most of the side-views of metaphase and anaphase were found to be regular, in Plate VII, figure 51, is shown an irregular anaphase. In Plate VII, figure 52 is represented the regular homeotypic divisions, where 56 chromosomes were counted in each diad.

From the very clear polar views of the equatorial plates observed in many sections, the haploid number in Co. 205 may be taken as 56. Root tips were not fixed in Co. 205, but as the haploid chromosome number was conclusively found to be 56, the somatic number would therefore be 112. This number can be arrived at by adding the diploid number of Vellai to the haploid number of the pollinating parent—*S. spontaneum* (Coimbatore), *i.e.*, 2(40) *plus* 32 which equals 112. This would confirm Bremer's [1923] observations on the increase in chromosome numbers in the seedlings of the cross between *S. officinarum* and (1) Glagah and (2) Chunnee.

IV. Chromosome numbers in relation to size of nuclei.

Definite relationship has been established between chromosome numbers and systematic position of the various species in certain genera of plants. According to Bremer [1925], there is in *Saccharum* a close relationship between the size of the nuclei of microsporocytes and the haploid chromosome number. The method adopted by him was to measure the largest and the smallest diameter of the nuclei of a large number of microspore mother cells in the diakinesis stage and then to calculate the radius from the mean diameter. When the radius was raised to the third power, it was found that r^3 was proportional to the haploid chromosome number. *e.g.*, for Glagah, which has 56 haploid chromosomes, r^3 was 588 and 539 or not far from 560, *i.e.*, ten times the haploid number. Similarly for four varieties of *S. officinarum* with 40 as their haploid chromosome number, r^3 was 403, 405, 426 and 384. The same ratio held good for *S. officinarum* × *S. spontaneum* crosses as also for Glagah Tabongo (N. Celebes), Tanangge and Hitam Rokan. The deviation from the above ratio was large in the case of Chunnee, Ruckree II and Katha, amounting as it did to 18 per cent., and was greater still in *S. arundinaceum* and *S. munja*, *i.e.*, 30 per cent., and was about the same as in *Erianthus*. The haploid chromosome number in *S. arundinaceum* and *S. munja* was also the same as in *E. ravennae* and *E. japonicus*. This fact and the same size of their nuclei led Bremer [1925] to conclude that *S. arundinaceum* and *S. munja* should belong to the genus *Erianthus*.

In view of the conclusions referred to above, it was decided to calculate r^3 in the varieties studied in this paper and to ascertain its relation to the haploid chromosome number. Only such nuclei were measured as were unmistakably in the diakinesis stage. The data are presented in Table I.

TABLE I.

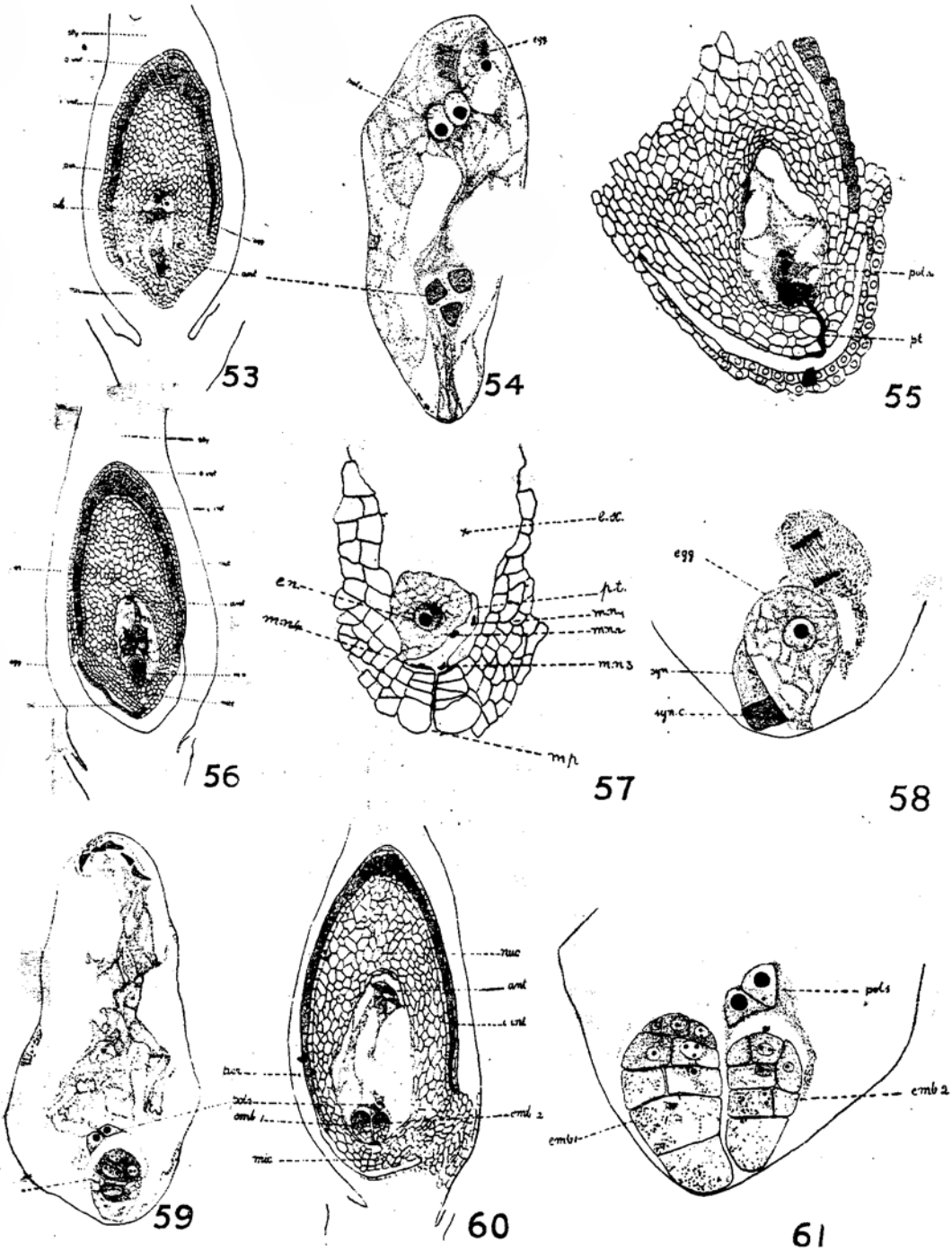
Size of nuclei of microsporocytes at diakinesis and haploid chromosome numbers.

Name of variety	No. of nuclei measured	Mean diameter in microns	Mean radius in microns	r^3	Haploid chromosome number
Poovan	40	9·84	4·92	119	About 40
Chittan	51	13·2	6·6	287	About 40
Puri	21	11·76	5·88	203	40
S. spontaneum (Coimbatore)	26	9·04	4·5	91	32
Co. 205	20	10·4	5·2	141	56

For the above measurements, the varieties Vellai, Kaludai Boothan and Shamshara were not included, as their microspore mother cells were not in the typical diakinesis stage. It will be seen from the above that r^3 deviates 70 per cent., 27 per cent., 50 per cent., 72 per cent. and 75 per cent. from ten times the haploid chromosome number in the varieties, Poovan, Chittan, Puri, *S. spontaneum* (Coimbatore) and Co. 205 respectively. It is difficult to explain so large a deviation unless it be that the pollen mother cells and their nuclei in the above preparations had become smaller owing to imperfect fixation, but this would appear to be hardly likely as no plasmolysis was noticed. Before any definite opinion can be expressed, it will be necessary to collect more data on these as well as on other varieties.

V. AN ABNORMAL EMBRYO-SAC.

In a normal sugarcane embryo-sac (1) the egg and the synergids are towards the micropylar end, (2) the polar nuclei immediately above the egg, and (3) the antipodal complex towards the chalazal end. In the course of the study of fertilization and embryogeny in sugarcane, an abnormal embryo-sac was met with in the cross Vellai × C. A. C. 87 and is shown in Plate VIII, figures 53 and 54. The antipodal nuclei are seen to be situated near the micropylar end while the polars and the egg are towards the opposite end. Since this is unusual, the writers



(For explanation see page 56.)

repeatedly and carefully examined the sections in question to make sure that no mistake was made in the identification of the structures. From their shape and size as compared with the normal cases, it appeared certain that the nuclei towards the micropylar end were the antipodals. The polar nuclei were also identified with certainty. Above the polars was seen the nucleus of the egg, and though the outline of the cell was not very clear, from its position with reference to other components of the embryo-sac, it would appear that the structure in question was the egg. Some dense cytoplasm with chromatin granules was seen near the egg which probably represents the remains of the disorganized synergids.

VI. Fertilization.

In a previous publication on the growth of sugarcane pollen tube *in vitro* [Dutt, 1929], it was stated that under favourable conditions, the sugarcane pollen tube might reach the ovary in about three to four hours. This has now proved to be an under-estimate by about three hours from the detailed studies that were taken up later.

Flowers of the variety Vellai were fixed at definite intervals after pollinating with C. A. C. 87 pollen in order to ascertain (1) the time taken by the pollen tube to reach the embryo-sac, (2) subsequent stages of fertilization and (3) embryogeny. The interval was half an hour from five to ten hours after pollination and half a day from one to nine days.

The pollen tube was found to have reached the embryo-sac 7½ hours after pollination in the cross Vellai × P.O.J. 1410 (Plate VIII, figure 56), and this was also confirmed in the cross P.O.J. 2725 × Co. 285 (Plate VIII, figure 55), where the pollen tube was seen entering the micropyle seven hours after pollination. In the preparations of the cross Vellai × C. A. C. 87, however, the exact time taken by the pollen tube to reach the embryo-sac could not be determined, but in two sections the primary endosperm nucleus was found to be in division eight hours after pollination. One of these is shown in Plate VIII, figure 58, in which the primary endosperm nucleus is seen to be in telephase. This would indicate that the pollen tube would have entered the embryo-sac some time before eight hours after pollination.

In the preparations, fusing sex nuclei were not observed, but in sections of the ovaries collected one day after pollination, the endosperm was usually found in the coenocytic stage, while fertilized egg was seen to be dividing not later than two days after pollination.

VII. Generative nuclei.

In a previous paper [Dutt and Krishnaswami, 1932], it was mentioned that two male nuclei were noticed to have been formed inside the sugarcane pollen

grains twenty-four hours before shedding. This condition has since been observed in nineteen more sugarcane varieties as also in *S. munja*. Very young flowers of C. A. C. 87 were stained in aceto-carmine and on examination, two male nuclei were seen to have been formed about five days before shedding. The observations on the occurrence of four male nuclei in certain sugarcane varieties were continued and the cross Vellai × B. 3412 was effected with the specific object of ascertaining the significance of the occurrence of more than two male nuclei in the sugarcane.

Further observations were made on the migration of the two male nuclei from the pollen grain to the pollen tube. Percentages of tubes into which the nuclei had migrated were worked out in the artificially cultured pollen of Co. 285 and *S. spontaneum*. Counts were made at intervals of thirty minutes, one hour, two hours and three hours after the first germination. In the one hour old cultures, the nuclei had migrated in 40 per cent. of the tubes, while in three-hour ones, the migration of the nuclei had taken place in 80 per cent. of the tubes. In certain thirty minutes and one-hour pollen tubes, one generative nucleus was noticed to be inside the grain while the second had migrated some distance into the tube. Such tubes were counted in one culture (Co. 285, one hour old culture), and were found to be six per cent. of the total germinations. No clear relationship was found between the migration of the nuclei and the length of the pollen tube. In three hours old cultures, certain tubes (about 400μ long) were found with the nuclei still inside the pollen grain. These tubes had probably stopped growing at an early stage. On the other hand, both the nuclei had migrated in certain ten minutes old cultures, the tubes being only 108μ long. Further, in a tube which was 1800μ long (P. 671, six hours old culture), the nuclei had travelled only 450μ from the grain, while it was not uncommon to find the nuclei at the extreme tip in much shorter pollen tubes.

As for the occurrence of more than two nuclei in other plants, De Mol [1923] who worked on *Hyacinthus orientalis* was successful in obtaining plurinuclear pollen grains experimentally. In most cases four of these nuclei were present, but five to eight have been observed by him. He further observed that these plurinuclear pollen grains (1) could be more easily induced to germinate in cane sugar solutions, (2) frequently sprouted while still inside the unopened anther and (3) formed wide, somewhat bladder-shaped pollen tubes. When four male nuclei were present in the tubes, one was sometimes lying at some distance from the other three and was larger than these. Such a large nucleus was frequently lying in the end part of the tube, while the other somewhat smaller ones had remained in the pollen grain or had just entered into the pollen tube. The observations

made on the four male nuclei in the sugarcane differ from those of De Mol [1923] in the following respects. (1) More than four male nuclei have not been observed so far, (2) the pollen grains and tubes with four male nuclei are not abnormal in any way and behave exactly as the normal ones in their germination capacity as well as in the nature of their pollen tubes, (3) the four male nuclei in the tube were observed to occur in pairs, either both the pairs moving closely together or at some distance from each other, and (4) the size of all the male nuclei was more or less the same. The usual size of the male nucleus inside the pollen tube is about 8 to 10μ long, though small globular nuclei about 5μ in diameter and very long vermiform nuclei measuring 26μ in length were occasionally observed.

Out of the several sections of ovaries of Vellai that had received B. 3412 pollen, only in one four male nuclei were observed inside the embryo-sac. This section is shown in Plate VIII, figure 57. It will be seen that the pollen tube has just reached the embryo-sac and the tip has not yet burst to liberate the four male nuclei, all of which are still seen to be inside the pollen tube. In this case, if the nuclei had been set free, they would clearly be all from the same pollen tube and there will be no uncertainty as was felt in *Gagea lutea* where Nemec [1912] was not sure whether the two sperm nuclei fusing with the egg and the other two fusing with the nucleus of the embroy-sac were derived from the same pollen tube or from two separate ones. Similarly Ishikawa [1918] who came across an aberrant case in *Oenothera mutans*×*Oe. pycnocarpa* found two male nuclei near the egg nucleus while the third was just coming in contact with the large pole nucleus. As the pollen tube was lacking in the preparation, he was unable to decide whether the extra nuclei were brought about by intrusion of two sets of sperm nuclei due to an attack of two pollen tubes on a single embryo-sac or by the production of excess generative nuclei in the male gametophyte.

As to the significance of the occurrence of four male nuclei the following points deserve mention. According to Coulter and Chamberlain [1909] this may have no further significance than that any active cell may be induced to divide by favourable conditions. Certain other investigators, however, are of opinion that two male nuclei fertilize the egg nucleus leading to the origin of a plant possessing triploid nuclei. Nemec [1912] often observed triple fusion in the egg nucleus in *Gagea lutea*.

De Mol [1923] observed two types of abnormal pollen grains in *Hyacinthus orientalis*, *viz.*. (1) Plurinuclear pollen grains, and (2) Large, globular, diploid pollen grains. He is inclined to the view that triploid seedlings owe their origin to the fertilization of a haploid egg nucleus by two haploid male nuclei or one diploid nucleus.

VIII. Ovogenic apogamy.

While examining the preparations of the cross Vellai×C. A. C. 87 for stages in the development of the embryo, it was observed in two sections that a few divisions had taken place in the egg, while the characteristic coenocytic stage of the endosperm was absent. One of these is shown in Plate VIII, figure 59. It will be seen that the polar nuclei are intact and have not fused. This particular ovary was fixed two days after pollination. While giving the details about fertilization, it has been mentioned that in the sugarcane, (1) the pollen tube reaches the embryo-sac in about seven hours, (2) the endosperm is in the free nuclear stage in about twenty-four hours after pollination, and (3) the fertilised egg usually starts division not later than two days. If, therefore, these embryo-sacs had received the male nuclei, there would normally have been a formation of the endosperm. From the above, it would appear that the embryos in question have in all probability arisen parthenogenetically.

IX. Polyembryony.

Many cases of polyembryonyo have been noticed in Angiosperms, the well-known examples being those of *Citrus aurantium* and other plants. The extra embryos arise either from the cells of the embryo-sac other than the egg—apogamy—or by sporophytic budding. In the latter, the cells of the nucellus and those of the integument are usually involved, while in the former, cases are known where every cell within the embryo-sac produced an embryo. Though the synergids and antipodal cells have frequently been noticed to give rise to embryos, cases where endosperm cells have formed embryos are very rare. Such cases according to Sharp [1926] are open to grave doubt. Woodworth [1930] working on *Alnus rugosa* has, however, reported a case of an embryo which apparently originated from endosperm material.

The occurrence of polyembryony in Graminese has been reported in the following cases :—Kuwada [1910] noticed in rice "an abnormal formation of two embryo-sac mother cells" which would suggest the possibility of polyembryony in rice. Komura [1922] reported the formation of two plumules in a rice seed after germination, and Rodrigo [1926] found that one seed of the rice variety Inintiw produced two plumules and two primary radicles. In the 214,000 rice seeds germinated by him he noticed only one which produced two plumules. Jones [1928] reports a case of two hybrid plants apparently "identical twins" derived from one fertilized egg in a cross of the rice varieties Yosemite and Nimai Kawa Mochi. Hansen [1920] found that double-germ grains occurred in Mahndorfer winter wheat at the rate of 1 : 10000, in Mahndorfer oats at the rate of 1 : 20000 ; and in 7 per cent. of the seeds

in one strain of rye. Nishimura [1923] noticed polyembryony in *Poa pratensis*. Ayyangar and Krishnaswami [1930] have reported the occurrence of polyembryony in *Eleusine coracana*.

While examining the sections of the cross Vellai×C. A. C. 87, two embryos in one embryo-sac were noticed. The section is shown in Plate VIII, figures 60 and 61. The embryos are lying side by side, one of them is normal while the other has apparently arisen as a result of the fertilization of one of the synergids by the second male nucleus. The two polar nuclei, it will be seen, have not yet fused. The second embryo in this case, *i.e.*, the one that has developed from the fertilized synergid, may also be regarded as normal and not apogamous. Over 100,000 seeds are germinated every year at the Thick Cane Area in connection with sugarcane breeding, and the writers have not so far come across a seed which produced either two plumules and two radicles, two plumules with a single radicle or a single plumule with two radicles.

X. Discussion.

Stages in meiosis pointed to the haploid number in Vellai, Shamshara, Poovan, Chittan and Puri to be about forty. All these canes apparently belong to the species *S. officinarum* and their chromosome number would appear to bring them into a line with the " noble " varieties studied by Bremer [1924].

In the cytoplasm darkly stained granules—about the size of univalents—were noticed in the varieties Vellai and Puri. These granules were the only indication of extruded chromatin. The long membranous body in the cytoplasm, usually near one of the poles, which according to Bremer [1923] is characteristic of the canes belonging to *S. Barberi*, was not noticed in any of the canes studied in this paper including *S. spontaneum*. The preparations of Co. 205 were rather dark, due to La Cour's [1929] fixative, but as far as could be seen, no chromatin in the cytoplasm, in the shape of the characteristic remains of the nucleolus, was noticed. It may be stated that the extruded chromatin noticed in Vellai and Puri was found to be an exception and not the rule. Extruded chromatin has been observed by various workers in other plants. Church [1929] noticed it in *Panicum festuca*, *Avena sativa* and *Spartina*, while considerable cytoplasmic chromatin was seen by Beck and Horton [1932] in all the three species of Bromus studied by them, particularly in *B. marginatus* in which a continuous mass of chromatin was found adhering to the cell wall. Often there seemed to be as much material in the mass as on the spindle. The continuous mass in *B. marginatus* would remind one, in certain respects, of the long membranous body noticed by Bremer [1923] in the Indian canes. Extruded chromatin has also been frequently observed in Rosa by Erlanson [1929].

According to Bremer [1925], the chromosome numbers found in Saccharum clearly point to 10 (or possibly 5) being the original number of the Maydeae and Andropogoneae. The haploid number 32 in the Coimbatore form of *S. spontaneum* would mean that this form is a dysploid, a term employed by Jeffrey [1925] to denote "non-multiploid variation in number of the nuclear chromosomes". Several instances of dysploidy in Gramineae have been given by Church [1929]. For instance, a series of 9, 8, 7, and 10 in the genus *Panicum*, and counts of 9 and 11 in *Paspalum*, though the well-established number in the latter genus is 10. If the haploid number in the Indian forms be taken as 48, then the haploid numbers of at least certain of the Saccharum forms, *viz.*, *S. spontaneum* (Coimbatore), *S. officinarum*, *S. spontaneum* (Glagah Tabongo), *S. Barberi* and *S. spontaneum* (Java) with 32, 40, 40, 48, and 56 chromosomes respectively, would form a series with 8 as the basal number. This is only a suggestion based on the occurrence of 32 haploid chromosomes in the Coimbatore form of *S. spontaneum* and may perhaps need to be revised as more data become available on other forms of *Saccharum*. The evidence as at present available on the majority of *Saccharums* points strongly to 10 (possibly 5) being the basal number, but as mentioned above in the case of *Panicum*, it is not unusual to find multiples of different basal numbers in the same genus. Of the euploid series in Gramineae, some of the most interesting are those in which, according to Longley [1932], the chromosome numbers in the perennial forms are twice as many as in the annual forms, *viz.*, *Sorghum halepensis* and *Sorghum sudanensis*.

The occurrence of four male nuclei has been found to be not uncommon in at least certain of the sugarcane varieties. Dispermatic fertilization is probably not the cause of increased chromosome number in the species hybrids in *Saccharum* as the chromosome counts indicate that a doubling has taken place only in the chromosomes of the female parent and not of the male parent. In one of the seedlings of the cross P.O.J. 2875 and Glagah, at Pasoeroean it was found that the chromosome number was 220, which would mean that the chromosomes in both the parents had doubled. This might perhaps be a case in which the chromosomes of the female had split longitudinally during fertilization and had also received two male nuclei.

In certain plant genera an increase in chromosome number has been found to be associated with an increase not only in the size of the cells but also in the size of plants. Sharp [1926] in discussing the relationship between tetraploidy and gigantism states that "the tetraploid mutants are frequently characterised by an unusually large size, not only in the plant as a whole, but also in its anatomical constituents. Winkler [1916] on *Solanum*; Tupper and Bartlett [1916] on *Oenothera stenomeres*. Not all cases of gigantism are associated with tetraploidy. In a form of *Primula sinensis* [Gregory, 1909 and 1914], it is associated with an increase in

the size of the chromosomes and not the number. Sinoto [1925] reports that in *Plantago japonica*, a giant form, the number of chromosomes is one-half than that in the ordinary *P. major*. var. *asiatica*". Denham [1924] found that the cotton plants having 26 chromosomes were on the whole much larger than those with 13 chromosomes. Erlanson [1929] measured the diameter of the microsporocytes of Rosa at diakinesis and found that the diploid types had the smallest cells and the hexaploid the largest, although there was considerable overlapping between the cell sizes at diakinesis in tetraploids and hexaploids. Heilborn [1927] compared the size of pollen tetrads in Draba and found that on the whole the size of the cells increases with the rise in chromosome number. Bremer [1925] found that the cube of the radius of the microsporocyte nucleus at the diakinesis stage was about ten times the haploid chromosome number. In similar measurements made in the varieties studied in this paper, this ratio was not found to hold good. It may, however, be stated that the nuclei of *S. spontaneum* were decidedly smaller in size than those of *S. officinarum*. Further, the three varieties of *S. officinarum*, *viz.*, Poovan, Chittan and Puri, all having the same haploid chromosome number differ from one another in the size of their microsporocyte nuclei. Tahara [1915] found that in the genus *Chrysanthemum*, different species with nine chromosomes had nuclei of very different dimensions.

A cytological examination of the various species of *Saccharum* and allied genera would help in deciding the systematic position of these forms. From morphological view point, Hooker [1897] mentions in the "Flora of British India", 'I find no characters whereby to distinguish *Erianthus* from *Saccharum* except that given above (glume IV awned), which is all but illusory, and a re-examination of both genera may lead to a better disposition of their species under two or more genera or sections'. In fact Bremer [1925] after a very careful examination of cytological data came to the conclusion that *S. munja* and *S. arundinaceum* should be classified under the genus Erianthus.

The abnormal embryo-sac having the antipodals towards the micropyle and the egg towards the opposite end, was the only one of its kind met with in an examination of the sections of over 600 ovaries comprising seven different crosses. The egg of an embryo-sac situated in the abovementioned unusual manner, would by normal fertilization give rise to embryos whose hypocotyle would point towards the chalaza, instead of the micropyle. The writers never came across any such embryo in the large number of sections examined. Such embryos, however, have been reported by Woodworth [1930] in *Alnus rugosa*, which according to him had originated apogamously from the antipodal cells.

Most of the varieties of *S. officinarum* are probably of hybrid origin. Lagging univalents were often met with and sometimes extruded chromatin was also noticed.

As is well known "the presence of unpaired or univalent chromosomes is one of the most striking indications of a hybrid". The occurrence of polyembryony and apogamy would lend support to the above supposition, as according to Ernst [1918] hybridization is the initial cause of meiotic irregularities, apomixis, polyembryony, etc.

XI. Summary.

The haploid chromosome number in Puri, Vellai and Shamshara was found to be 40, and about 40 in Poovan and Chittan.

The Coimbatore form of *S. spontaneum* was found to have 32 haploid chromosomes, while Co. 205, a seedling of the cross between Vellai and *S. spontaneum* (Coimbatore), had 56.

The size of the nuclei of the microsporocytes was not found to be definitely proportional to the haploid chromosome number.

An abnormal embryo-sac was met with in the cross Vellai×C. A. C. 87 in which the antipodal cells were situated towards the micropyle and the egg and polars towards the chalaza.

The pollen tube was found to have reached the embryo-sac seven hours after pollination. The endosperm was seen to be in the coenocytic stage one day after pollination and the division of the egg had commenced two days after pollination.

A pollen tube containing four male nuclei was seen inside the embryo-sac in the cross Vellai×B. 3412.

Two cases of probable parthenogenetic origin of embryos were noticed.

A case of polyembryony was observed in the cross Vellai × C. A. C. 87. The second embryo had probably arisen from a fertilized synergid.

The occurrence of dysploidy in the genus Saccharum and the increase in the chromosome number in the species hybrids is discussed.

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XIII. Explanation of plates.

Except as otherwise stated, all figures were drawn with a Leitz periplanatic eyepiece No. 20 and 1/12 achromatic oil-immersion objective, with the aid of Zeiss Abbe's Camera Lucida at stage level. They were reduced two-thirds in reproduction.

PLATE V.—*Vellai.*

Fig. 1.—Regular heterotypic metaphase.
Fig. 2.—An irregular heterotypic metaphase.
Fig. 3.—Heterotypic metaphase, polar view, showing forty bivalents.
Fig. 4.—Heterotypic metaphase, polar view, showing 41 chromosomes, probably 39 bivalents and two univalents.
Fig. 5.—Heterotypic anaphase; note lagging chromosomes and extrusions.
Fig. 6.—Homeotypic divisions; polar view of the equatorial plate in one of the diads and side-view in the other.

Shamshara.

Fig. 7.—Diakinesis, 33 pairs and 14 univalents. Reconstructed from two sections.
Fig. 8.—Heterotypic metaphase, polar view, 40 bivalents.
Fig. 9.—Same as above, but with 38 bivalents and 4 univalents.
Fig. 10.—Regular heterotypic metaphase.
Fig. 11.—Interkinesis, diad split nearly completed.
Fig. 12.—Diads.
Fig. 13.—Homeotypic divisions, metaphase somewhat irregular in one of the diads.
Fig. 14.—Cross section of a flower, showing 3 anthers and 2 styles.
Fig. 15.—Same as above, showing only one anther, the other two being suppressed.
Fig. 16.—Same as above, but partition wall in one of the locules incomplete.

PLATE VI.

Fig. 17.—Cross section of the flower of Shamshara showing two pairs of styles.

Poovan.

Fig. 18.—Diakinesis, showing 34 bivalents and 12 univalents.
Fig. 19.—Heterotypic metaphase, polar view; 38 bivalents and 13 univalents.
Fig. 20.—Same as above, but with 23 bivalents and 39 univalents.
Fig. 21.—Heterotypic metaphase somewhat irregular.
Fig. 22.—Heterotypic anaphase, with lagging univalents.
Fig. 23.—Somatic plate, showing 78 chromosomes.

Chittan.

Fig. 24.—Diakinesis, showing 40 pairs.
Fig. 25.—Heterotypic metaphase, polar view. The chromosomes are closely packed together.
Fig. 26.—Heterotypic anaphase with lagging univalents.
Fig. 27.—Somatic plate, showing 78 chromosomes.

Puri.

Fig. 28.—Prophase. Note the protuberance on the nucleolus.
Fig. 29.—Diakinesis, showing 40 pairs.

Fig. 30.—Heterotypic metaphase ; side view.
Fig. 31.—Heterotypic metaphase ; polar view, showing 40 bivalents.
Fig. 32.—Heterotypic anaphase.
Fig. 33.—Heterotypic telophase. Note the extruded chromatin.
Fig. 34.—Interkinesis ; diad split almost completed.
Fig. 35.—Homeotypic divisions ; 40 bivalents in each of the diads.

PLATE VII.—*Saccharum spontaneum* (Coimbatore).

Fig. 36.—Diakinesis ; showing 32 pairs.
Fig. 37.—Heterotypic metaphase.
Fig. 38.—Heterotypic metaphase, polar view, showing 32 bivalents.
Fig. 39.—Same as above in another microsporocyte.
Fig. 40.—Same as above in a third microsporocyte.
Fig. 41.—Heterotypic anaphase.
Fig. 42.—Interkinesis ; diad split not yet commenced.
Fig. 43.—Diads.
Fig. 44.—Homeotypic divisions ; 32 chromosomes in each diad.
Fig. 45.—Pollen grains just released from the tetrad stage.
Fig. 46.—Somatic plate, showing 64 chromosomes.

Co. 205.

Fig. 47.—Diakinesis ; showing 56 pairs. Reconstructed from two sections.
Fig. 48.—Heterotypic metaphase, polar view showing 56 bivalents.
Fig. 49.—Same as above in another microsporocyte.
Fig. 50.—Heterotypic metaphase.
Fig. 51.—Heterotypic anaphase, showing lagging univalents.
Fig. 52.—Homeotypic divisions, 56 chromosomes in each diad. Lower diad reconstructed from two sections.

PLATE VIII.

(In this plate the figures were reduced to one-half in reproduction.)

Fig. 53.—Vellai × C. A. C. 87. Longitudinal section of the ovary showing an abnormal embryo-sac. Note the occurrence of the antipodals towards the micropylar end and of the egg and polars towards the opposite end. Reconstructed from two sections. *sty*, style ; *o int*, outer integument ; *i int*, inner integument ; *per*, pericarp ; *pols*, polars ; *mic*, micropyle ; *ant*, antipodals. (Leitz eye-piece No. 6, objective No. 4.)

Fig. 54.—Embryo-sac in above, enlarged. (Leitz eye-piece No. 10, objective No. 7.)

Fig. 55.—P.O.J. 2725 × Co. 285. Pollen tube entering the micropyle. Seven hours after pollination. (Zeiss eye-piece No. 10, objective No. 40.)

Fig. 56.—Vellai × P.O.J. 1410. Pollen tube inside the embryo-sac. 7½ hours after pollination. *m n*, male nucleus ; *pt*, pollen tube. (Leitz eye-piece No. 6, objective No. 4.)

Fig. 57.—Vellai × B. 3412. Showing the pollen tube inside the embryo-sac with four male nuclei. (Zeiss eye-piece No. 5, objective No. 100.)

Fig. 58.—Vellai × C.A.C. 87. Showing the first division of the primary endosperm nucleus ; telophase. Eight hours after pollination, *syn*, synergid ; *syn c*, synergidal cap. (Leitz eye-piece No. 6, objective No. 1/12.)

Fig. 59.—Vellai × C.A.C. 87. Showing ovogenic apogamy. *emb*, embryo. (Leitz eye-piece No. 15, objective No. 4.)

Fig. 60.—Vellai × C.A.C. 87. Showing Polyembryony. (Leitz eye-piece No. 6, objective No. 4.)

Fig. 61.—Same as above, embryos enlarged. (Leitz eye-piece No. 6, objective No. 1/12.)

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A PRELIMINARY NOTE ON THE MEMBRANEOUS BODY IN THE CYTOPLASM AS CHARACTERISTIC OF THE INDIGENOUS INDIAN CANES.

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(With Plates XVI and XVII.)

The indigenous Indian canes were first exhaustively studied by Barber [1916] who, on their morphological characters, classified them into five separate groups, *viz.*, Mungo, Saretha, Sunnabile, Pansahi and Nargori. Jeswiet [1916] working in Java, classified the Pansahi group of Barber as *Saccharum sinense* (Roxb.), and placed the rest under a new species *Sacch. barberi* (Jesw.). Bremer [1932] has shown that the Indian canes differ in chromosome numbers not only from *Sacch. officinarum* and *Sacch. spontaneum*, but also among themselves, thus confirming Barber's classification of these canes into various groups. The diploid chromosome numbers in Mungo, Saretha, Sunnabile and Nargori, according to Bremer, are 80, 90-92, 116 and 124 respectively. Since these groups further possess distinct morphological characters which demarcate them from one another, Bremer doubted the desirability of placing all the four groups under one species *Saccharum barberi*.

According to Bremer, one interesting feature, characteristic of the whole Indian group of canes, including the Pansahi, is the presence of a long membraneous body in the cytoplasm (usually near one of the poles) during the metaphase and telophase of the reduction division. The presence of such a characteristic body would, no doubt, be a reliable criterion to separate the Indian forms from others.

The writers [Dutt and Subba Rao, 1933] had occasion to ascertain the chromosome numbers in certain sugarcane varieties that are being grown in the tropical parts of India and inci dentally noticed that the Coimbatore form of *Saccharum spontaneum* differed in chromosome number from the Java and the North Celebes forms mentioned by Bremer. The relationship of the size of nuclei of the microsporocytes to the haploid chromosome number in the various sugarcane varieties, including Saretha, was also studied. In the latter variety, while searching for the diakinesis stages several other stages were met with and the absence of the characteristic body in all

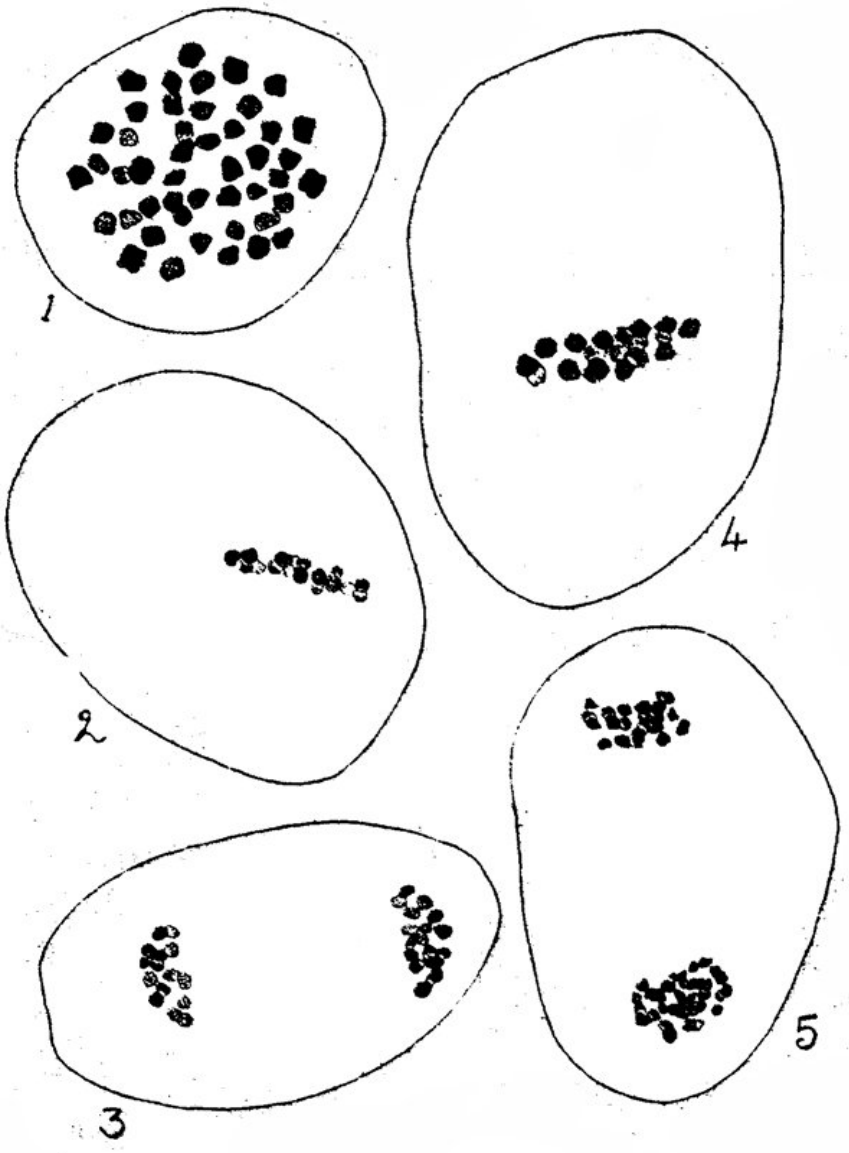
the metaphase and the telophase stages was noted. It appeared worthwhile to pursue this point further, and material was, therefore, fixed in the following varieties during the current flowering season: Uba, Ketari, Merthi, Tekcha, Ohima (Pansahi group); Lalri, Kansar, Katha, Saretha (Saretha group); Hemja, Kharwi (Mungo group); Putli Khajee (Sunnabile group). The material of Saretha, collected last year, was fixed in Allen's modification of Bouin's fluid and the sections were stained in Haidenhain's iron alum hæmatoxylin. For purposes of comparison it was thought better to use the same fixative as that employed by Bremer and accordingly material was fixed this year in acetic alcohol.

The large number of sections that were cut last year in Saretha were again examined carefully for the presence of the body. The body was not noticed in any of the sections examined. Figs. 2 and 3 are camera lucida drawings of metaphase and telophase of Saretha, while Fig. 1 shows a metaphase plate of Saretha with 46 chromosomes. Before taking up the material fixed this year, through the usual grades of alcohol and xylol for embedding, a preliminary study was made of the same by staining in aceto-carmine. Fig. 6 shows a photomicrograph of one such variety, *i.e.*, Kansar, studied in this manner and the absence of the characteristic body in all the dividing pollen mother cells may be noted. Similarly a preliminary study by staining with aceto-carmine was made in all the other varieties fixed this year (representative of four of the groups of the indigenous Indian canes) and the body was again not traceable. To make sure about the correctness of the above observations, further detailed work is in progress.

An interesting corollary of Bremer's work regarding the presence of the membraneous body, was its application to the origin of the yellow Egyptian cane or Creole. Bremer noticed that the number of chromosomes in the somatic cells as also in the anaphase of the reduction division was 81, which was exactly the sum of the haploid number 41 of the Mungo group and 40 of *Sacch. officinarum*. The characteristic body was also noticed and that afforded Bremer a further indication of the Indian and hybrid origin of Creole. In the preparations of Creole made by the present writers last year, not a single pollen mother cell was met with that showed the characteristic body. Figs. 4 and 5 are camera lucida drawings of microsporocytes of Creole at metaphase and telophase.

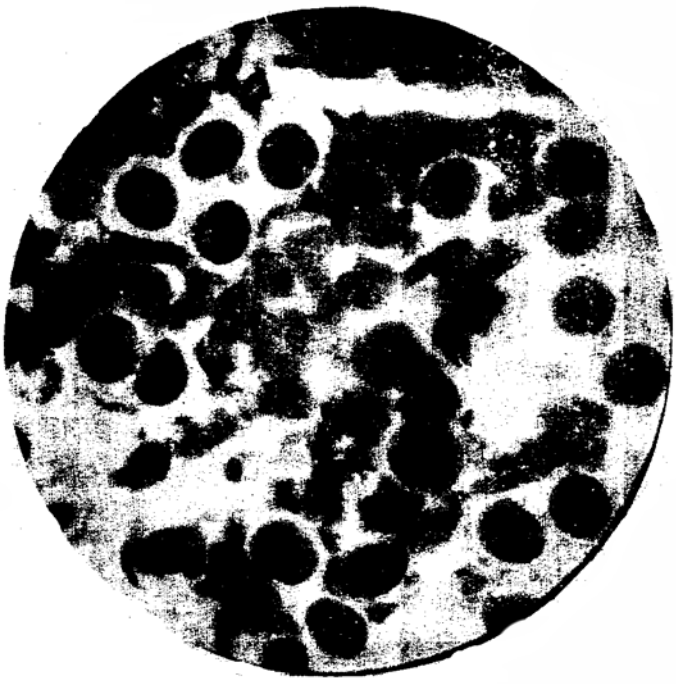
From the above-mentioned preliminary observations, it will be seen that we have not so far noticed the characteristic body in either the indigenous Indian canes examined by us or in Creole, which is believed to contain the blood of a cane belonging to the Mungo group. If Bremer's observation on the presence of the membraneous body as characteristic of the whole Indian group of canes, could be confirmed, it would afford a valuable aid not only in identifying the Indian canes

XVI.



Figs. 1-3 are of Saretha, and 4 and 5 of Creole.
Note the absence of membraneous body in figs. 2-5 (×2,000).

PLATE XVII.



Photomicrograph of dividing pollen mother cells of Kansar. Note the absence of membraneous body.

cytologically, but also in tracing out their blood in the seedling cane varieties suspected or believed to have arisen from them.

We are indebted to Rao Bahadur T. S. Venkatraman for kindly placing the material of the Indian canes at our disposal. The Creole cane in the varietal plot at the Imperial Sugarcane Station, Coimbatore, was obtained through the courtesy of Mr. Noel Deerr in 1929.

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(Translation of the Key to the Species of *Saccharum* from the above has appeared in *J. Agric. Res.* **39**, 1-30, 1929.)

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A NOTE ON SEED-SETTING AND SEED-GERMINATION IN CERTAIN SUGARCANES*

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(With Plate XVIII)

I. Introduction

In the breeding of the thick canes for India, one of the problems which has engaged the attention of the writers during the last ten years is the improvement of germination of the thick cane seeds. The growing needs of the sugar industry and the demand for high-yielding, disease-resistant varieties has necessitated the utilization of a wide range of parents. Some of the parents chosen were, therefore, of the hardy type, a number of them containing the blood of two or three of the following species of *Saccharum* :—*S. officinarum*, *S. barberi*, and *S. spontaneum*. As good seed-germination is a desideratum in sugarcane breeding, a number of varieties and seedlings have been tested to ascertain their value as breeding material.

II. Material and methods

The seed† employed in these experiments was collected from unbagged inflorescences, as previous experience at the station had shown [Barber, 1916; Venkatraman, 1925] that enclosing the inflorescence in a cage adversely affects seed-setting. For preliminary seed experiments the fuzz or fluff used was taken from what are called 'G. Cs.' (General Collections), that is, from unprotected arrows in the open. In such cases, therefore, only the female parent is known. These General Collection sowings have been quite useful because by growing a hundred seedlings from each lot in the field, a good indication is obtained of the type of seedlings to be expected from the particular female parent. The method for sowing seeds [Barber, 1916] was the one which has been in vogue at the station since its inception.

* Paper presented at the Indian Science Congress, Hyderabad, January 1937.

† By seed in this note is meant the unthreshed caryopsis.

FIG. 1. Seed-pans showing poor germinations of seeds of certain sugarcane varieties

FIG. 2. Seed-pans showing satisfactory germinations of seeds of certain sugarcane varieties

III. Experiments

(*a*) *Seed treatment*

Attempts were made to treat the seed before sowing with a view to see if it would improve the percentage of germination. The treatments were :— (1) Soaking in water for fifteen hours before sowing ; (2) soaking in concentrated sulphuric acid for five minutes and thoroughly washing before sowing ; (3) soaking in 0·1 per cent ortho-phosphoric acid for fifteen hours before sowing ; (4) soil-fluff mixture ; for this treatment the fluff was mixed with an equal quantity of seed-pan mixture and spread over the pan, the pan being watered in the usual manner. In the soil-fluff mixture the germinations were better than the other treatments but not better than the control (Table VI).

The seed of the varieties used in the above experiments was also sown twenty-seven and forty-seven days after the date of collection to see if desiccation after collection would improve germination or, in other words, if there is any after-ripening in sugarcane seed. In all the above treatments, the seed sown twenty-seven and forty-seven days after collection gave less germination than the control.

(*b*) *Seed-germination in different varieties*

Though for a number of experiments (Table II) equally weighed quantities (3 grammes per seed-pan) were sown, for bulk sowings (Table I) which involved as many as one thousand pans each year, a handful of fuzz as judged by trained labour was sown. The averages given in Table I are from such bulk sowings. For certain varieties the data presented are for seven or eight seasons. It will be seen from the same table that varieties like POJ 2364, POJ 2878 (Plate XVIII, fig.2) and, to a certain extent, POJ 2725 have given uniformly high germinations year after year, while certain typical *S. officinarum* varieties such as Vellai, Chittan, Striped Mauritius (Plate XVIII, fig. 1) and Gillman* have consistently yielded poor seed germinations. Mauritius 55 and 131 are, however, instances of *S. officinarum* type of canes which have given satisfactory germinations. *S. spontaneum* (both Coimbatore and Java forms) tops the list. Among the commercial varieties there is an improvement as we come to Co 205 and Co 285, apparently due to the *S. spontaneum* which they possess. Cos 213 and 290, on the other hand, give moderate germinations. A judicious combination of *S. officinarum* and *S. spontaneum* blood in Co 419 and Co 421 has resulted in these varieties giving seed of high germinating capacity.

For the large majority of cases in Table I, a variation will be noticed from year to year due, most probably, to the weather conditions—chiefly rainfall—prevailing at the flowering time. It is well known that such rains adversely affect seed setting.

* This is a bud sport obtained from Striped Mauritius.

(c) Influence of pollinating parent on seed-germination

The differential effect of various pollinating parents on the same female variety will be seen from Table II. The pollen of over fifteen varieties was dusted on Vellai and though the pollen of Co 205 and Co 243 gives high percentage of germinations as tested on artificial culture media [Dutt and Ayyar, 1928 ; Dutt, 1929], the seed germinations of Vellai × Co 205 and Co 243 are poor as compared with D 74 and 247 B, whose pollen-germination percentages are low. Similarly, Co 285 which is well known for its high pollen germination, has given rise to only moderate seed germination in the cross Vellai × Co 285. Varieties with such high pollen germinations as *S. spontaneum* (Coimbatore), Glagah and Saretha have also been no exceptions. On the other hand, the thick seedling varieties B 3412 and D 131, whose pollen germinations are high, have yielded high germinations in the crosses Vellai × B 3412 and Vellai × D 131. From the above data there would appear to exist a certain amount of incompatibility between the species of *Saccharum*. This point, which is well worth investigation, will be made the subject of further studies.

The crosses made with Chittan, Karun, and Striped Mauritius as female parents are also similar to Vellai in that they give poor germinations even with the best male parents like Co 243 and Co 285. Further, Karun and Chittan have given poor germinations, also with the only thick cane male parent used on them, namely, 247 B. Based on experience, it may be said that though certain *S. officinarum* varieties like Vellai, Karun, Chittan, and Striped Mauritius may yield very good seedlings off and on, the care and labour involved in raising a large population is far too great. The inherent capacity of these varieties for seed germinations is low ; for instance, Vellai, even in the most favourable combination, hardly ever gives 200 germinations per seed-pan. On the other hand, varieties like POJ 2878 have, from the point of view of breeding of economic types, been found to be quite good. No dearth of seedlings is felt when such varieties are used as ovule parents and it is possible to repeat the majority of the desired crosses year after year as varieties like POJ 2878 seldom fail to flower. In the number of germinations even the lowest for POJ 2878 in any combination is over 200 per seed-pan, while in quite a number of crosses it exceeds 600.

The variety B 6308 was used for a few seasons as a female parent and in one or two on a fairly large scale. It was only in the cross B 6308 × Co 290 that satisfactory type of seedlings were obtained and even these after further tests had to be discarded. The preference of B 6308 for Co 290 lends support to the view that, as regards not only compatibility but also the securing of desirable type of seedlings, the problem is intimately connected with intervarietal rather than inter-specific crosses, that is, the most suitable pollinating parents for each female variety can be ascertained only after experimentation.

IV. Germination of seed from pedicelled and sessile spikelets

It was noticed, while examining some pans in which the seeds had just germinated, that most of the germinations were from sessile spikelets. As the pans in question related to a thick cane cross it was thought that the above characteristic might hold true for *S. officinarum* varieties in which the sessile spikelets usually open first and the converse might be the case for *S. spontaneum* and *S. barberi*, where the pedicelled spikelets are the first to open. To test this, some crosses and G. Cs. were taken, the seeds of pedicelled and sessile spikelets separated and sown in different pans. The result of germination counts are given in Table IV. It will be seen that more germinations were obtained from seeds of sessile spikelets in all cases including *S. spontaneum* G. C. It was further observed that the seedlings from the sessile spikelets were relatively more vigorous. Percentages of seed setting were determined in sessile and pedicelled spikelets. For this, 300 sessile and 300 pedicelled spikelets were examined in certain crosses. It will be seen from Table V that there were more seed settings in the sessile than in the pedicelled spikelets.

V. Size of seed in certain species of *Saccharum*

Observations were made on the length and thickness of seeds from the general collections (G. C.) of five representative varieties of three species of *Saccharum* and Co 205, an inter-specific hybrid (*S. officinarum* × *S. spontaneum*) (Table III). The measurements are the average of over one hundred readings. The diameter of the cane stalk is also given in each case, and it will be seen from the last column (Table III) that there is a high positive correlation between the thickness of the cane stalk and the length as also width of the seed.

VI. Summary

1. The seed-germinations of over forty varieties were studied for five to seven seasons. Varieties like POJ 2725 gave uniformly high germinations, while *S. officinarum* varieties, such as Vellai, Chittan, etc., gave consistently low germinations. The *S. spontaneum* forms topped the list. A judicious combination of *S. officinarum* and *S. spontaneum* blood in Co 419 and Co 421 has resulted in these varieties, giving seed of high germinating capacity.

2. The attempt to improve germination by chemical means was not successful.

3. While a certain amount of influence of the pollinating parent was evident, the high or low germinations seem to depend more on the inherent capacity of the female parent.

4. The securing of desirable type of seedlings appears to be intimately connected with inter-varietal rather than inter-specific crosses.

5. Seeds of sessile spikelets gave more germinations than those of pedicelled ones in all the cases examined, including *S. spontaneum*.

6. There is a high positive correlation between the thickness of the cane and the length as also width of the seed.

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TABLE

Seed-germinations in G.

Varieties	1928-29			1929-30			1930-31		
	Total No. of germinations	No. of seed pans	Germinations per seed pan	Total No. of germinations	No. of seed pans	Germinations per seed pan	Total No. of germinations	No. of seed pans	Germinations per seed pan
Vellai	600	20	30	190	10	19	420	25	17
K. Boothan	145	5	29	75	5	15	300	10	30
Karun	...	...	...	100	3	33	30	6	5
Chittan	...	...	...	50	3	17	160	15	11
Puri	...	...	...	30	3	10	...	...	...
Str. Mauritius	200	5	40	30	5	6	300	10	30
Green sport	280	5	56	75	3	25	1,500	7	214
Gillman	150	5	30	42	5	9	1,600	10	160
S. spontaneum (Coimbatore)	...	...	...	...	...	...	...	...	...
Glagah	...	...	...	...	...	...	...	...	...
B 3412	2,000	12	167	450	5	95	2,600	7	371
B 6308	425	11	39	200	5	40	2,200	12	183
CAC 87	...	...	...	...	...	...	...	...	...
D 74	700	10	70	200	6	34	500	10	50
D 131	6,160	26	237	1,500	3	500	1,200	5	240
HM 539	...	...	...	300	3	100	...	...	...
Maur 55	...	...	...	...	...	...	1,500	2	750
„ 131	1,866	5	373	600	5	120	3,700	12	308
„ 1237	20	3	7	...	...	...	...	...	...
POJ 100	200	5	40	55	5	11	110	5	22
„ 1410	75	5	15	...	...	...	3,000	10	300
„ 2364	...	...	...	1,400	9	156	4,000	8	500
„ 2696	700	2	350	...	...	...	2,500	4	625
„ 2725	150	1	150	800	10	80	5,000	10	500
„ 2727	1,145	5	229	40	7	6	3,000	16	189
„ 2878	...	...	...	9,000	15	600	4,200	9	467
EK 28	250	10	25	400	5	80	900	10	90
SW 111	150	5	30	2,300	6	383	3,500	5	700
247 B	200	10	20	140	9	16	1,500	10	150
Q 813	350	7	50	240	18	13	1,500	7	215
Co 205	...	...	...	...	...	...	...	...	...
„ 213	75	3	25	15	2	8	1,700	5	340
„ 243	...	...	...	700	1	700	1,200	3	400
„ 281	...	...	...	...	...	...	...	...	...
„ 285	...	...	...	720	1	720	1,200	1	1,200
„ 290	...	...	...	700	5	140	600	10	60
„ 360	...	...	...	...	...	...	350	9	39
„ 361	...	...	...	...	...	...	4,500	10	450
„ 363	...	...	...	...	...	...	...	...	...
„ 400	...	...	...	...	...	...	...	...	...
„ 403	...	...	...	...	...	...	...	...	...
„ 405	...	...	...	...	...	...	...	...	...
„ 406	...	...	...	...	...	...	...	...	...
„ 408	...	...	...	...	...	...	...	...	...
„ 413	...	...	...	...	...	...	...	...	...
„ 415	...	...	...	...	...	...	...	...	...
„ 419	...	...	...	...	...	...	...	...	...
„ 421	...	...	...	...	...	...	...	...	...

I

Cs. of different varieties

1931-32			1932-33			1933-34			1934-35			1935-36		
Total No. of germinations	No. of seed pans	Germinations per seed pan	Total No. of germinations	No. of seed pans	Germinations per seed pan	Total No. of germinations	No. of seed pans	Germinations per seed pan	Total No. of germinations	No. of seed pans	Germinations per seed pan	Total No. of germinations	No. of seed pans	Germinations per seed pan
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
12	3	4	75	25	3	150	5	30	72	3	24	...	...	...
20	5	4	12	5	2	240	5	48	479	3	160	90	4	23
...	...	...	4	5	1	...	...	...	22	3	7	...	...	...
27	4	7	25	5	5	...	...	...	19	5	4	...	...	...
...	...	...	6	3	2	8	2	4	...	...	...	...	...	...
200	4	50	36	6	6	230	2	115	50	5	10	40	3	13
85	5	17	35	5	7	...	...	...	...	...	...	...	...	...
70	5	14	35	5	7	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	2,102	3	704	...	...	...
...	...	...	...	...	...	...	...	...	1,072	3	357	...	...	...
...	...	...	79	6	13	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	60	12	5	...	...	...	...	...	...
260	10	26	100	3	33	360	3	120	...	...	...	...	...	...
400	5	80	110	8	14	...	...	...	70	5	14	300	7	43
...	...	...	100	2	50	...	...	...	...	...	...	...	...	...
1	1	1	...	...	...	...	...	...	...	...	...	...	...	...
1,700	4	425	...	...	...	240	4	60	200	3	67	...	...	...
1,200	6	200	900	6	150	60	2	30	...	...	...	...	...	...
32	2	16	...	...	...	91	8	11	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1,250	5	250	130	5	26	700	5	140	...	...	...	...	...	...
631	3	210	...	...	...	670	4	168	300	5	60	...	...	...
600	3	200	...	...	...	360	3	120	...	...	...	...	...	...
1,500	4	375	379	6	63	1,800	4	325	320	5	64	1,200	3	400
180	3	60	107	6	18	650	6	108	...	...	...	...	...	...
3,000	8	375	704	6	117	3,000	6	500	1,700	5	340	1,900	3	633
40	8	5	130	5	26	85	3	12	10	5	2	36	7	5
...	...	...	...	...	...	2,000	5	400	...	...	...	...	...	...
250	5	50	14	2	7	120	5	24	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1,800	3	600	...	...	...	...	...	...	...	...	...	...	...	...
650	3	216	245	6	41	230	3	77	...	...	...	...	...	...
1,100	3	367	...	...	...	...	...	...	...	...	...	...	...	...
2,000	4	500	870	6	145	2,200	3	733	...	...	...	...	...	...
3,465	3	1,155	521	3	174	...	...	...	...	...	...	...	...	...
47	3	16	50	4	13	330	4	83	...	...	...	...	...	...
147	9	16	700	10	70	2,530	5	506	...	...	...	...	...	...
3,000	6	500	...	...	...	2,060	3	687	1,100	5	220	...	...	...
236	10	24	...	...	...	305	4	76	...	...	...	250	5	50
46	8	6	1,200	15	80	1,840	12	153	...	...	...	...	...	...
...	...	...	400	5	80	900	8	113	...	...	...	...	...	...
...	...	...	...	...	...	1,200	4	300	...	...	...	...	...	...
...	...	...	...	...	...	1,800	4	450	...	...	...	...	...	...
...	...	...	300	5	60	1,600	5	320	500	5	100	...	...	...
...	...	...	...	...	...	900	6	150	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	1,660	5	332	...	...	...
...	...	...	...	...	...	5,000	8	625	1,600	5	320	2,600	5	520
...	...	...	...	...	...	...	...	...	1,850	5	370	6,200	8	775

TABLE II

Influence of pollinating parent on seed-germination

Cross	1929-30	1930-31	1931-32	1932-33	1933-34	1934-35	1935-36
Vellai × EK 28	...	...	...	...	240	...	...
× Co 243	112	17	...	29	13	113	...
× POJ 2878	186	25	60	19	...	53	...
× 247 B	234	...	...	...	...	...	...
× B 3412	215	...	133	247	...	168	...
× Co 281	8	...	...	...	...	...	...
× D 74	72	125	...	...	...	...	...
× Co 290	4	...	...	...	...	...	...
× POJ 2727	...	19	...	...	...	...	...
× Co 285	...	8	...	...	...	88	...
× POJ 1410	...	...	10	...	...	...	...
× Glagah	...	...	...	12	...	56	...
× Co 205	...	...	...	15	19	...	...
× K. Boothan	...	...	...	11	...	...	5
× *S. spontaneum* (Coimbatore).	...	...	...	...	...	40	7
× D 131	...	...	...	...	...	199	...
× Saretha	...	...	...	...	...	56	14
Maur 1237 × Co 285	30	...	...	...	...	...	...
× B 3412	30	...	...	...	...	...	...
× Co 243	121	...	...	...	...	175	...
× D 74	107	...	...	...	...	...	...
× Co 281	20	...	...	...	...	...	...
× Q 813	8	...	...	...	...	...	...
× Co 290	50	...	...	...	...	...	...
× Fiji B	22	...	...	...	...	...	...
× Co 213	...	...	...	150	...	...	...
B 6308 × Co 281	188	...	...	85	...	...	...
× Co 290	40	344	...	...	...	61	...
× D 74	142	435	...	...	...	...	...
× Fiji B	150	...	...	...	...	...	...
× Q 813	200	...	...	...	...	...	...
× EK 28	...	190	...	...	...	...	...
× Co 214	...	50	...	...	...	...	...
× Co 243	...	360	...	...	...	...	...
× Co 360	...	...	100	...	...	...	...
× POJ 1410	...	...	90	...	...	...	...
× CAC 87	...	...	86	...	...	...	...
× Co 419	...	...	...	...	110	...	...

TABLE II—*contd.*

Influence of pollinating parent on seed-germination—contd.

Cross	1929-30	1930-31	1931-32	1932-33	1933-34	1934-35	1935-36
POJ 2878 × B 3412	233	...	...	...	...	...	...
× Co 243	375	755	...	...	...	...	...
× Co 285	643	...	...	...	...	...	...
× Co 361	...	866	...	...	...	...	...
× POJ 2727	...	866	...	...	...	...	...
× EK 28	...	950	...	...	...	...	...
× D 74	...	875	...	...	...	...	...
× Co 290	...	350	...	867	302	...	...
× Co 214	...	833	...	...	...	...	...
× Co 364	...	...	725	...	...	...	...
× EK 2	...	...	...	700	...	...	...
× Co 281	...	...	...	...	...	550	...
× P 1587	...	...	...	...	...	520	...
× Co 213	...	...	...	...	...	...	285
× Co 331	...	...	...	...	...	...	704
× Co 508	...	...	...	...	...	...	611
Co 290 × 247 B	60	...	...	...	...	...	133
× Q 813	66	...	...	...	...	...	...
× SW 111	50	...	...	...	...	...	...
× Fiji B	39	...	...	...	...	...	...
× POJ 2878	...	72	...	...	...	...	160
Kassoer × D 131	50	...	...	...	...	...	...
× B 3412	50	...	...	...	...	...	...
× Co 290	650	...	...	...	...	...	...
× Fiji B	100	...	...	...	...	...	...
× BH 10 (12)	400	...	...	...	...	...	...
Chittan × Co 243	140	...	...	...	...	...	...
× 247 B	32	...	...	...	...	...	...
Karun × Co 243	55	...	...	...	...	66	...
× 247 B	50	...	...	...	...	...	...
× Co 244	...	...	...	...	...	33	...
× Co 312	...	...	...	...	...	42	...
× POJ 2878	...	...	...	...	...	53	...
× CAC 87	...	...	...	...	...	80	...
× P 1629	...	...	...	...	...	109	...
Striped Mauritius × Co 290	27	...	...	...	...	...	...
× Co 285	...	...	...	...	...	36	...
× Co 360	...	...	...	...	...	11	...

TABLE III

Seed measurements

Variety from which the general collection was taken	Diameter of the cane stalk in mm.	Length of the seed in μ	Width of the seed in μ	Coefficient of correlation
S. spontaneum (Coimbatore)	6·64	1192·95	461·45	Between diameter of cane and length of seed.
S. spontaneum (Java) Glagah	10·53	1416·25	555·50	
Saretha (*S. barberi*) . .	17·18	1301·02	569·25	$r = +0·89 \pm 0·085$.
Co 205 (Vellai × *S. spont.*) .	17·87	1574·37	523·05	Between diameter of cane and width of seed.
K. Boothan (*S. officinarum*)	26·60	1561·17	582·17	
Vellai (*S. officinarum*) .	34·18	1787·50	607·75	$r = +0·82 \pm 0·134$.

TABLE IV

Percentage of germinations of seeds from sessile and pedicelled spikelets

Cross	Germinations out of 500 sessile spikelets	Per cent	Germinations out of 500 pedicelled spikelets	Per cent
S. spontaneum G. C. .	29	5·8	20	4·2
Co 205 G. C. . . .	175	35·0	151	30·2
Co 421 × Co 285 . .	288	57·6	220	44·0
Co 419 × Co 285 . .	189	37·8	123	24·6

TABLE V

Seed-setting in sessile and pedicelled spikelets

Cross	Seed-setting out of 300 sessile spikelets	Per cent	Seed-setting out of 300 pedicelled spikelets	Per cent
Vellai × EK 28 . .	95	31·66	48	16·00
Co 400 × EK 28 . .	133	44·30	75	25·00
Co 243 × Co 205 . .	69	23·00	32	10·60
Vellai × Co 205 . .	9	3·00	2	0·60
Co 400 × Co 205 . .	108	36·00	54	18·00
Co 243 × EK 28 . .	34	11·30	21	7·00

TABLE VI

Germinations of seed variously treated before sowing

——	Ortho-phos-phoric acid	Water	H_2SO_4	Soil-fluff mixture	Control	Remarks
POJ 2725 . .	1085	1035	28	1241	1500	Germination counts are totals of three seed-pans in each treatment.
POJ 2878 . .	313	390	10	485	1400	
SW 111 . .	1326	1653	305	1793	2100	
Co 243 . .	610	885	13	957	1200	
K. Boothan . .	59	70	2	132	90	

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THE PRESENT POSITION OF THICK COIMBATORE SUGARCANES

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THE thick canes have an importance of their own in India. They are the types chiefly grown in ordinary cultivation in the Madras and Bombay provinces and also in Assam and the North-West Frontier Province. In the rest of India, particularly in the United Provinces, Bihar and the Punjab, they are grown on a limited scale and principally for chewing purposes. It is perhaps these chewing canes which come to the mind of the average person when the word 'sugarcane' is mentioned. These are the thick or so-called 'noble' canes and the familiar examples are *Pundia* of Bombay, *Poovan* of Madras and *Pounda* of North India.

Tropical origin

The thick cane is essentially a tropical plant: it is of tropical origin and shows its best performance in tropical regions. That explains why it is at home in the Madras and Bombay provinces which are entirely within the tropics. Assam and the North-West Frontier Province are outside the tropics but the conditions there are sufficiently humid for the suitable growth of these canes. In the United Provinces, Bihar and the Punjab the climatic conditions are too rigorous for the growth and proper ripening of these canes. They are, however, grown in the neighbourhood of towns under intensive methods of agriculture and sold for chewing purposes. For chewing what is required is soft rind and enough sweetness for the palate and these qualities the thick canes possess in a satisfactory degree. Besides, for chewing purposes cane need not necessarily be mature as glucose also is sweet.

The fact that the thick canes are perfectly at home in tropical India and have been grown even in sub-tropical parts for quite a long time, acquiring such local names as *desi Paunda*, *Vellai* and *Hottai kabbu* should not lead one to think that they are indigenous to India. They are of foreign origin and have been imported into India at one time or another. Their place of origin is supposed to be the South Pacific Islands, while India is the home of the thin or 'reed' canes. The dual origin of the cultivated canes and their migration to other parts of the world from the respective places of origin are shown in Plate 101.

Apart from difference in their thickness the above two classes of cane show differences in botanical and agricultural characteristics as well. In fact they are two separate 'races' or species. To give them their technical names, the thick canes, which were the first to receive a botanical name, are called *Saccharum officinarum* L., while the bulk of the Indian canes have recently been designated *Saccharum barberi* Jesw. in recognition of the classical work of Dr Barber (who laid the foundations of sugarcane breeding in India) on the Indian group of canes.

Thick canes cross freely

A circumstance of importance in breeding is that the thick canes cross freely with the Indian canes (*S. barberi*) and also with the wild cane—*Saccharum spontaneum* (the weed known as *kans* in India). That the thick canes are not only capable of being crossed with other cane species but with other *genera* also is borne out by the epoch-making crosses effected by Rao Bahadur Sir T. S. Venkatraman between sugarcane and sorghum and more recently between sugarcane and bamboo. This has enabled the range of possible crosses with sugarcane to be widened, and the importance of this will be realized when it is remembered that every one of the various species and genera possesses qualities peculiar to itself which, by suitable crosses, can be 'blended' in the seedlings resulting therefrom.

'Nobilization'

The wild cane (which is, as it were, the antithesis of the thick or 'noble' cane) is hardy and deep-rooted, tillers well and withstands extremes of temperature. It passes on these qualities to its progeny. These qualities, desirable as they are, are not all that a good sugarcane should possess. Herein comes the importance of the thick cane, as it contributes sugar. With a view to combining the above qualities a wild cane is crossed with a 'noble' cane. This is termed the first 'nobilization', as actually the first step towards ennobling the wild cane has been taken. But as the seedlings which result from this first or direct cross are generally on the thin side and are also not quite good as regards sugar content, it becomes necessary to cross these particular seedlings again with a thick cane. This constitutes the second nobilization. By such successive nobilizations the stage is reached when the yield and recovery of sugar greatly improve and the resultant seedlings come to possess, besides the good qualities of the thick cane, other desirable qualities like good root system and tolerance to extremes of temperature derived from the thin cane parents. Often four or five such nobilizations are required to produce the desired type.

Nobilization has played an important role in the breeding work at Coimbatore and in other countries. At Coimbatore its chief use has been for breeding canes for North India, and for the thick cane work also the nobilized canes have been very useful as parents. The Indian canes (*S. Barberi*) also possess certain desirable qualities and have been employed in breeding. All the three species have, therefore, taken part in building up the characteristics of the improved canes. Indeed, the breeding of sugarcane, whether thick or thin, now involves such elaborate stages that practically all the improved canes have in their 'veins' the 'blood' of two or more species. This 'blending' of different bloods is absolutely necessary, for if it is not done then, the seedlings lack in such characters as hardiness, yield, sucrose, etc. It may be added that the famous sugarcane-sorghum and sugarcane-bamboo crosses are also in a sense sorghum and bamboo nobilized.

Defects of thick canes

The thick canes are excellent canes in their own way provided they are looked after well and are in their proper environment. But they have certain very serious defects. Firstly, all of them have a shallow root system which is a distinct disadvantage in that the plant is unable to tap the lower soil strata for food and anchorage. This deficient root system also entails frequent and copious irrigations. Secondly, there are the diseases, mosaic and red rot, from which none of them is free. Thirdly, all of them have a soft rind which renders them an easy prey to wild animals.

Every one of the above defects takes its own toll in the ryot's bill of costs, but when all of them occur in one and the same variety, that variety becomes more of a liability than an asset. Unfortunately, the majority of the thick canes and the best among them fall in this category. In spite of this, the careful and hardworking cultivators of Bombay and Madras have been getting good yields from the varieties available to them. But whenever Nature conspired by visiting them with a year of exceptional drought or of unusually heavy rainfall or of disease in an epidemic form, the bad points of the varieties showed themselves at their worst and well nigh spelt ruin to them. It was imperative, therefore, to do away with these defects.

Varietal position

The varieties that were holding the field in the thick cane tracts of India were as follows. *Pundia* was the variety that was being chiefly grown in the Bombay-Deccan. In Madras the canes in cultivation were *Poovan*, *Vellai* and Purple Mauritius. In Assam, Striped Mauritius was the favourite variety and in the North-West Frontier Province, the cane *desi Paunda* was the one liked most. All these belonged to the shallow-rooted, soft-rinded, and susceptible class. There were a few other canes also which had been imported and were beginning to show promise. These were 247 B—a Java cane (incorrectly though popularly called J247) in certain Madras tracts; EK28—another Java cane in the Bombay-Deccan and POJ2714 (also a Java cane) in Assam.

About 1924 the sugarcane breeders of Java succeeded in evolving that marvellous and aptly termed 'wonder cane' POJ2878 which revolutionized the sugar industry of that country. In the interest of the sugar industry of India prompt steps were taken to import this cane and distribute it without loss of time to the provincial experimental stations for trial. It is satisfactory to be able to record that till Coimbatore was in a position to breed and send out its own thick canes, POJ2878 did good service in quite a few tracts, particularly in the Bombay-Deccan. Such was the position when the Coimbatore Station took up the breeding of thick canes in 1926.

Thick canes for India

Enough has been said above to show that considering the defects of the canes in cultivation, the problems connected with the breeding of thick canes were as varied as they were difficult. A lesson which impressed itself at the very start was that pure noble blood would not do. Wherever canes of pure noble lineage like *Pundia*, *Poovan*, or certain Barbados or Mauritius canes had been grown in India, they had been an unqualified success nowhere. They were, of course, giving good yields under favourable conditions and do so still, but a really good cane should yield well in good as well as bad years. If any advance was to be made, the necessary requisites were canes combining hardiness with a sufficiency of thick-cane traits.

A fact which contributed greatly to the solution of these difficulties was the very valuable knowledge and experience already available at the Station in connection with the breeding of thin or medium canes and the success which these Co canes had attained all over North India and in several other parts of the world. Two rules of guidance came from this thin cane work, namely: (1) that an efficient root system was not only desirable but absolutely necessary for a good cane, and (2) that infusion of hardy blood makes for an all-round hardiness in a seedling.

In view of the above, the first step taken in the improvement of the thick canes was to evolve types with satisfactory root system. Plate 101 shows the root systems of two of the thick Co canes, viz. Co 419 and Co 421, against the standard varieties. It will be seen that the root systems of these two canes are definitely superior to those of *Pundia* and *Poovan*. They are also fully as good as those of POJ2878 and Co 290, two of the world's most famous varieties.

The next point to receive attention was yield. It may look paradoxical when it is said that for the thick cane work yield was, and at the same time was not, a problem. It was not a problem in the sense that the extant canes in the Bombay and Madras provinces were already giving quite satisfactory yields, in fact more than twice or nearly thrice the yields that obtained in North Indian tracts from the thin and medium types. It was at the same time very much of a pressing problem because the best solvent of the ryot's difficulties was a high-yielding variety.

The breeding qualities of the several thick canes available from the large world-collection of cane varieties maintained at the station were determined with the requisite thoroughness. As for the infusion of hardy blood, it was decided that it should be done only in a dilute form. This led to the utilization of certain selected medium Co canes as parents. It was in 1931 that the first fruits of thick cane work became available, but it was not till 1933 and 1934 that canes of the calibre of Co 419 and Co 421 were evolved. In what follows we shall try to examine the service or more correctly the promise of service of these canes to the cane-grower and the sugar industry of India and the directions in which further work is still necessary.

Co 419 in tropical India

Practically from the moment of its arrival at the provincial experimental stations, Co 419 began to make its presence felt by virtue of its very good growth and high yield. This was true of all the experimental stations at which it was tried in the Bombay and Madras provinces, in Assam and also in Burma, which then formed a part of India. Co 419 not only gave much higher yields than *Pundia*, J247 and Striped Mauritius, but also out-yielded

POJ2878. Its yield in all the above places was of the order of 55 to 60 tons of cane per acre. As this was the highest ever recorded in certain places and eminently satisfactory in others, Co 419 found itself in the hands of the cultivators in such a short period as three or four years after its release from Coimbatore. As regards cost of production per ton of cane, it was found at one of the experimental stations in Madras that the cost of Co 419 was Rs. 6 per ton (equal to about 3½ annas per maund of 82 lb.) against Rs. 8 and Rs. 9 per ton of J247 and POJ2878 respectively.

The rise of Co 419 in the estimation of the grower and the factory has been rapid. That is why it is already one of the outstanding canes in the Bombay-Deccan. In Madras it is fast becoming the prime favourite in several areas. Very nearly the same may be said of Assam and perhaps Burma also.

Co 421 in North India

We should now try to see if the thick cane work at Coimbatore has been of any assistance or use to the main sub-tropical cane belt situated in the United Provinces, Bihar and the Punjab. The answer to this question will be found in the performance of the cane Co 421 in the above tract.

Co 421 is a thick-medium type and has impressive, erect, and tall canes. Because of this and its very good yield it rapidly rose to the front rank in many experimental stations from the Punjab to Bengal. It has yielded about 950 md. (equal to about 35 tons per acre) at the experimental stations at Muzaffarnagar, Shahjahanpur and Gorakhpur in the United Provinces. That is quite a good yield for North India. In the United Provinces, 'Co 421 has been found to be an all-round good, early mid-season cane with vigorous germination and good stand. Like Co 312 it is doing well all over the United Provinces. It responds very well to intensive cultural methods and does not lodge, as Co 312 does, under rich conditions.'

In the Punjab too Co 421 has proved to be a very heavy tonnage cane and is believed to be an improvement over Co 312. It is also a much higher yielder than Co 285—at present the most widely grown variety in the Punjab. Its *gur* is better than that of Co 285. In Bengal Co 421 came out successful in many experimental stations and as a result of its success, it has been distributed to factory plantations, private farms and cultivators. In one of these farms it gave a yield of 1,333 md. (nearly 50 tons) of cane and 161 md. (nearly 6 tons) of *gur* per acre. The performance of Co 419 and Co 421 in certain parts of India is illustrated in Plate 102.

Co 419 and Co 421: defects

Now that Co 419 and Co 421 bid fair to come into cultivation on a commercial scale, it is worth while to know their drawbacks. This is all the more necessary if the high yields, for which they have come to be favoured, are to be obtained under ordinary methods of cultivation. The good points of Co 419 are that it is capable of high yields on a variety of soil types and under different conditions of water availability. It has been reported to have grown well even under waterlogged conditions and in *chopan* soil (alkali soil with a large amount of sodium colloids). The above good points combined with high yield are substantial enough to offset any drawbacks that it may possess, but it is better to be warned about defects when they exist. The defects are that Co 419 is liable to lodge and its stalks sometime break in the process. Further, it should be crushed soon after being cut as it has a tendency to deteriorate quickly after harvest. Co 419 is also susceptible to various pests and diseases and every precaution should, therefore, be taken in the proper selection of planting material. Lastly a word of caution: Co 419 is a late variety taking about thirteen months to ripen and there is a complaint that when crushed earlier it sometimes gives *gur* of poor quality. In such cases it would be worth while, wherever possible, to mix the juice with that of some other cane whose *gur* is of better quality.

Co 421 has a good habit (that is, stands erect) and does not usually lodge. It possesses 'a high degree of resistance to borer and other pests and diseases but appears susceptible to wilt and needs watching in this respect carefully.' During the recent vigorous and efficient campaign by the United Provinces

authorities to combat the red-rot menace, Co 421 was one of the varieties which was distributed to replace the susceptible Co 213.

Other thick Co canes

Besides Co 419 and Co 421, there are certain other useful canes which have resulted from thick cane work and which deserve mention. These are Co 360, Co 400, Co 401, Co 412, Co 413, Co 426 and Co 432. Of these Co 360 is a high sucrose cane giving *gur* of good quality, but it is top-heavy and lodges badly. Co 400 and Co 401 are tolerably good chewing canes which have had some success for this purpose. Co 412 has given fairly good yields at the experimental stations in the North-West Frontier Province, while Co 413 has done well in parts of the Bombay and Madras provinces, and is grown to a certain extent by the ryot. Co 426 has shown some promise at Padegaon but it is too early to say much about it. The importance of Co 432 lies in the fact that it is a salt-resistant variety and is likely to be of use in salt-affected soils. It is a thin-medium cane and since it is one of the later productions, it represents the border line between the thick and thin cane work at Coimbatore. It should be mentioned that it is becoming difficult to draw a hard and fast line now and that the two methods of breeding have tended to approach each other in outlook and technique. That is why canes like Co 349 resulting from thin cane work at Coimbatore are definitely thickish while canes like Co 421 and Co 432 emanating from the thick cane work are unmistakably on the medium side.

Future trends

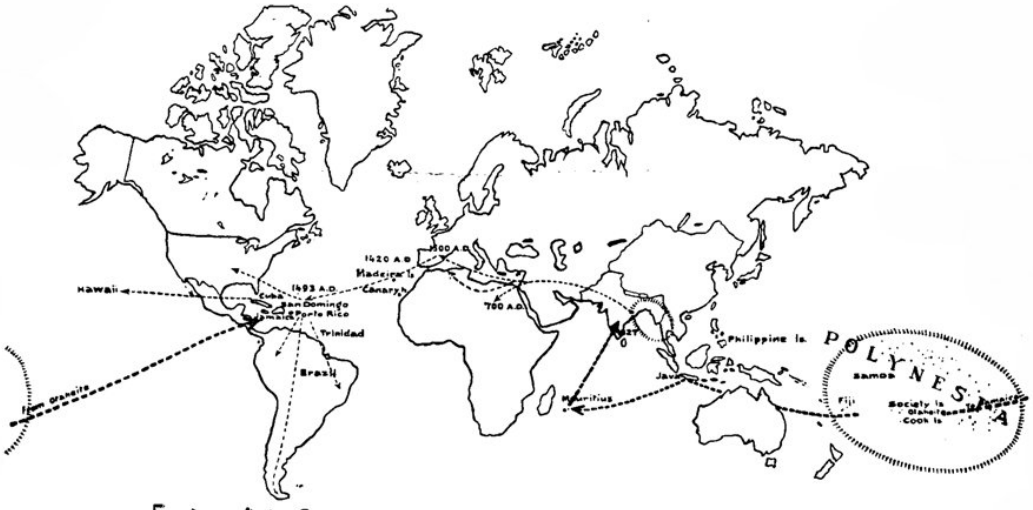
The present position may very briefly be summed up. Co 419 is fairly on the road to becoming somewhat of a universal cane in several parts of tropical India, while Co 421 is likely to prove of definite utility in certain tracts in North India. The phenomenal rise of Co 419 and Co 421 is due as much to the thorough testing and efficient distribution by the provincial stations as to the intrinsic merits of these canes. But in spite of this, the spread of these canes is not as rapid as it might have been or as their qualities justify. In Java POJ2878 became available in 1924 and by 1929 it occupied 95 per cent of the area under cane in that country. Compared to that the spread of Co 419 and Co 421, quick as it has been, seems slow. In India, where the industry is at the present moment helped greatly by the tariff, every effort should be made to place in the hands of the cultivator, while the tariff is in force, canes that should give him not only yields comparable to other parts of the world but also at a strictly comparable cost of production.

There are still gaps in the thick cane work in the directions of suitable early, late, and disease- and pest-resistant canes. But careful and intensive work has revealed that among the Co canes themselves there are useful parents which have enabled the above qualities to be combined to a fair, if not highly satisfactory, extent. The inter-generic hybrids also are being utilized as parents. The sorghum hybrid Co 356 has already been crossed with certain thick canes, while two of the bamboo hybrids have been crossed this season with a few thick canes possessing high sucrose with a view to improving the juice quality. During the tariff period the tempo of work is being maintained at its usual high level to remove the above deficiencies.

It has already been said that the distinction between the two types of breeding is rapidly vanishing. Co 421, which may be called thick-medium and Co 290 which may be classed as medium-thick, typify, therefore, the class of canes which will hereafter be produced at Coimbatore in greater number. The production of the thick class represented by Co 419 and thin class represented by Co 313 will also continue.

In conclusion, it might perhaps be said that the success of the Co canes not in one but in four continents, the unrivalled breeding material at its disposal and its experience of nearly a third of a century lead to the hope that the Coimbatore Station will be able to continue to serve all the sugarcane tracts of India.

ORIGIN & MIGRATION OF SUGARCANE



Eastern Asia Canes

{Indian canes – S.Barberi
{Chinese canes – S.Sinense

Eearly years. xian era – by Arabs
1420 A.D. Medeira, Canaries, W.Africa
1493 A.D. Santo Domingo (Columbus)
16th Century Cuba, Porto Rico, W.Indies.

South Pacific Canes
(S.Officinarum)

To various Pacific Islands – by Polynesians
Java, Mauritius etc – by Malays
1791 A.D. Otaheite to Jamaica – Capt. Bligh
1827 A.D. Mauritius to India – Capt. Sleeman

ROOT SYSTEMS

of two Co. Canes against the Standards

Scale – Each square represents one square foot

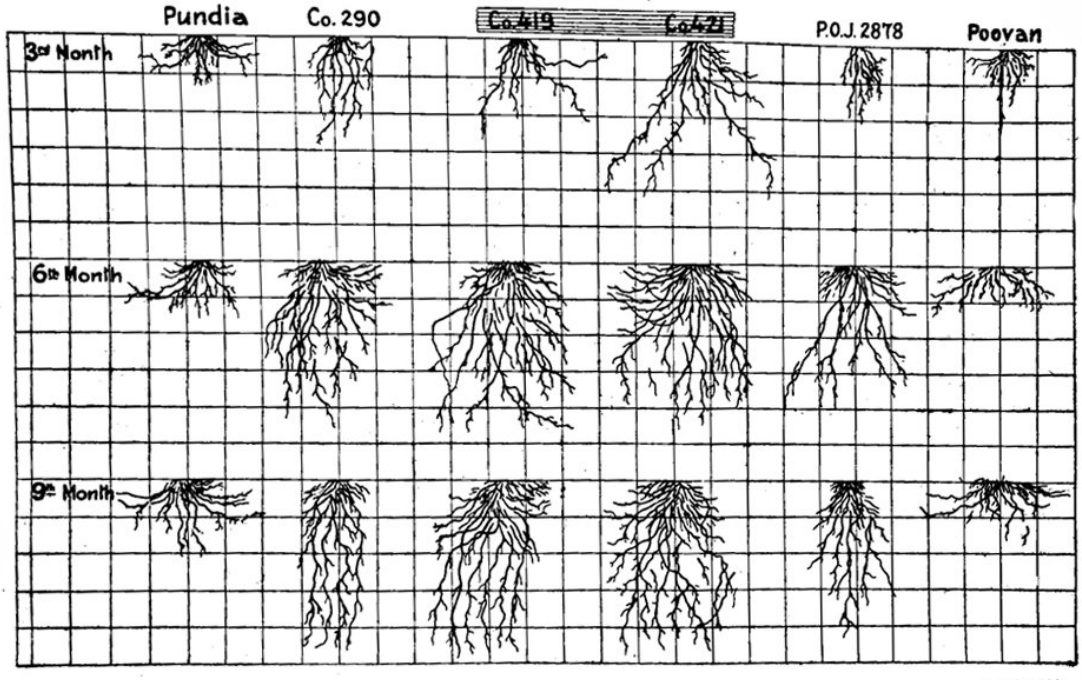


PLATE 101

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CONTROL OF FLOWERING IN SUGARCANE

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Imperial Sugarcane Breeding Station, Coimbatore

IT is only after flowering that plants become functionally capable of procreation by sexual means. For certain plants, and sugarcane is one of them, the commonest method of reproduction is vegetative. The new crop thus obtained from setts (that is cuttings containing two or three buds) is not in any sense of the term a new plant. It is merely a continuation of the old individual with all its good points and defects. This is at once the strength and weakness of such crops, for if the good points can be maintained in an unadulterated condition, the same also applies to the bad points. To introduce any new qualities, it is necessary to cross the flowers of two individuals, preferably belonging to separate varieties or even species.

A close study of flowering is, therefore, a necessary pre-requisite for any plant-breeding project. It is particularly so in the case of sugarcane, which is accustomed for ages to propagate itself vegetatively, with the result that not a few varieties have lost the habit of flowering. In fact, there are varieties which have not flowered even once during the last 30 years at Coimbatore where a large world-collection of varieties is being maintained for breeding purposes. Varieties of the above type form a problem by themselves, but they are by no means the main stumbling-block. A good deal of trouble comes from varieties which flower and that too regularly but whose flowering time does not synchronize with that of others. This difference or disparity between the flowering periods extends in certain cases to as much as four or five weeks (Plate 4, fig. 4). As it is very often desirable to cross these varieties to combine in one and the same cane such qualities as high yield, good sucrose, disease resistance, etc. found in some and lacking in others, the question of manipulating the time of flowering assumes great importance. In order to be able to cross them, it becomes necessary to delay the flowering of some and to hasten that of others. Several devices have been pressed into service to bring this about but the salient results of only two of them will be mentioned in this article, namely (1) artificial regulation of daylight, and (2) 'topping'.

Flowering is seasonal

Flowering occurs usually at the end of a long or short duration of vegetative growth. In sugarcane it is definitely seasonal and at Coimbatore it occurs, depending on the variety, from the end of September to about the middle of December. As between the period of time spent in vegetative activity and the amount of vegetative growth itself, it is the former that seems to be a requisite preliminary to flowering of cane. For instance, a variety planted, say in June or July, even though it may have grown well, does not usually flower the following October (if that is the month when it normally flowers) but only in October of next year, that is after 15 or 16 months. On the other hand, the same variety planted in February or March, even though it may have for some reason not made good growth, does generally come into flower the following October (see flowering of Co421 in Plate 4, fig. 3).

Sunlight and flowering

There would be no food on earth without the sun. And it is this food stored during the vegetative phase that most of the green plants draw upon for their flowering. Before referring to the special relation that exists between light and flowering, a mention might briefly be made of the relation between light and food production. The green colouring matter (chlorophyll) of plants utilizes the radiant energy of the sun to build up carbohydrates (sugar and suchlike substances) from the simple compounds carbon-dioxide and water. This is the well-known process of carbon-assimilation or photo-synthesis (Gk. *phos*, light; synthesis, putting together) which is the basis of all food production since carbohydrates are themselves 'energy-producing' foods and also lead on to the formation of further complex compounds on which growth and other life processes depend. The plants

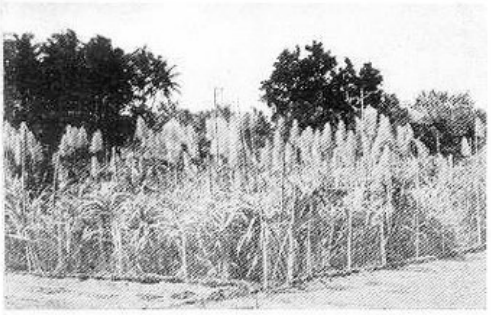

FIG. 1. A field of sugarcane in flower

FIG. 3. A row of Co421 flowering. Note clump on the left which has flowered though poor in growth and with little cane formation.

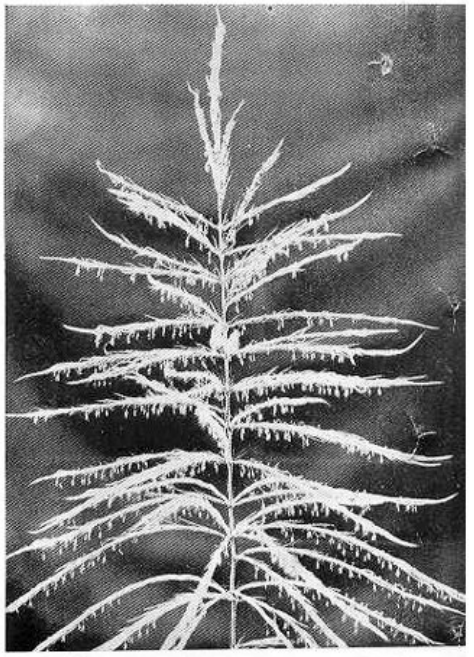

FIG. 2 Sugarcane 'arrow' or inflorescence. An inflorescence contains about 35,000 tiny flowers. Note the hanging anthers of the flowers.

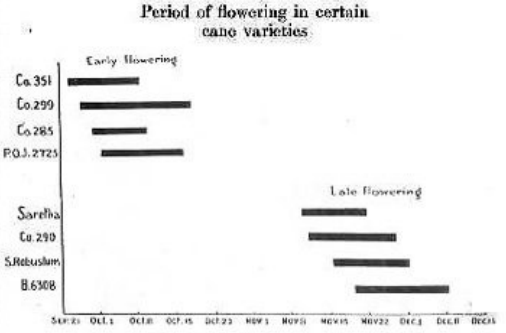

FIG. 4. Note the disparity of 4 to 5 weeks in the flowering of some varieties. The two cannot be crossed unless their flowering periods are synchronized.

PLATE 4

thus alone can and do build up food, the animals feed on plants and some animals feed on other animals. The starting point is undoubtedly sunlight and chlorophyll, but the chlorophyll is absolutely inoperative without sunlight. That is why it is said that the sun is, directly or indirectly, the giver and maintainer of all life on earth.

The above relation between light and food production is the most familiar aspect of the relation between light and plant life, but we are concerned here with another and not so familiarly known aspect of sunlight. It is the relation of sunlight to the initiation of the flowering stages in plants. Barring few data which appear to have been collected in the eighties of the last century and earlier, the intensive study of this aspect of sunlight has been made during the past 20 years or so. The fact that has emerged from these studies is that the relative length of day and night or, in other words, the duration of day-length has a definite influence on the flowering and fruiting responses of plants. It is a matter of common knowledge that the length of day in proportion to night varies with the season and latitude. And, as it is now known that day-length influences flowering, it is easy to see that it acts as one of the important factors which determines why particular crops are suited to particular seasons and why certain types of vegetation are found only in the equatorial, others in the temperate, and still others in the arctic, zone. For this response to the particular day-length, Garner and Allard (who have done extensive work in this field) have proposed the term photo-periodism.

Long-day and short-day plants

Under experimental conditions it is quite simple to increase or shorten the day-length. To make the day longer, additional light (usually electric light) is provided to the plants during a part or whole of the night as desired. For the short-day all that is necessary is to remove the plants to a dark chamber so as to shorten day-length as desired, or black cloth may be used to screen off sunlight.

The practical application of these methods on a large scale has been done by florists for commercial flower-forcing. It is true that in India we have not as yet learned to 'say it with flowers' even on suitable occasions, but in countries where people are 'flower-conscious' big floricultural establishments are in existence. They maintain greenhouses where plants are grown under glass and treated with suitable light-periods to make them flower earlier or later than their normal flowering time, according to the requirements of the market.

The underlying principle which enables the above manipulation is that certain plants flower readily under a long day while for others the most suitable condition for flowering is a short day. The former are called long-day plants and the latter short-day plants. Each type is governed by, what may be called, a critical day-length. As a result of this the long-day plants remain in the vegetative stage and do not flower in day-lengths below the critical, while the short-day plants begin to exhibit excessive vegetative vigour without flowering in day-lengths in excess of the critical. Though a good number of plants have been found to fall in one or the other of the two categories, there are plants which cannot be classed in either of them and which have no definite critical day-length for flowering.

Effect of short day on sugarcane

A preliminary experiment conducted by the writer in 1932 gave indications of sugarcane being a short-day plant. The early flowering varieties, Co 285 and POJ 2725, were subjected to short days of six and four hours' duration for a period of 35 days and 45 days respectively at the sixth month of their growth. The treated canes flowered 14 days and 11 days earlier than the controls. The percentage of flowering in POJ 2725 was 98 in the control and 76 in the treated, while in Co 285, 75 per cent of the canes flowered in the control and only 30 per cent in the treated.

If the short-day treatment was to be of any help, it should be used on the late-flowering varieties. During the next year, therefore, the late-flowering variety, Co 290, was subjected to six hours' daylight and the treated canes flowered 26 days earlier than the control. The experiments were repeated with a few more varieties in 1934 and the treated canes flowered about a fortnight earlier than the controls. It is true that in no sugarcane tract in the world is a day-length of six hours met with, but the object was to find out some day-length with which under experimental conditions the canes could be made to flower earlier than their normal time. Besides the above 'unnatural' period of day-length, another difficulty in this treatment was the

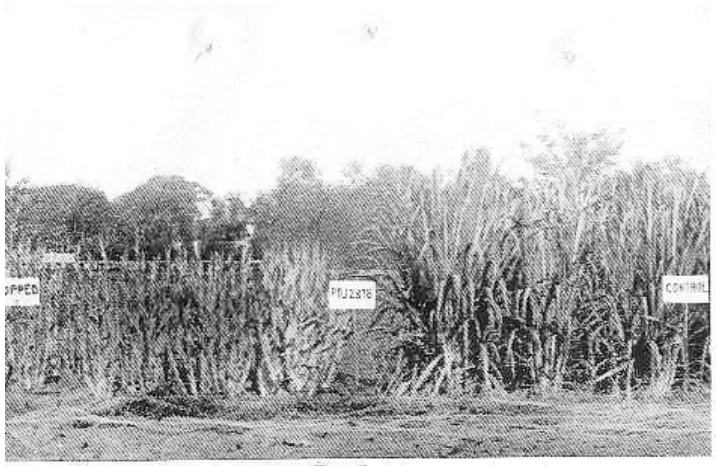

FIG. 5.

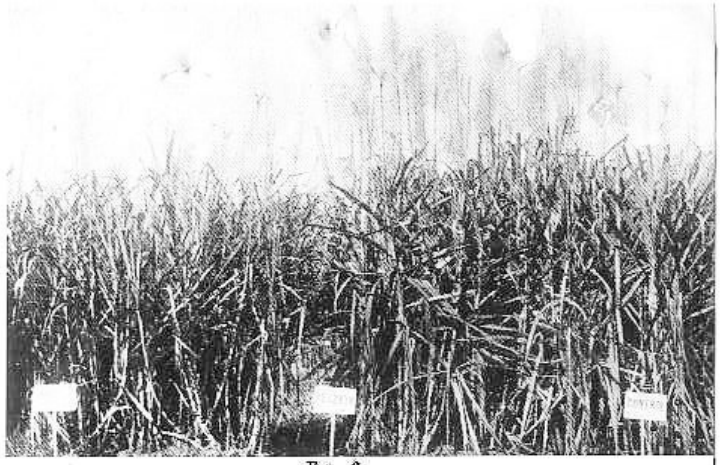

FIG. 6.

'Topping' delays flowering. Fig. 5 shows topped canes and the control. The same in fig. 6 but after flowering.

PLATE 5

FIG. 7. Plants in the field provided with extra illumination. This is the 'long-day' treatment.

FIG. 8. The effect of the 'long-day' treatment may be seen. The control has flowered while the treated canes have not commenced flowering. Variety POJ 2725.

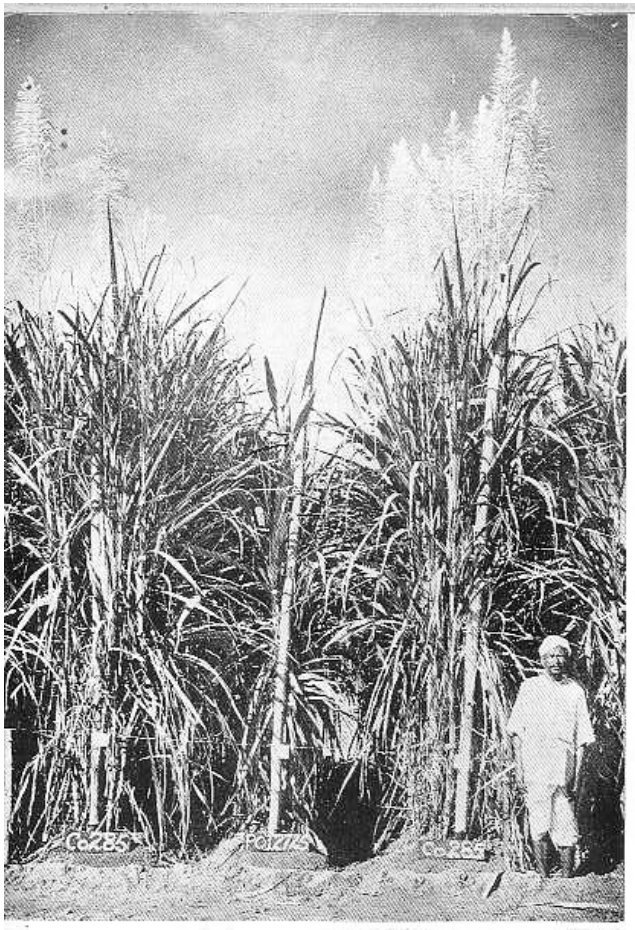

FIG. 9. Effect of 'long-day' treatment on Co 285. The control is flowering profusely and the treated just beginning to flower.

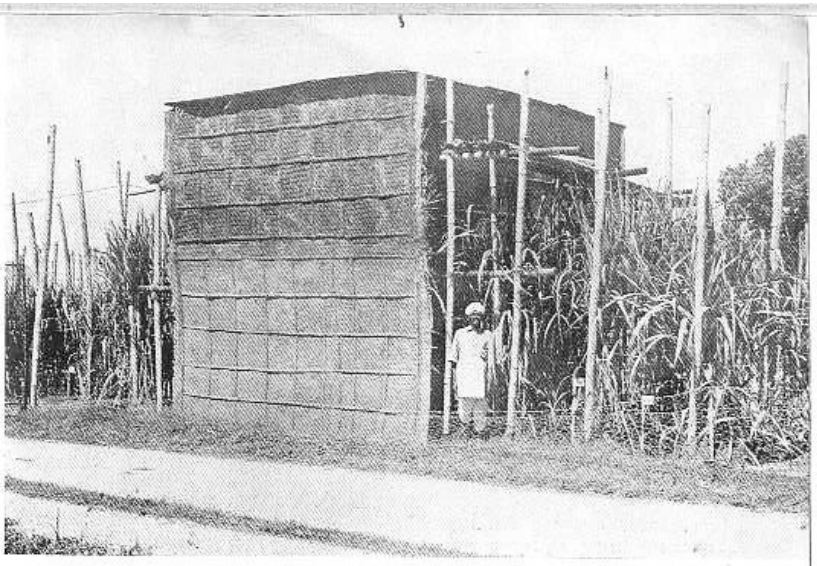

FIG. 10. A shed in which plants have been enclosed to screen off sunlight. This is the 'short-day' treatment.

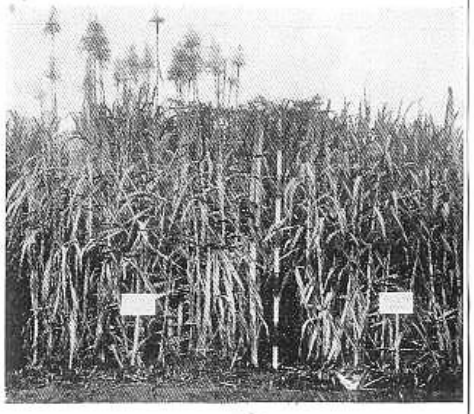

FIG. 11. Effect of 'short-day' treatment. The treated plants have flowered earlier.

PLATE 6

absence of greenhouse facilities. The improvised shed (Plate 6, fig. 10) was not at all satisfactory as aeration, ventilation, temperature, etc. could not be regulated. Attention was, therefore, directed to the long-day treatment, an account of which is given below.

Effect of long day on sugarcane

A feature of these experiments was that additional light was given to the plants under field conditions (Plate 5, fig. 7). After an indication had been obtained that supplementary illumination delays the flowering of sugarcane, the exact stage at which it should be most usefully applied was determined. This was found to be the fourth or fifth month of the plant's growth, and if the treatment was given earlier or later than this, the desired results were not obtained. The additional light supplied was for 250 hours or eight hours every night for a month with 60 watt bulbs.

These experiments have been of very great assistance in the breeding work at Coimbatore. The extant thick canes like the *Pundia* of Bombay, the *Poovan* of Madras and the *Paunda* of North India (all belonging to *Saccharum officinarum* L.) lack vigour of growth and hardiness. Though the first two do not flower at Coimbatore, a few varieties of the third and certain foreign canes having the pure thick cane 'blood' do flower and were fully utilized. The vigorous and hardy parent Co 285 flowers very early in the season, but with the help of the long-day treatment its flowering has been delayed and it has now been extensively utilized for introducing hardiness into the thick canes. Another useful parent, Co 421, also flowers very early in the season. It is a very desirable 'mother' (that is male sterile and thus used as a female parent). Its flowering also has been delayed by long-day treatment, thus enabling its being crossed with certain valuable but late-flowering parents like Co 290 and Co 440. The long-day treatment delays the flowering by about a fortnight.

'Topping'

This treatment consists in decapitating the plants above the growing point (Plate 5, fig. 5). It has been tried by the writer since 1931 on about half a dozen varieties. The tops may be removed at two or three stages at intervals of one month, the first 'topping' being given in the fourth or fifth month of the plant's growth. This treatment delays the flowering by about a fortnight. One defect accompanying this treatment is that the size of the 'arrow' or inflorescence is reduced. There is, however, no appreciable difference in the fertility of pollen or in seed setting as compared with the controls. The size of the 'arrow' is reduced in the long-day treatment also but not so much as in 'topping'.

Estrogen therapy.—A group of immature female rats (30 days) were kept on the following diet:—

Sugar 10, casein 14, butter 15, Osbourne Mandell salt mixture 5, and rice flour 56 parts. The diet was supplemented by ½ tablet of yeast and 2-3 drops of cod-liver oil per day per rat.

The experimental rats received 3-4 drops of the cress oil in addition to the above diet, whereas the control rats received only the above diet. All the rats were killed on the 72nd. day, having received the oil for six weeks. The ovary, thyroid and thymus glands were removed and weighed.

The ovaries of the experimental rats weighed consistently more than that of the control rats. The average weight of the ovaries from the experimental rats was 0·45 gm. per Kg. body weight, whereas that of the control rats was 0·25 gm. per Kg. body weight. Macroscopic examination of the ovaries of the rats receiving the oil was very significant and exhibited several hæmorrhagic follicles on the surface. No such characteristics were observed on the ovaries from control series. The uterus, thymus, thyroid and other organs did not show any abnormality. The results along with the details of histological examination will be reported later.

There was no significant difference in growth rates of the rats. The rats receiving the oil weighed comparatively less (average 83 g.) than the control ones (average 88 g.) but were significantly more active than the control series.

Thanks are due to Dr. V. Subrahmanyan for his keen interest.

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N. N. DE.

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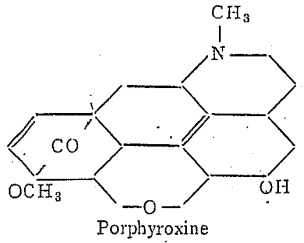
December 9, 1942.

A SEARCH FOR PORPHYROXINE IN BENGAL OPIUM

PORPHYROXINE $C_{16}H_{23}O_4N$ was isolated[1] by Rakshit from the Indian variety of *Papaver somniferum* L. He represented[2] the base as a derivative of a tetrahydro codeine with the carbonyl group in a bridge position in the aromatic ring of Pschorr's codeine formula:



Porphyroxine

Later, Machiguchi[3] isolated from Japanese opium, an identical product which, however, proved to be a mixture of codamine, laudanine and meconidine. Recently[4] the view has been expressed that the constitution proposed for porphyroxine can only be accepted with reserve. It was, therefore, considered necessary to re-investigate the occurrence of porphyroxine in Bengal opium, a specimen of which was purchased as a dry powder from the Government opium factory at Ghazipore.

Following Rakshit's method[1] the total water-soluble non-phenolic bases were isolated by ether-extraction of a lime-water extract of opium. Further treatment of the crude bases with dilute hydrochloric acid gave a sparingly soluble hydrochloride (A) in an yield of about 0·34 per cent. The same hydrochloride (m.p. 265°-269° d., after a slight darkening at 240° C.) was prepared in an yield of 2·6 per cent. by extracting the total alkaloids of opium with chloroform and subsequent treatment of the alcoholic solution of the bases with dilute hydrochloric acid. On recrystallisation from alcohol the hydrochloride (A) in colourless needles melted at 276°-277° c.d. after sintering at 270° C. The free base corresponding to this was crystallised from alcohol in colourless rectangular rods. (M.P. = 152°-153° C., unchanged on mixing with a genuine specimen of codeine for which the author is deeply indebted to Prof. B. B. Dey.)

The above yield of codeine from Bengal opium is much higher than Rakshit's estimate,[5] but agrees well with that of Annet[6] and Dunnicliff.[7]

Attempts to isolate porphyroxine from the mother-liquors of codeine hydrochloride have so far proved fruitless. Only a more intensive search can finally settle the possibility that Rakshit's porphyroxine might be an impure specimen of codeine.

As the author is at present unable to continue this work, owing to other preoccupations, he leaves this question to be settled by others interested in the subject.

The author is highly grateful to Prof. L. F. Small for suggesting this problem, and to Mr. J. N. Rakshit and Col. S. S. Sokhey for their kind interest.

S. RAJAGOPALAN.

Haffkine Institute,
Bombay,
December 28, 1942.

1. Rakshit, *J C.S.*, 1919, **115**, 455. 2. Rakshit, *Ber.*, 1926, **59**, 2473. 3. Machiguchi, *J. Pharm. Soc. Japan*, 1926, **592**, 19. 4. Small, "Chemistry of the Opium Alkaloids," 1932, p. 308. 5. Rakshit, *Analyst*, 1921, **46**, 485; *Ind. J. Pharm.*, 1942, **4**, 53; *Science and Culture*, 1942, **8**, 16. 6. Annet, *Biochem. J.*, 1920, **14**, 621; *Mem. Dep. Agric. India*, 1921, **6**, Nos. 1 & 2. 7. Dunnicliff, Private Communication.

PROTOGYNY IN UGANDA *SPONTANEUM*

THE wild species of *Saccharum spontaneum* has been of particular importance and use at the Imperial Sugarcane Station X CBE. Most of the Co. canes found useful in cultivation have in them the blood of some form of *Saccharum spontaneum* and sometimes of two

forms of it. The Station now possesses one of the best collections of this species collected practically from all parts of the world. Recent additions to this collection are certain *spontaneums* from Uganda (East Africa). Two of these flowered last month and exhibited peculiarities which have so far not been recorded in any variety of *S. spontaneum* or in any species of *Saccharum*. While this is interesting in itself, the main point to which attention is now invited is their protogyny which enables their employment as ovule parents in sugarcane breeding.

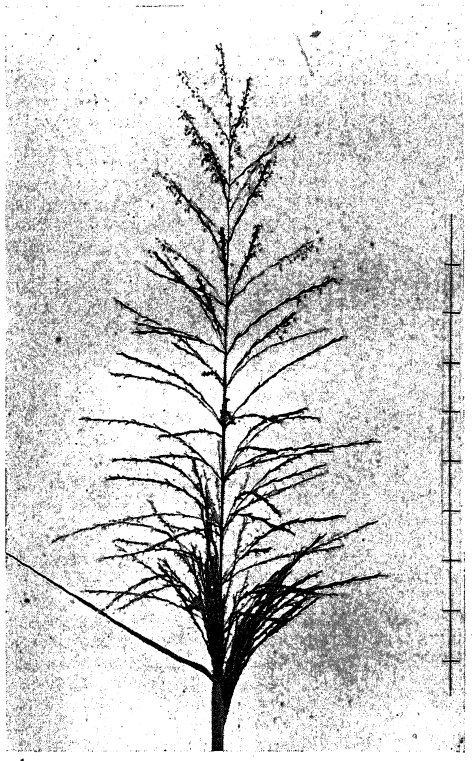


FIG. 1

The arrow of Uganda *Saccharum spontaneum*

The spikelets have opened in the upper portion. In the lower portion the stigmas are protruding from the tips of the unopened spikelets and can be made out with the help of a hand lens. The scale alongside shows inches.

In the other forms of *S. spontaneum* the spikelets begin to open only after the arrows have emerged about four inches from the leaf-sheath and the sequence of exsertion of essential organs is that the sigmas protrude as soon as the glumes are thrust apart by the swelling of the lodicules; and after an interval of about 15 minutes anthers also come out of the glumes. In the Uganda *spontaneum*, on the other hand, the stigmas begin to come out of the glumes while the arrow is still inside the leaf-sheath in the top two to three inches of the arrow. The spikelets do not open till four or five days after the protrusion of the stigmas. In Uganda *spontaneum* the flowers are thus protogynous which renders self-fertilization difficult.

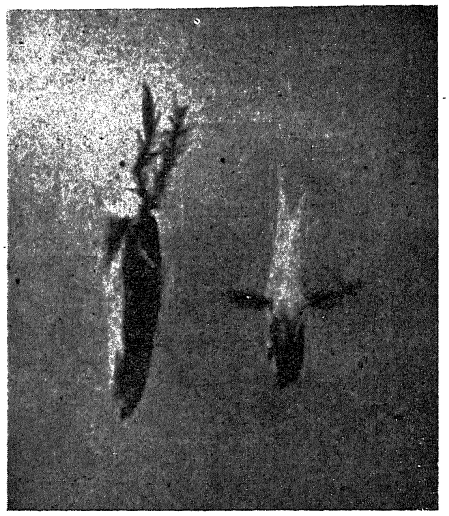


FIG. 2

The spikelets of the Uganda and Coimbatore *spontaneums*

Note the stigmas protruding from the apex of the Uganda spikelet and from the sides of the Coimbatore spikelet. Note also the difference in the size of stigmas.

The diurnal opening of the *S. spontaneum* spikelets is between 7-00 and 7-15 a.m., but the Uganda *spontaneum* spikelets open only at about 9-00 a.m. Its anthers are yellow like the other *spontaneums* though somewhat deeper in colour and the tips are reddish-brown. In all the other *spontaneums* the pollen flows out easily and very little remains inside of the anther-sac. The Uganda spikelets close at 11-00 a.m., so that they remain open for two hours while in the other *spontaneums* spikelets close one hour after their opening. It will be seen in Fig. 2 that the stigmas of the Uganda *spontaneum* protrude from the apex of the spikelet while those of *S. spontaneum* Coimbatore protrude from the sides of the spikelet.

Protogeny is essentially a device to secure cross-pollination. As is well known, protandry is the more frequent form of dichogamy and occurs in most plants.[1] Even in grasses protandry is characteristic of the majority of the genera and though protogyny is rather rare, it is met with in a few genera like *Anthoxanthum, Pennisetum*, etc.[2]

One very good characteristic of the Uganda *spontaneums* is their erect habit. Advantage has, therefore, been taken of the protogynous nature of the Uganda *spontaneums* and one of them has now been crossed with different species of *Saccharum*. It is also proposed to cross them with certain of the *Sorghum* and

Bamboo seedlings to yield a few more trigeneric hybrids of desirable characteristics.

N. L. DUTT.
M. K. KRISHNASWAMY.
Imperial Sugarcane Station,
Coimbatore,
November 2, 1942.

1. Strasburger's *Text-Book of Botany*, 5th Eng. Ed., 1921, p. 719. 2. Rees, J. W., *The World's Grasses*, 1929, p. 22.

ON AKINETE FORMATION IN *ZYGNEMA TERRESTRIS* RANDH.

THE object of this communication is to describe a peculiar method of akinete-formation in *Zygnema terrestris* Randh. from material collected near Dhakuri in Kumaon Himalayas, and to record the presence of this alga in Kashmir.

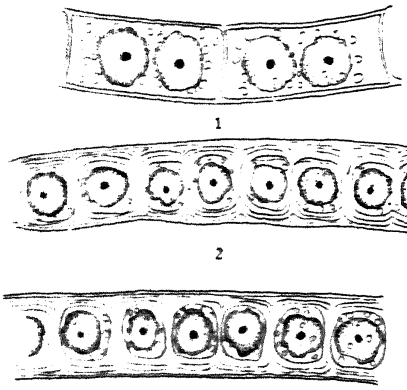
AKINETE-FORMATION

The following three modes of reproduction have been described by the present author[2,3] in this alga, so far.

1. Scalariform conjugation.
2. Lateral conjugation.
3. Aplanospore formation.

The material was collected by the author from near Dhakuri in Almora district at an altitude of about 9,000 feet above sea level in the middle of September 1939. In this material no conjugation lateral or scalariform was observed, and akinete-formation appears to be the exclusive mode of perennation.

Prior to akinete-formation cell-wall becomes thickened and lamellated. In mature akinetes cell-wall is about 6 μ thick, while in ordinary vegetative cells, it is only about 2 μ thick (Fig. 1). **The peculiarity of this form lies in the fact that akinetes are not formed by the direct conversion of vegetative cells into** akinetes, as in *Zygnema giganteum* Randh. or oher forms, but the vegetative cells divide into two more or less equal halves by the ingrowth of septa from the side walls, which ultimately meet in the middle (Fig. 2). So each half contains one chloroplast only surrounded by food-reserves, like starch and oil (Fig. 3). The cell-contents stain more or less black with iodine, and deep blue with Nile Blue. The akinetes are 24-27 μ broad and 18-21 μ long, *i.e.*, half as long as an average vegetative cell. There is greater economy of material in this mode of akinete-formation, for double the number of akinetes is formed. Akinete-formation is a mode of perennation in this alga in the high altitudes.



Zygnema terrestris Randhawa

FIG. 1. Vegetative cells. Mark the thin cell-wall. FIG. 2. Early stages in akinete formation. FIG. 3. Mature akinetes. Mark the single chloroplast in each akinete.

As regards the cause of their formation, it is very likely that low temperatures prevailing in high altitudes are responsible. This is partly borne out by the fact that no akinetes were ever observed in the material of this alga collected from the plains. According to Fritsch[1] in species of *Mougeotia* and *Zygnema*, which inhabit mountain-lakes in Europe with relatively low temperatures, akinete-formation is common. This alga too was collected from the alpine zone in the Himalayas and intense cold may be the cause of akinete-formation.

It is remarkable that this alga in the plains and at an altitude between 5,000 to 6,000 feet shows scalariform conjugation, between 7,000-8,000 feet shows lateral conjugation exclusively, and higher up shows akinetes only.

DISTRIBUTION

Originally collected from certain fields in Fyzabad district, in the plains of Oudh, this alga was later on collected from Kausani and Binsar in Kumaon Himalayas, Almora district. A laterally conjugating form of this alga was found near Dhakuri, at an altitude of about 8,000 feet. The material showing akinete-formation described in this paper was collected higher up in the alpine zone above Dhakuri.

On 4th August 1941, the author collected this alga from the shores of Sheshnag, an alpine lake, with glaciers on two sides, at an altitude of about 12,100 feet. This lake which is the source of Sheshnag river, a tributary of Liddar, lies on the pilgrim route to Amar Nath Cave. There was a pure growth of this alga, visible from the bridle-path in the form of a yellowish-green belt contrasting with the turquoise blue water of the lake. It formed a mat-like covering over a huge area. It was found in a purely vegetative stage, and it is likely that akinetes or conjugating material may be found in September. It is of interest to find this alga so widely distributed in the Western Himalayas from Kumaon to Kashmir.

M. S. RANDHAWA.
Deputy Commissioner's House,
Rae Bareli (U.P.),
November 28, 1942.

1. Fritsch, F. E., *The Structure and Reproduction of the Algæ*, Cambridge Univ. Press, 1935. 1, 336. 2. Randhawa, M. S., "Observations on some Zygnemales from Northern India, Part I." *Proc. Ind. Acad. Sci.*, 1938, 8, 144 and 149. 3. Randhawa, M. S., "*Zygnema terrestris* Randh. from the Kumaon Himalayas," *Curr. Sci.*, 1940, 9, No. 8, 373 and 374.

SECTION OF AGRICULTURAL SCIENCES

PRESIDENT :— N. L. DUTT, M.Sc., F.A.Sc.

Presidential Address

SUGARCANE IN INDIA—A RETROSPECT AND PROSPECT

I have great pleasure in welcoming you to the deliberations of the Agricultural Section. I should like to thank my colleagues in the Sectional Committee for electing me to preside. Allow me to say that I take this as a tribute to the Coimbatore Station and to the importance of the Sugar Industry at the present time, rather than to any little work that I may have done in the cause of surgarcane research. I am particularly happy that quite a few among the sugar factories and their staff from the different provinces have enrolled themselves as members of the Indian Science Congress Association thus giving proof of their interest in scientific research.

The sugar industry is now the second largest industry in the country. The special feature of the industry is its close connexion with agriculture. Indeed, the agricultural aspect is the most important. There are some twenty million cultivators scattered in all parts of India whose well being depends upon the cultivation of sugarcane. The white sugar industry is, so to speak, but a growth of yesterday, while sugarcane itself has been grown in India from time immemorial and the sugarcane industry properly so called has been in existence for now over 2,000 years. Even now the 150 factories consume among themselves only about 25 per cent. of the total cane crop while the bulk of the remaining crop is turned into that typically Indian product, the *gur*, which is a very wholesome food and whose manufacture is an age-long village industry. To the Indian cultivator, sugarcane has always been one of the chief money crops for meeting his cash requirements. And then the leaves and tops of sugarcane serve as useful fodder, and cane has been regarded, therefore, in many tracts as a valuable insurance against fodder famine. These few facts have been mentioned to indicate that sugarcane holds an important place in the agricultural economy of India. Sugarcane, in fact, occupies a definite position in the rotation of agricultural crops in several tracts. It is obvious, therefore, that anything which affects the sugar industry is going to affect the petty cane grower most. It is also obvious that one thing more than any other which should be ensured in a well organized industry is the proper growth of the cane crop in the cultivator's field. It is with a view to the proper cane development that the Government of India were good enough last year (in 1945) to place Rs. 125 lakhs at the disposal of the Indian Central Sugarcane Committee.

I should now like to turn to the main theme of the present address, namely, the sugarcane plant itself or rather the particular variety or varieties of cane grown and its or their function in the past, present and future. India has always been rich in the number of indigenous varieties of sugarcane though most of them were poor yielders. A number of canes were also introduced from other countries at several stages and from 1912 new varieties of cane (called Co. canes) have been evolved by hydridization at Coimba-

tore. The aspect of the cane field, from the varietal point of view has been changed completely owing to the success of the Co. canes and almost a new era in cane varieties has begun. The present is therefore a fit time to review the efforts made in the distant past as also in the immediate past regarding cane varieties so that some facts might emerge which might be well worth closer attention in the interest of the sugarcane crop.

Sugarcane in the Pre-historic and the Historical Times

Sugarcane and sugar have been known in India from the earliest times. In fact it is from India that sugarcane spread to other countries. There is considerable philological and botanical evidence that India is the home of Sugarcane (that is, the *Katha* or the *Saccharum Barberi* canes). There is mention of sugarcane in the Atharva Veda (perhaps 5,000 B.C.), the Institutes of Manu and the medical treatises of Charaka and Susruta There are as many as nine different products or preparations of sugarcane which are mentioned by Sanskrit writers including *Gaudi* or fermented liquor from treacle and *Sidhu* or fermented liquor from sugarcane juice. According to U. C. Dutt (quoted by Watt, 1893) there are twelve varieties of sugarcane mentioned by Sanskrit writers but which cannot all be identified at present.

Alexandar the great and his soldiers were the first Europeans to see sugarcane when they came to India in 327 B.C. The Saracens introduced sugarcane to Egypt in A.D. 641 and later to Spain. The spread of sugarcane in the fifteenth century from Europe to America and the movements of the various canes from place to place (West Indies, Brazil, Mauritius etc.,) have been given in fair detail by Noel Deerr (Deerr, 1921).

Coming to relatively recent times in India, Ibn-i-Batuta who travelled in this country in the 13th century alludes frequently to sugarcane in his *Safar-namah*, and speaks eulogistically of the Paunda cane of Malabar coast. The *Ain-i-Akbari* contains a detailed description of the methods of sugar cane cultivation, manufacture of all forms of sugar and the distillation of spirits from it. Munshi Sabhan Rai of Patiala (1695) furnishes interesting particulars of sugarcane in his *Khulastu-'t'-Tawarikh'*. Sher Ali Afsos (1804) gives in his *Araish-i-Mahfil* the currently accepted classification of the canes of Upper India during the seventeenth century.

Sugar and Sugarcane in the East India Company's Days

The introduction of Mauritius and other canes into India may be said to belong to the latter half of the East India Company's days and is discussed below separately under the next section 'Sugarcane in the Nineteenth century'. The present section relates to the early period of the Company. The space in this address is barely sufficient to indicate (1) that the attempt made by the Company to encourage European plantations to grow the introduced canes after the method practised in the West Indies was doomed to failure because the introduced tropical varieties of canes (sought to be acclimatized by enthusiastic planters) were unsuitable to the sub-tropical tracts of Bihar and Bengal ; (2) that India was during this period one of the main exporters of sugar to Great Britain, but the possible growth of its trade was precluded because of the prohibitively heavy import duty on Indian sugar by Great Britain, and (3) that this period saw the birth of a rival to sugarcane, viz., Beet, which in the course of thirty years or so, after the first attempt to commercialise it, opposed itself to the growth of the Indian foreign sugar trade.

With regard to (1) above, viz., the encouragement of the introduced tropical canes, it has to be said that this was done because the refiners of Europe believed that the Indian sugarcane contained too little crystallisable sugar and was therefore of not much use for refining as compared to the West Indian forms. But the experiments conducted by the first sugarcane Company of those days, soon demonstrated that certain cultivated races of sugarcane, grown in India, were quite as rich in crystallisable sugar as the West Indian forms. That the indigenous Indian canes are no mean canes in themselves and that they possess valuable qualities was proved later by the usefulness of *Chunnee* (taken by Kobus from India in 1891) to the sugar industry of Java after suitable hybridization and by the work at the Coimbatore Station in utilising these canes in breeding for the benefit of the various cane growing tracts of India from 1912 onwards. As regards (2) above, viz., the heavy import duties in Great Britain on Indian sugar, it may be stated that Indian sugar had to pay an import duty in 1792 of £ 37-16-3, per cent. while the West Indian sugar paid only £ 0-15-5 per cwt. That duty amounted to about 8 shillings per cwt. more than what was charged on colonial sugar. It existed until 1836, but by then beet had already established itself in Europe. The first direct effects of beet sugar production of Europe on India were (a) the closing of the markets to which India exported refined sugar, and (b) the throwing on the market large quantities of colonial sugar which sought an outlet in India, and this is how India gradually found herself an importer instead of an exporter of sugar. The curious can see the annual figures of export by sea of Indian sugar to foreign countries from 1800 to 1878 and of imports of sugar from 1871 onwards. As regards (3) above, viz., the discovery of beet as a source of sugar, it may be of historical interest to know that in 1747 Marggraf discovered common sugar in beet and that it was not until 1801 that his pupil Achard established a factory in Silesia. Napoleon I encouraged this new industry in France and by 1830 it had become firmly established. By 1840 it had grown to a national enterprise, especially in Germany, and has since then controlled the sugar market of the world.

Sugar in the Nineteenth Century

It was in 1827 that Capt. Sleeman brought the Mauritius canes into India and deposited them in the Botanical Gardens at Calcutta. The *Transactions* of the Agri-Horticultural Society of India contain details of the cultivation, etc., of these and other foreign canes. Capt. Sleeman received the gold medal of the above soceity in recognition of being the most energetic worker in the experimentation and introduction of foreign canes. Watt 1893 gives the details of these canes under (1) Mauritius, (2) Otaheite, (3) Bourbon cane, (4) Batávian canes, (5) China canes, (6) Singapore canes, and (7) Indian canes.

The introduced thick canes which belong to *Saccharum officinarum* L. are still being grown in certain parts of the country, but on a limited scale. These have by now acquired local names. Thus the 'Vellai' of Coimbatore district, the Desi or Peshawri Paunda of North Western Frontier Province and the 'Toungoo Yellow' of Burma are one and the same cane, viz., Otaheite. Then there are other thick canes (including Otaheite types) which are known as Paunda canes and are grown for chewing purposes. The Pundia cane of Bombay Presidency falls in this class (*S. officinarum*) and Poovan of Coimbatore district, Hottai Kabbu of Bellary and Patta Patti of Mysore are the the same canes as Pundia. The Patta Patti is a striped variant of Poovan

and is said to have been introduced into Mysore from Vellore (Iyer, 1944). Canes of Paunda type must have existed in India earlier than the introduction in 1827 by Sleeman, as Ibn-i-Batuta makes a mention of them in the 13th century.

The indigenous Indian canes mentioned by Watt and grown in the 19th century were a good many in number and in fact every district or local tract had its own characteristic variety. These are now under *Saccharum Barberi*, Jesw. These were in the opinion of Watt so diversified that he did not attempt a classification.

The China canes, according to Roxburgh, the famous Botanist, were introduced into the Botanical Gardens, Calcutta, in 1796. He rightly regarded them as a separate species and gave them the name *Saccharum sinensis*, Roxb. It is stated, however, by Watt that the distinction which Roxburgh tried to establish has not been maintained. Later work has undoubtedly supported Roxburgh in the recognition of the Chinese canes as a separate species (Jeswiet, 1916, and 1925). Watt in his later publication (1908) stated that if the original stock of China canes survives to this day at all, the plants have very largely merged into the indigenous forms and their origin forgotten.

The last decade of the century under review saw a revolution in the method of cane improvement. The discovery of fertile seed in surgarcane was made by Soltwedel in Java in 1888, and quite independently in Barbados by Bovell and Harrison in 1889. These two countries thenceforward made great advances in the production of seedling canes to serve their sugar industries. Watt (1893) does make a mention of flowering and seedling of cane and of cane improvement by "seminal selection", but India had to wait for 31 years after the discovery of fertile cane seed and its utilization by Java and Barbados before she was to have a Cane Breeding Station of its own at Coimbatore in 1912.

Watt (1893) devotes ten well written pages on the subject of improvement of sugarcane. He rightly mentions the following four methods : (1) by experimenting with all available canes to test their adaptability to a new environment, (2) by ascertaining the effect of peculiar methods of cultivation, (3) by selection and propagation of sports or buds found advantageous to the object aimed at, and (4) by a similar selection from seedlings. The first two of the above had reference to the then rage in India of growing and encouraging the cultivation of the introduced canes after the pattern of the West Indian methods and with regard to these he deservedly makes the following pungent remarks, "It seems to be the prevailing evil tendency of agricultural reformers to look to countries outside India for new economic products or superior races of existing crops. A state of indebtedness in these matters must necessarily mean the absence of the vitality to progression. Witness the load alaid by its pioneers on the tea industry through the importation of the chinese plant. It was not until the so-called indigenous tea was taken in hand and the Chinese stock largely exterminated that tea planting gave indications of success". With regard to (3) and (4) he pertinantly points out, "these are the natural processes which would be expected to suggest themselves from the dictates of personal advantages, alike to the ignorant and the educated cultivator, In India the principle of selection has been in operation for countless ages of sugarcane cultivation and nearly every district possesses slightly different forms that are not to be met with anywhere else".

Sugarcane in the Early Years of the Agricultural Departments

The credit of establishing an Agricultural Farm devoted chiefly to the work on sugarcane goes to the Bombay Agricultural Department for establishing a farm for sugarcane at Manjri, near Poona in 1894. The second earliest farm was the one established at Samalkota in 1902 by the Madras Department of Agriculture. Mollison's work at the Manjri farm has been described in a note in the Agricultural Ledger 1898. Forty six varieties have been described in this note and a classification has been attempted based upon the shape of the internodes, into five groups called A, B, C, D, and E. This classification is at best an artificial one and not strictly scientific, as both the *S. officinarum* and *S. Barberi* types have been made to fall in one or the other group according to the shape of the internode. It may be stated, however, that the thicker or the *S. officinarum* class of canes fall under the A and C, groups, while the B, D, and E groups include the *S. Barberi* canes. The work on sugarcane varieties at the Manjri farm was again taken up by J. B. Knight and his work is described in the Department of Agriculture, Bombay, *Bulletin* No. 61 of 1914, Knight mentions sixteen varieties and divides them into three groups, called soft, hard and "grassy."

Hadi's work on the sugar industry of the United Provinces appeared in 1902. He deals comprehensively with the various varieties and we see here for the first time, an attempt for the serious study of the Indian sugarcanes with a view to classification. His descriptions are detailed, though not strictly in botanical terms and he himself mentions that his classification is not strictly scientific and is based on the general appearance (mainly colour) and the agricultural characters of the different varieties. He describes six series of canes of which the fifth and sixth, namely, the Ganna and Paunda canes, would now fall under *S. sinense* and *S. officinarum* respectively His first four series, namely, (1) the Dhaul canes, (2) the Matna canes, (3) the Kuswar canes, and (4) the Chin group would come under *S. Barberi*. Hadi was also interested in the manufacture of sugar by the Kandsari method and developed a system of his own for open pan boiling. A comparison of Hadi's method with the Rohilkhand method was made by R, L. Sethi (1933). In view of Hadi's work on sugarcane and sugar manufacture, no work dealing on sugarcane in India should be considered complete without paying a tribute to Hadi and his work. Khan Bahadur Syed Mohd. Hadi maintained his interest in sugarcane throughout his life. In his later days he was the Director of Agriculture, Bhopal, and published a voluminous book on the Indian Sugar Industry under the auspices of the Government of Bhopal.

Perhaps the most scientific study and classification of sugarcane (other than at the Coimbatore Station, dealt with below in a separate section) is by Woodhouse and Basu (1915) at Sabour, Bihar. The writer feels that Woodhouse and Basu's work has not been given proper recognition in sugarcane literature. Woodhouse began work on the Bihar canes about the year 1908 and was thus earlier in the field than Barber. The publication of Woodhouse's *Memoir* (1915) was also earlier than the classification of Indian canes by Barber (1916). In his Memoir, Woodhouse has described as many as twenty four indigenous Indian canes, the description in each case being fairly detailed and strictly botanical and classified them into eight groups. A comparison of certain groups shows that the canes listed in comparable groups agree with those listed later by Barber in his groups. While tabulating the distinguishing character of certain groups, Woodhouse gives the name of the type specimen at the head of respective columns. The Baraukha

and Maneria groups correspond to the Nargori and Pansani groups respectively of Barber. Since Woodhouse's work appeared earlier Barber might appropriately have called his Nargori and Panshahi groups as Baraukha and Maneria groups respectively, particularly as both Nargori and Pansahi in the Coimbatore collections had been obtained from Sabour.

The work of G. Clarke in the United Provinces consisted of evolving an improved method of cultivation as also of recommending certain foreign varieties tested by him. He distributed Ashy Mauritius, a thick cane of the Paunda type, to the cultivators of the Rohilkhand division and recommended it to be grown under his improved method, namely, with trenching. He also gave Shahjahanpur numbers to the varieties under trial. Thus S.48 which is really P. O. J. 213 came to be known in U. P., under the name S.48. As regards the growing of Ashy Mauritius with the trench method in the sub-tropical area of the U. P., one is constrained to remark that the lesson of the failures in the 19th century of such attempts in Bihar and Bengal which were so properly condemned by Watt had not evidently been learnt even by scientific workers like Clarke.

One of the greatest landmarks for the good of sugarcane in India towards the close of the period 1900-1920 was the able report by the Indian Sugar Committee of 1920, which after a careful examination and scrutiny of the work on sugarcane by the Agricultural Departments, as also of the then existing Sugar Factory Industry, laid the foundation of all future work in India. The question of sugarcane varieties has been dealt with in this report in as great a detail for their period as was done by Watt (1893) for the 19th century.

The Coimbatore Station and Co. Canes

The Coimbatore Sugarcane Breeding Station was established in 1912 and the able work of Dr. Barber and Sir T. S. Venkatraman in evolving suitable seedling canes (Co. canes) has considerably benefited the Indian cane grower and the Indian Sugar Industry. Three competent reviewing authorities, namely, (1) Sugar Committee of 1920, (2) The 1930 Indian Tariff Board on the Sugar Industry, and (3) The 1937 Tariff Board on the Sugar Industry have paid well deserved tribute to the great work of Dr. Barber and Sir T. S. Venkataraman for the main or the North Indian sub-tropical belt and the economic results obtained therefrom. Barber's and Venkatraman's work at Coimbatore represents "the first attempt in the sugarcane world at improving the sub-tropical type of canes and the parents employed for hybridization have had to be wider than in most other countries because of special features associated with the type of cane and growth conditions of the Indian sugarcane area". The Coimbatore work on the economic Co. canes for the Tropical belt, that is, for Bombay and Madras Presidencies is a relatively later activity of the Coimbatore Station and has been mentioned in a brief article by the writer (Dutt, 1942). The cane breeding aspect of the Coimbatore work has been reviewed from time to time by Barber himself in the *International Sugar Journal* as also by Sir T. S. Venkatraman in his two able Presidential Addresses to the Section of Agriculture at Indian Science Congress. I will not attempt here to repeat the ground already covered by the above publications, but will confine myself mostly to the systematic (taxonomic) and varietal aspects of the work.

Barber's monumental work on the Indian canes has been recorded in voluminous *Memoirs* of the Agricultural Department of India. The

first of these *Memoirs* on the Indian Sugarcanes appeared in May 1915. Never before in the history of sugarcane in India had the indigenous Indian canes been so thoroughly and scientifically studied. The Indian canes were raised later to the status of a separate species and appropriately named *Saccharum Barberi* (Jeswiet 1916 and 1925), The Pansahi group of Barber has, however, been put in another species, namely *S. sinense*, (Jeswiet, 1916 and 1925).

The actual allocation of the indigenous Indian canes to specific groups appeared in a small article by Barber (1916) in the *Agricultural Journal of India*. In that note some sixteen canes have been listed under "6. Unclassified at present". A serious study to allocate these unclassified canes has yet to be made. A study of the chromosome numbers of Barber's groups by Bremer (1932) revealed that these groups have each a characteristic chromosome number, with the exception of Dhaulu, Rakhra, Rakri, Mungo, Kewali, etc., the chromosome numbers of which differ from the typical group numbers. The Dhaulu canes of the Sunnabile group have each $2n=82$ chromosomes, the number characteristic of the Mungo group, though they differ from them in morphological characters. This led Bremer to the conclusion that the Dhaulu canes of the Sunnabile group of Barber should be separated and placed under a new group, the 'Dhaulu group' in close relation with the Mungo group. He also considers that the varieties Manga and Kewali placed under the Nargori group by Barber should be considered as hybrids between a cane of the Nargori group and one of the Saretha group based on their chromosome number. Venkatraman (1938) also states that the Mungo, Sunnabile and Nargori groups of canes cannot be definitely placed either in *S. Barberi* or *S. sinense* because of certain important differences in vegetative and field characters, though they are perhaps allied to *S. Barberi*, *S. spontaneum* and *S. sinense* in some respects. It is evident, therefore, that a good deal of morphological work has still to be done at Coimbatore. In the period of thirty years that has elapsed since the publication of Barber's classical work the attention of the Coimbatore workers has been devoted exclusively to economic work, with a view to meeting the needs of the rather young and growing sugar industry in the country. It is time, however, that botanical studies were again taken up and the writer has already proposed as a first step in this direction the setting up of a *Saccharum spontaneum* expedition party for studying the wild *S. spontaneum*, as this particular species has been of the greatest assistance in the Coimbatore work for evolving economic types. There is a real need for such study, for similar studies at the hands of Vavilov (1926) the great Russian worker on wheat, oats, barley and many other cultivated plants have yielded very valuable data. It is hoped that the above work will form the nucleus of a Botanical Section at Coimbatore, to which later on, the task of a detailed botanical study of *S. Barberi* and *S. officinarum* will be entrusted.

The Pansahi group of Barber has been recently placed by Jewiet (1916) and 1925) under *S. sinense*. The canes in the Pansahi group are what are called the Ganna canes, which are thicker and softer as compared to the canes of *S. Barberi*, but not so thick or soft as the canes belonging to *S. officinarum*. With regard to Kahu, the only Punjab cane belonging to the Pansahi group, Barber states that it is susceptible to red rot. He further states that he has no information as to the migration of this cane, but its allies are Dikchan, Pansahi, Lata, Maneria, Chynia and Yuba. Perhaps the canes of the Pansahi group are remnants of the Chinese canes introduced

into India by Roxburgh in 1796. It has to be mentioned, however, that reports on the Chinese canes (Watt, 1893) showed that when actually grown they were extremely hardy and very prolific and resistant to white ant and jackal attacks and able to bear drought and hot weather better than the indigenous Indian canes. This, however, does not accord with the experience of Barber (1915) regarding the canes of the Pansahi group. With regard to Kahu (Pansahi group) he states that it requires more water, better land and is subject to red rot. It has a soft rind which accounts for its being a favourite for chewing purposes.

The wild Kans (*S. spontaneum*) which is known to the agriculturist in India only as a troublesome weed has been of very great use to the Coimbatore Station in its breeding programme. Barber (1915) mentions *S. spontaneum* as a variable species in India. Hole (1911) also mentions that this species varies greatly according to its habitat and recognises three ecological forms. Venkatraman (1936) mentions that certain of the *S. spontaneum* forms in the collection at Coimbatore possess juice qualities equivalent to the Indian forms. Panje (1933) made at Coimbatore a comparative study of the forms of *S. spontaneum* and recognised two definite sub-species based on the constancy and distinctness of characters which were few but important. Dutt and Krishnaswami (1943, b) noticed protogyny in the Uganda form of *S. spontaneum*. The work on cytology of *S. spontaneum* at Coimbatore (Parthasarathy and Subba Rao, 1946, b) reveals that the forms with smaller numbers are found in North and North-West regions of India and that the geographical trend of distribution in respect of forms with increased numbers is form North-West to South-East. For instance, starting from Lahore and Dehra Dun forms (n=27) ; the Bihar types have (n=28, 30, 32, and 36) ; Assam forms (n=40) ; the Burma form (n=48) ; and East Indian types have (N=50 and 56). From the directional trend it may be inferred that more primitive types with chromosome numbers smaller than n=27 are likely to be found in the slopes of the Himalayas or in regions further North-West.

The present position regarding the taxonomy of *Saccharum* and allied genera has been reviewed by the writer (Dutt and Thuljaram Rao, 1946, b) in a brief paper. The question of the validity of *Erianthus* as a separate genus has yet to be settled. The morphological studies on the available forms of *Erianthus* at Coimbatore were continued. From his studies the writer is led to the conclusion that *Erianthus* should be separated from *Saccharum*. It should form a separate group as it shows the following characters in contra-distinction to *Saccharum* : (1) culms biennial, (2) root eyes mostly absent, if present only one row, (3) leaf insertion finely bearded extending into the mid-rib, (4) callus hairs shorter or as long as the spikelets, never longer, (5) glume I and II of the pedicelled spikelet always villous dorsally and often glume I of sessile spikelet, (6) glume IV always present, prominently awned in most cases, often being exserted beyond the spikelet and (7) glume IV ovate lanceolate. The above distinct characters were also found in the forms now being labelled as *Saccharum munja* and *Saccharum arundinaceum* which should therefore be transferred to *Erianthus*. One important point of difference between the two genera, which is rather significant is the villous nature of the first and second glumes of the pedicelled spikelets in all the species of Erianthus. This gives the flowers a woolly appearance and the very word *Erianthus* means 'woolly flowered'.

The writer's studies on *Erianthus* give an indication of the probable origin of the noble canes belonging to the species *S. officinarum*. Some of

the characters of *Erianthus* are noticed *S. officinarum*, to the exclusion of the other species of *Saccharum*. These are (1) the earlier opening of the sessile spikelets, (2) the glabrous nature of the peduncle, (3) the occasional presence of an awn to the IVth glume, (4) glumes I and II with three or more nerves and (5) glume III with one median nerve. These characters are common between *Erianthus* (all the three sub-groups) and *S. officinarum*. One sub-group, namely, *E. arundinaceum* has more points of resemblance to *S. officinarum*. The forms are vegetatively very similar to those of *S. officinarum* in size,, thickness of stem and nature of leaves. They are propagated by setts and the arrows are showy and large as in the varieties of *S. officinarum*. The similarity in characters leads to the inference that species of *Erianthus*, especially *E. arundinaceum* might be considered as probable source of the origin of the cultivated canes. Brandes and his co-workers (1938) were also led to the same conclusion basing their observation on the venation of the spikelet parts, namely, points (4) and (5) above. Grassl (1946) suggests on the basis of morphological and geographical evidences that noble sugarcanes are most closely related to S. *robustum* and *E. maximus*. He adds that there might have been separate origins of sweet forms in both of these groups but it seems more likely that the main origins were from *S. robustum*, and that as these forms were carried eastward beyond the range of wild *Saccharum* they were modified by hybridization with forms of *E. maximus*. Grassl (1946) concludes his observations rightly with the remarks—"the story of sugarcane origins is by no means told. Critical cyto-genetical studies of the complex groups involved remain to be made". Grassl (1946) also mentions *S. edule*, detailed descriptions for which have been prepared by Artschawager. These have abortive inflorescences which are edible. The Coimbatore collection has got a representative of the group, namely, Taboe Treboeq.

From his cyto-genetic studies at Coimbatore the writer's colleague Dr. N. Parthasarathy (Parthasarathy, 1946, a) has suggested a theory of the probable origin of the indigenous Indian canes. He considers that the North Indian canes have been evolved by extensive hybridization between *S. officinarum* and *S. spontaneum*. He believes that *S. officinarum* must have been in cultivation in Peninsular India earlier than the North Indian canes and cites interesting references in the Dravidian literature of the Sangam period before second century A.D., which shows that in South India also there is evidence of intimate knowledge of the cultivation of sugarcane (probably the thicker class of canes) at quite an early period of India's civilisation.

The present position regarding the origin of sugarcane is that India is (1) the home of the indigenous Indian canes which originated in India, (a) either (Barber, 1915) from the *S. spontaneum* or (b) as a result of extensive hybridisation between *S.officinarum* and *S. spontaneum* in the regions of Bengal, Bihar and Orissa (Parthasarathy, 1946) ; (2) the thicker class of canes belonging to *S. officinarum* are probably of tropical origin, the place of origin being probably the South Pacific Islands and originated either from (a) *E. arundinaceum* or (b) from *S. robustum* or hybridisation between *S. robustum* and *E. maximus* (Grassl, 1946). The question of the origin of the sugarcane as also of the taxonomy of *Saccharum* may be said to be in somewhat of a nebulous state. It is hoped that the collections and studies of the *spontaneum* expedition which is being organised by the Coimbatore Station will throw light on the above subject. It is suggested that a symposium on this subject should be organised by the International Society of Sugarcane

Technologists at their next Congress or in the Agricultural Section of the Indian Science Congress in another three or five years.

We should now turn to the subject of the economic Co-canes with which is intimately connected the immediate present and the future of the Indian sugarcane industry. The varietal composition of the sugarcane crop of India as it stood in the year 1941-42 has been described by the writer in a brief article (Dutt, 1943, a). In the United Provinces the famous Co. 213 has had to be replaced on account of the Red Rot epidemic of 1939. The main cane now is Co. 312. The other important canes are Co. 290, Co. 370, and Co. 421 which have their special areas. In Bihar also the once dominant Co. 213 had to be replaced. The main cane at present is Co. 313 (in North Bihar) which has contributed to high recoveries of Bihar factories as compared to factories in other North Indian provinces. One wishes that the yield of Co. 313 was better or at least equal to Co. 213 which it has replaced. Though the Bihar factories have gained, the cane grower has suffered a loss. This subject has been dealt with at some length in a recent report (Dutt, 1946, a) and there is no need to repeat the arguments here. The main cane in South Bihar is Co. 331, but as it is susceptible to red rot it is being replaced by Co. 453. In the Punjab the days of Co. 205 are long past and Co. 285 is now the main cane but for its factory areas, Punjab will have to depend, for the present, on Co. 312, Co. 421 and Co. 313. It should be stressed, however, that the income of the cane grower should not be adversely affected. Sugarcane has been in a bad way in Bengal, but there are signs of recent activity in the right direction. Co. 213 should be completely replaced and the alternatives, at present, are Co. 421, Co. 527 and Co. 313. In the North West Frontier Province the once favourite, Desi or Peshawari Paunda has given place to Co. 290. Bombay and Madras have had to wait for a long time for a suitable Co. cane. This is because the work on thick Co. canes was taken up later at Coimbatore. Co. 419 which was distributed about 1934 has now proved of service to the Deccan and Madras cultivator and may be said to be the main cane in these tracts.

The early batch of Co. canes, viz., Co. 205, Co. 210, Co. 213 and Co. 214 had replaced the indigenous canes and has in its turn been replaced by the canes mentioned in the para above. It is admitted on all hands that the Co. canes have, in the North-India or main belt (and now also in the tropical belt of Bombay and Madras), appreciated the cane yields by at least about 50 per cent, and have provided the needed improved raw material for the success of the sugar industry. The stage has now been reached when each province should have a varietal advisory committee which should attempt to map out the utility or otherwise of Co. canes for each district or local tract both from the point of view of the needs of the cane grower and the factory. The manufacturing qualities of canes and their performance in the factory should receive greater attention. Close attention should also be devoted to the early, mid, and late ripeners and also to ratooning qualities. The Coimbatore Station has not had so far a live touch with factory performance of the Co. canes but its activities have recently been expanded with a small nucleus of staff on the chemical side. No cane should hereafter be given out for general cultivation for which a Mill Trial has not been conducted. I shall not weary you with details of recent Coimbatore work on early and late canes and crosses for evolving relatively non-pithy types. I shall refrain also from mentioning the plant physiological and chemical aspects of Coimbatore work. There is space and time only to refer to certain aspects of the place of early ripening canes and of ratooning in planned cane growing

and these have been discussed under the section on Cane Development below.

Before closing this section I should like to reiterate my faith in the centralization of sugarcane breeding at the Coimbatore Station. For fuller details reference may be made to chapter viii of the report on Survey of Sugarcane Research (Dutt, 1946, a). The other stations where breeding work is being permitted are either not fully equipped or are situated in a tract not climatically suited for large scale hybridization and raising of sugarcane seedlings. There does not seem to be much good in duplication of this work which is highly specialized.

The Chain of Provincial Sugarcane Stations

Soon after its formation in 1929 the Imperial Council of Agricultural Research constituted a Sugar Committee. As a result of the deliberations of this Committee in its annual meetings various schemes of sugarcane research were passed and the progress scrutinized and co-ordinated. This Committee and the Imperial Council of Agricultural Research have with characteristic foresight spent over Rs. 50 lakhs on sugarcane researeh. Very useful work has been done at the chain of sugarcane research stations which were established in the various provinces and Indian States with the help of funds from the Imperial Council of Agricultural Research. Work of great utility on the varietal, cultural, manurial, cane growth and sucrose development, entomological and mycological aspects of the cane crop has been done at the Shahjahanpur sugarcane station, U.P. There are two sub-stations, one at Muzaffarnagar and the other at Gorkahpur. An intensive soil survey of the sugarcane soils of Gorakhpur district is in progress. The Pusa Sugarcane Station in Bihar has also done equally important work on all the above aspects of cane. A feature of the Pusa Station is the live contact it has all along maintained with the sugar factories in Bihar. The Station has conducted soil surveys (with rapid chemical methods), as also disease and pests surveys. A certain amount of cane breeding work has also been done at this station, amidst the rather unfavourable climatic conditions of Bihar. There is a sub-station at Patna for South Bihar conditions. In the Punjab there is a sugarcane research station at Risalewala (Lyallpur) and a sub-station at Jullundur. Work on seed rate, time of planting and interaction of these two as also on the manurial, irrigational and entomological aspects has been done. Frost is a factor to reckon with in this tract and the resistance or otherwise of the varieties to frost is noted before release to cultivators. In Bengal, work on sugarcane has been on a very limited scale, but schemes for intensive work are under way. In the North Western Frontier Province the intensity of cane cropping is high in the Peshawar valley and the useful work begun in 1910, but more intensively from 1940, should be continued in the interests of the cane grower. In Bombay, the Deccan canal area is important and there is a concentration of sugar factories in this tract. Some of the best work on sugarcane soils has been done at the Padegaon Sugarcane Station of Bombay Presidency. Sugarcane research has been a feature of Madras work for a long time. Useful information has been obtained on varietal, manurial and cultural aspects at the Anakapalle sugarcane station. There is a sub-station at Gudiyattam.

Renaissance of the Sugar Industry

The Sugar Committee of the Imperial Council of Agricultural Researeh in its very first meeting in October 1929 recommended that an enquiry

be held by a Tariff Board on the necessity of protection for the Indian Sugar Industry. The Tariff Board was constituted in 1930 and studied all aspects of the industry comprehensively and critically and in their able report of 1931 reported that a case for protection had been established and recommended protection for a period of 15 years. In coming to their decision the Tariff Board, among other factors, stated that much progress had been made at the Coimbatore Station and the Co. canes had increased the output by 50 per cent. and that there had also been a remarkable increase in the efficiency of the Indian sugar factories since the Sugar Commimittee of 1920 last reported. The Government of India accepted the recommendations of the Tariff Board and the Sugar Industry (Protection) Act, 1932, was passed by the Legislature. In accepting the Board's recommendations, the Government considered that an initial protective period of 15 years was unduly long and decided that the protective duty be imposed until 1938 after which a further enquiry into the question of continuing the duty be held. This further enquiry was referred to the Tariff Board in 1937 who in their report of 1938 recommended that the duty be continued. This Board also paid tribute to the Coimbatore work and recommended that the Station be expanded to provide for new lines of investigation.

The protective policy of the Government was immediately successful. Indian capital which was previously shy in investing money in the sugar factories responded at once and showed that given proper conditions it was not behind any other country in the world in enterprise and organizing ability. The number of sugar factories in the pre-protection period was 32. In two years after the grant of protection the number of factories rose to 112. By 1941 the number of sugar factories had risen to 150. This is probably a record in the annals of the growth of any industry in the world. In four years (1936-37) the sugar produced in Indian factories had risen from the pre-protection figure of about 1 lakh tons to over 11 lakh tons. In fact in that year (1936-37) the production of sugar in India by all processes was 1,254,000 tons which was 53,000 tons in excess of the estimated consumption. The imports of foreign sugar into India began to decrease from 1932-33 and reached a very negligible figure in the course of a few years.

The signs of a live industry are that it should have business syndicates, technologists' Associations, and journals to serve as a forum ford iscussing the problems facing it from time to time. The Indian sugar industry has its Sugar Mills Association, Calcutta, the Sugar Syndicate, Cawnpore, the Sugar Technologists' association, Cawnpore, and the Journal *'India Sngar'* Cawnpore. The sugar industry has also found an able exponent in Mr. M. P. Gandhi, whose *Annuals* contain very informative expositions of the needs and problems of the Industry. His two able publications (Gandhi, 1934 and 1945) deserve to be read with as much interest for the post-protection period as Watt's work for the nineteenth century and the report of the 1920 Sugar Committee for the pre-protection period. The 1938 Indian Sugar Industry Annual of Mr. Gandhi contains a well-informed and illuminating foreword by the Hon'ble Dr. Rajendra Prasad.

Cane Development in India

The work of improvement of sugarcane in the fields of cultivators had merely formed one of the so many items of work of the Deputy Directors of Agriculture in the various provinces. The beginnings of whole-time cane development work date from 1935 when the Government of India placed sums from the Sugar Excise Fund at the disposal of provincial governments

with the specific object of the improvement of this important crop. The Sugar Committee of 1920 had in their able report stressed the need and justification of whole-time staff for cane development, but it took 15 years for the above recommendation to be given effect to, in part. In 1937-38, however, a separate Cane Development Department was formed in the United Provinces under the charge of a Cane Commissioner. Mr. Vishnu Sahay, I.C.S., was the first Cane Commissioner and it is largely due to the sound foundations laid by him that such excellent results were obtained in the succeeding years. A Cane Development section has also existed in Bihar since 1939. The writer when touring in 1944 in connexion with the Survey of Sugarcane Research noticed that 80 per cent. of the cane crushed by the United Provinces factories had been supplied by the Cane Growers' Co-operative Societies while the corresponding figure in Bihar was only about 20 per cent. The best way of judging the cane deve opment work is the general condition and growth of the cane crop. This was very good in the U.P. and the writer has no hesitation in saying that the cane development work as originally laid down by Mr. Vishnu Sahay and subsequently developed by Mr. R. L. Sethi, I.A.S., should serve as a model to the other sugarcane growing provinces in India. Barring U.P. and Bihar no cane development officers have yet been appointed in other provinces. The co-operation of the sugar factories is essential for the success of cane development work. Unfortunately this co-operation has not been forthcoming in full measure on account of the factories looking askance at the work of the cane growers' co-operative societies, perhaps more so in Bihar. Wherever in U.P. the sugar factories had co-operated whole-heartedly, the condition of the cane crop was good and resulted in well grown and healthy raw material being brought to factories. The lack of interest and help in cane development had invariably resulted in poor cane crop and indifferent raw material being supplied to the factories. The sugar factories can be a great influence for good in cane development and a good many of them have given all the assistance and encouragement in their power. There may be, it is true, certain aspects of the working of the cane development departments or of the provisions of the Sugar Factories Control Act to which the factories may legitimately take objection, but the remedy lies in constructive suggestions and co-operation and not in openly or covertly hindering the admittedly useful work of the cane growing co-operative societies.

Even in the U.P. where the cane development work has been in progress now for seven or eight years, let alone the provinces where this work has not yet begun or has been done with not quite full zeal, there is a big gap between the acre yields as obtained by the average cane grower and those obtained by the sugarcane research stations or by progressive cultivatiors or at factory farms. Not till this gap is filled will the sugar industry be able to stand on its legs and to produce sugar at competitive prices for the major part of the cost of production of sugar is the cost of raw material. The writer had suggested the details of cane development work and the strength of the staff (Dutt, 1946, a, Chap.X, pp. 86-91 and Chap. XI, pp. 123-132), and still feels that at least Rs. 2 crores should be spent for development alone every year for a period of 10 years before the desired end will be in sight. A cess of one anna per maund of cane crushed in sugar factories will bring a revenue of Rs. 2 crores and should be exclusively spent on cane development. Attention may also be invited here to at least a few of the important points made in the above mentioned report, viz., the sugarcane advisory committees in each province should seek to remedy the varietal muddle that there is in certain tracts by recommending the cultivation of

only the approved varieties and by discouraging the undesirable varietie ; the main cane in each tract should be essentially a good yielder and not one calculated to give merely high recoveries or selected only from some other particular point of view ; no new variety should be released for general cultivation which has not passed through a Zonal Trial and for which a proper Mill Test has not been conducted ; the cane development work should be judged by the growth of the crop in the whole area of the zone and not by growth of the demonstration plots alone ; the cane growers' co-operative societies should be under the cane development department and the primary officer, namely, the Assistant Cane Development Officer who is usually the Secretary of these societies should invariably be an agricultural graduate ; the help to the cane grower regarding manures, cane setts, improved implements, etc., should be in kind and not in cash ; the taking of one ratoon should not be discouraged, but on the other hand be made quite a normal practice with instructions and supervision as to how to grow it properly ; bad debts from the cane grower are few as the price of manure and other facilities can be recovered at the time of purchasing cane ; esential staff to watch pests and diseases should be appointed.

The new era which has opened with the inauguration of the Indian Central Sugarcane Committee in 1944 augurs well for the success of the sugarcane and sugar in India and will always be associated with the great names of Sir Jogendra Singh, K.C.S.I., and Sir Pheroze M. Kharegat, C.I.E., I.C.S. They have placed the magnificent sum of Rs. 125 lakhs for sugarcane development at the disposal of the Committee.

Varietal Aspect (including ratooning) for the immediate future

Proportion of varieties and ratoons.

It is usually stated in Departmental reports that the improved varieties now occupy in the tract or province, say 80 per cent. or 90 per cent. of the area. This is not enough because the word improved variety in the parlance of the departments includes such varieties as P. O. J. 2878 or other foreign canes or even Co. canes like Co.213 which the varietal advisory committees are seeking to replace. The time has come when we should know the area under each variety and if proper cane development has to take place, we should decide upon the area under each variety, as also the area under ratoons. And then the proportion of the early, mid-season and late varieties (plant canes) among themselves should also be decided.

For purposes of illustration we may take a unit area of 5.000 acres in a factory zone. In the present illustration the case of a factory in the western U.P. has been taken. For the other tracts in India suitable changes may be made according to local circumstances. The idea is to indicate how we might plan the planting and crushing of the plant cane varieties and ratoons. The crushing season in the present instance may be divided into four months, viz., first month (from last week of November to last week of December), second month (from last week of December to last week of January), third month (from last week of January to last week of February), and fourth month (from last week of February to last week of March). It is suggested that the early variety should occupy 30 per cent. of the area and should be crushed in the first month. The ratoon should be crushed in the second month. Only the main and mid-season variety should be ratooned from the third month harvest, thus only 25 per cent. of the area will be under ratoons and one ratoon should be taken. The area under the late variety

should only be 20 per cent. of the total area and should be crushed in the fourth month. In the absence of a suitable late variety the fourth month crush should come from the main variety. The area under early variety should in no case exceed 30 per cent. Assuming Co.313, Co.312 and Co.421 to be early, mid-season and late varieties respectively, for the present illustration and assuming a unit area of 5,000 acres for the factory the disposal of the crop will be as follows :—

TABLE I

Disposal of crop in a unit area of 5,000 acres in a factory, say in western U.P. for a four month crusing period.

YEAR / MONTH	FIRST MONTH	SECOND MONTH	THIRD MONTH	FOURTH MONTH
First Year	1,500 acres Early variaty Co.313	1,250 acres Main variety Co.312	1,250 acres Co. 312 TO BE RATOONED	1,000 acres Late variety Co.421
Second Year	1,500 acres Early variety Co.313	1,250 acres Ratoon Co,312	1250 acres Plant cane Co.312 TO BE RATOONED	1,000 acres Late variety Co.421

Policy regarding early varieties.

In the above scheme or illustration, 30 per cent. has been allotted to the early variety. It is well known that early varieties are usually low yielders, at least in the present instance, viz., Co.313, it is so. We have, therefore, to consider whether the early varieties should not be omitted altogether considering the national loss in sugar per acre and concentrate only upon the ratoons of the main variety for the first month's crush. The ratoons do ripen early as compared with the plant canes, but are not quite fit for the first month's crush and an early variety would be more suitable. That apart, we may consider the question from three points of view, viz., (1) from the miller's or factory point of view, (2) from the cane grower's point of view, and (3) from the national point of view, that is, sugar per acre. Taking the miller's view point, the instance of a certain factory in U. P. may be taken. In 1939-40 nearly 90 per cent. of its area was under Co.210 and Co.213 (late and mid-reason in ripening) and it got a recovery of 8.97 per cent. By 1942-43 after the Red Rot epidemic there was a change over of varieties and nearly 100 per cent. of its area was under Co.299 and Co.313 (both relatively high sucrose and early canes) and the recovery was 10.63 per cent. The above figures are for the whole season, but for the sake of comparison these figures may be applied to the first month of the crushing period. The above figures show that the factory is able to get 25 per cent. more sugar from early varieties. Taking the yield of early variety (say Co.313) to be 350 maunds per acre and that of the main variety (say Co. 213) as 450 maunds per acre, the net loss to the cane grower comes to Rs. 50/- per acre. He has, therefore, to be compensated for this loss by the payment of higher

prices for the early variety. Suppose this is fixed at 20 per cent. more than the price of the main cane, even then, as will be clear from the following calculations, the factory gains and the cultivator still loses after receiving an extra 20 per cent. The calculations are based on the pre-war figures, but that should not make any difference while deciding about the policy. For the sake of convenience the profit and loss have been calculated as for 100 maunds of cane in the case of the factory and on acre basis for the cane grower.

		Rs.	A.	P.
(1)	*Miller or factory*			
(a)	With main variety (Co.213)			
	Cost of 100 maunds of cane at 8 as. per md.	50	0	0
	Amount recovered from 8.5 mds. of sugar at Rs. 10/8/- per md.	89	4	0
	Gross profit	39	4	0
(b)	With early variety (Co.313) at ordinary price.			
	Cost of 100 maunds of cane at 8 as. per md.	50	0	0
	Amount recovered from 10.6 mds. of sugar at Rs. 10/8/- per md.	111	4	0
	Gross profit	61	4	0
(c)	With early variety (Co.313) at 20 per cent. premium in price over the main variety			
	Cost of 100 mds. of cane at 20 per cent. premium over 8 as.	60	0	0
	Amount recovered from 10.6 mds. at Rs. 10/8/- per md.	111	4	0
	Gross profit	50	4	0
(2)	*CaneGrower.*			
(a)	With main variety (Co.213)			
	Price of 450 mds. of cane per acre at 8 as. per md.	225	0	0
b)	With early variety (Co.313) at ordinary price			
	Price of 350 mds. at 8 as. per md.	175	0	0
	Net loss per acre	50	0	0
(c)	With early variety (Co.313) at a premium o 20 per cent. over 8 as. per maund			
	Price of 350 mds. of cane at a premium of 20 per cent. over 8 as. per md.	210	0	0
	Net loss per acre.	15	0	0

(3)	*National View pont (sugar per acre)*	
(a)	Main variety	
	Cane yield per acre	450 mds.
	Sugar per acre at 8.5 per cent. recovery	38.25 mds.
(b)	Early variety	
	Cane yield per acre	350 mds.
	Sugar per acre at 10.6 per cent. recovery	37.1 mds.
(c)	Loss of sugar per acre by growing early variety	1.15 mds.

It will be seen from the above that even with a premium of 20 per cent. for the early variety over the price of the main cane, the cane grower loses

Rs. 15/- per acre and that the loss to the community in sugar per acre is about one maund of sugar per acre. But the compensating feature to the industry is that the plant cane or even the ratoons would not give satisfactory recovery in the first month of the crushing period as they are not ripe at that time, but the early variety is quite suitable for crushing. The place of the early variety, however, consistent with national welfare and the good of the cane grower is only to occupy not more than 30 per cent. of the area in the factory unit and to be crushed in the first month of the crushing season. The gain to the cultivator is that he gets his lands cleared early and receives cash early in the season.

Conclusion

The Indian farmer is no fool, in fact, in the knowledge and practice of the art of agriculture he is second to no other farmer anywhere else. Along with his Chinese compeer he is also a farmer of forty centuries. If he is conservative he is rightly so, for have not his methods evolved through the course of so many centuries served him well, but when once he is convinced of the utility of an innovation he is not slow in taking it up. In sugarcane he had evolved through the course of centuries varieties which were a perfect fit in each local tract, indeed each district was found to have its characteristic cane variety. Attempts were made to foist on him in the nineteenth century, the foreign canes and foreign methods of cane culture. These failed as his own varieties and methods were good and the foreign ones unsuitable. Attempts were again made in the early years of the Agricultural Departments to recommend the foreign varieties and so called improved methods and these were adopted so along as any particular officer remained in office and were given up as soon as he retired or was transferred. Some years ago there was an attempt to try Co.419 for sub-tropical North Indian tract and to try Co.213 for the tropical South Indian parts, on the plea that for the former the irrigational and other facilities were available in the tracts in view and in the case of the latter as a means of reducing cost of cultivation, owing to its requiring less or 'no' water. There is perhaps a scope for the thick class of canes in such sub-tropical area as North Western Frontier Province and Assam and as chewing canes in other sub-tropical tracts, and similarly for thin or medium canes in certain tropical areas where there are no irrigation facilities, but it is doing the cultivator a harm to recommend the growing of tropical types in North and the sub-tropical types in South as a general policy. The lesson of the nineteenth century should be learnt once for all. Now that we have provinc al stations devoted exclusively to sugarcane, the varieties should be tested both in the field and the mill before adopting for general cultivation. We do not want square pegs on round holes.

Ratooning is another instance of the misguided enthusiasm. Certain departments had made it their policy to discourage ratoons. But the wise cultivator again and again returned to the ratoon. The recent experiments at Kalai in U.P., and Mushari in Bihar, have shown that the ratoons play no greater part than plant cane in the spread of insect pests and that the cost of cultivation of a ratoon is much less than that of a plant crop. Ratooning is, therefore, a great factor in reducing the cost of cultivation and is essential for the success of the industry, but the ratoon should not be grown merely as a 'free' crop and should receive proper cultural, manurial and other care. A note of warning is, however, necessary and that is that ratooning should be suspended in the event of outbreak of diseases, say red rot or smut. There is a definite place for one ratoon in planned cane growing and it should

be crushed in the early part of the crushing season and should on no account be allowed to linger till the begining of February or thereafter.

Owing to limitation of space in a presidential address and that of time for delivering it, it has not been possible to touch upon the problems of gur and gur industry in India. It may, however, be briefly stated here that in spite of the growth of the white sugar industry, the gur will for all times to come continue as an important village industry in India. Considerable work is still necessary regarding the quality, manufacture and storage of gur. The preparation of a monograph on the 'Gur Industry in India' was sanctioned by the Imperial Council of Agricultural Research in 1942 and its publication is eagerly awaited. As regards cane varieties for gur, it may be stated that though all varieties suitable for gur may be acceptable to the white sugar factory, the reverse is not true. And lastly a word regarding cane development for gur areas. There is no objection to making the factory areas as the first stage in cane development with a view to stabilising the industry, but the cane development must be extended to gur areas also, particularly the providing of nurseries of suitable varieties, manurial facilities and proper field hygiene in guarding against pests and diseases. Co-operative facilities should be provided for the purchase of crushers and construction of suitable furnaces.

Barring United Provinces, the cane development work is still in infancy or not yet even begun, in other provinces. Even in U.P. there is still a big gap to be filled between the yields of cane per acre as obtained by an average cane grower and those realised at Research Station farms and the Factory farms and by progressive cultivators. Not till this is done will the sugar industry in India be able to stand on its legs and to produce sugar at competitive prices, for the bulk of the cost of production falls on the price of raw material. The first Tariff Board in their able report of 1931 rightly laid stress on the importance of the agricultural aspect. The second Tariff Board in their report of 1938 stressed on the need for proper translation of the results of research to the ryot's fields. They also laid stress on the utilisation of the by-products of the industry and recommended the manufacture of power alcohol for admixture with petrol as the only possible means of absorbing surplus molasses. Sir Purshotamdas Thakurdas, K.B.E., in his foreword to Mr. M. P. Gandhi's 1945 publication "Problems of Sugar Industry in India" mentions two main things for the success of the sugar industry, viz., utilization of molasses, and obtaining of greater yield of cane per acre. The cane development work is yet in its early stages and utilisation of molasses is also being done only on a small scale. The beet industry of Europe took 30 to 40 years to get stabilised. Sir Byrce Burt (1935) in an able paper refuted the ill-informed criticism that the Indi n experiment in protection was hasty or ill-conceived and unequivocally stated that the "development and maintenance of her sugar industry is every whit as important to Indian agriculture as is the encouragement of sugar-beet cultivation in Europe". The best augury for the future of sugarcane and sugar in India is that the Hon'ble Dr. Rajendra Prasad and the Hon'ble Dr. John Matthai who have such intimate knowledge of the needs of the nascent industry and of the importance of sugarcane in the agricultural economy of the nation are at the helm of affairs. The work on planned cane cultivation has only just begun and the Coimbatore canes have begun to contribute to the success of the industry in North India (and now also in Bombay and Madras). The present is, therefore, not an Epilogue but a Prologue for the great Chapter on Sugarcane Research which it is hoped will be written in the wake of the stabilization of the nascent sugar industry in the next decade.

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that emerged. Table I gives the sex ratio of adults which emerged from parasite grubs in different intensities of superparasitism on the larva of *Corcyra cephalonica* and also the average duration of the developmental period under the different conditions.

TABLE I

No. of parasite grubs per host	Adults bred		Mean No. of days taken for emergence from egg to adult
	Percentage Males	Percentage Females	
1	33·4	66·6	8·6
2	16·7	83·3	8·3
3	22·2	77·7	9·0
4	25·0	75·0	9·0
5	26·7	73·3	8·3
6	26·7	73·3	9·0
7	57·2	42·8	8·5
8	62·5	37·5	8·5
9	44·5	55·5	11·0
11	63·7	36·3	9·5
18	61·2	38·8	11·0
19	73·7	26·3	11·2
29	82·8	17·2	10·5

It can be seen from the above table that as the number of parasite grubs which share a single host increases, the number of males also increases, or in other words, when the food supply is sufficient more females are produced and this number decreases as the food supply becomes less and less. The intensity of superparasitism depends on the density of female parasites in the ovipositon cage. It may be also seen from the table that as the number of parasite grubs that shared a single host increased the developmental period was prolonged or the emergence of the adult parasites was delayed.

These findings are of considerable interest and also of practical importance in the propagation of insect parasites. Further work is in progress to find out the influence of different species of alternate hosts on the parasite, *B. gelechiœ*. Full details on these studies will be published elsewhere.

Division of Entomology, I.A.R.I., New Delhi, *June* 29, 1948.

E. S. NARAYANAN.
T. V. VENKATRAMAN.
G. C. SEN GUPTA.

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PELLICULARIA FILAMENTOSA (PAT.) ROGERS, COMB. NOV. CAUSING A ROOT-ROT OF BERSEEM (*TRIFOLIUM ALEXANDRINUM* LINN.) IN THE UNITED PROVINCES

IN April 1948 the fungus *Pellicularia filamentosa* (Pat.) Rogers, formerly known as *Rhizoctonia solani* and *Corticium solani* was found causing a severe root-rot of berseem (*Trifolium alexandrinum*) in the United Provinces at the Government Agricultural Farm, Nawabganj (Bareilly). This is the first record of this fungus on berseem from the United Provinces.

In the first week of April 1948 the berseem crop suddenly began to die. The havoc was hastened by the easterly winds that blew during this period. Watering had only an adverse effect. The seed obtained from the fields where infection was severe remained shrivelled up due to the premature drying of the crop. In a number of plants the seeds did not form at all. In some fields the infection was only slight or took place when the seed was mature. The seed obtained from such fields was apparently healthy. The same disease was observed in berseem fields of cultivators situated at some distance from the farm. Usually plants 5″ to 12″ were affected by this disease. In the early stage of the disease the parts attacked are the roots and the crown, where a slight discolouration is produced which gradually deepens to black. By this time the leaves and branches of the plant begin to wither. In a later stage, the bark of the crown dries up. The tap root rots and the development of secondary roots is restricted. In advanced stages very small scattered dot-like structures are formed on and near the crown. These can be seen even by the naked eye. They are the sclerotia. It is through them that the disease is carried from year to year. They are known to remain viable in the soil from four to five years. Hence crop rotation is the only suitable means of controlling this soil borne disease.

I am very much grateful to Dr. U. B. Singh, M.SC., D.PHIL., ASSOC. I.A.R.I., Plant Pathologist to the Government, U. P., for his helpful suggestions and kind interest in going through the manuscript.

Section of the Entomologist, to Government, U.P., Kanpur, *July* 1, 1948.

D. N. GARG.

UNIFORM GLAZED PANS FOR RAISING SUGARCANE SEEDLINGS

AT the Coimbatore Station, countrymade earthenware pots have been used all these years for germinating sugarcane seeds and raising seedlings. Dr. J. N. Mukherjee, Director, Indian Agricultural Research Institute, during his inspection visit of the Station in January 1946 remarked on the patchy character of the variations in the germination and vigour of seedlings and their markedly non-uniform stand in the same pot in which fluff from the same cross was used. The pots have the shape of a truncated conical pyramid with the narrower side resting on the floor. They are not of very uniform size and their bottom surface is uneven. Besides, the bamboo platform on which they rest also sags somewhat and the surface is uneven. All these features combined, in his opinion, to affect the seed-

lings differently in different parts of the pot and it was decided to try for comparison glazed pots of standard cylindrical shape made in the pottery furnaces. In the countrymade pots sometimes water accumulates in certain places and the finer particles sometimes gather in the lower portions as a result of watering. Many seedlings die off or become pale and look sick. The countrymade pots are, however, much cheaper, but this is partly offset by the greater durability of the glazed pots. The glazed pots have shown so striking a difference in the health and vigour of the seedlings that it is considered desirable to bring the difference to the notice of others.

Two different crosses were tried. The pans, as has been the usual practice in this Station, were filled with equal quantities of horsedung and sand in equal proportions and two grams of fluff was sown in each pan and care was taken to see that each pan received the same quantity of water. The pans were kept on level surface and germination counts recorded at intervals of five days till the 25th day. After the 60th day when the seedlings had established themselves, certain of the seedlings were noticed to have died possibly due to competition. The mortality rate was recorded on the 30th day.

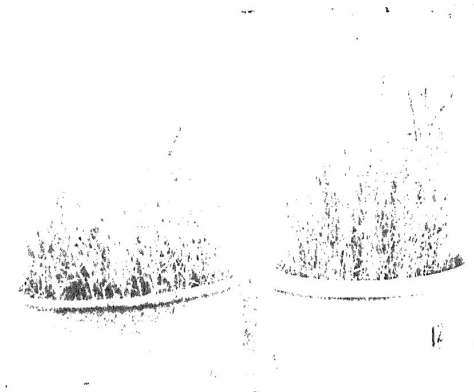

Plate I

Earthenware pan Glazed pan

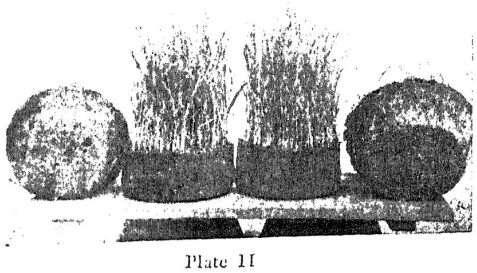

Plate II

Earthenware pan Glazed pans Earthenware pan

The germination percentage was found to be slightly higher in the glazed pans but is not significant. As regards mortality of the seedlings, the difference appears to be significant (5% level) in the batch of seedlings of the cross Co. 453 × Co. 557 and also if both the crosses are taken together. The main difference, as will be seen from the accompanying photograph (Plate I) was in the health, vigour and uniform growth and distribution of the seedlings. The seedlings in glazed pots are vigorous and uniform in growth and distribution and the seedlings at the periphery did not differ in growth from the rest of the pot while the seedlings in the usual pot were not uniform in stand and many of them showed yellowish leaves and the seedlings at the periphery were definitely poor in growth.

A peculiarity that will be noticed in the countrymade pots is that the roots come out of the soil on to the inner surface of the pot but not so in the glazed pots ; evidently owing to the better aeration through the walls of the countrymade pots. The difference in the behaviour may partly be ascribed to greater loss of water through evaporation through the sides of the locally made pots and irregularity in shape. Also, the seedlings near the periphery of the locally made pots have a much lower thickness of the nutrient material available to them.

Sugarcane Breed. Station, N. L. DUTT.
Coimbatore, J. THULJARAM RAO.
August 17, 1948. T. A. DAVIS.

A CHROMOSOME DEFICIENT PADDY TYPE

A STRAIN of the cultivated paddy Muthusamba, which was segregating for barren sterile plants on a simple mendelian ratio, was reported previously[1] in this journal. The segregating form has been grown every year and probable reason for its genetic behaviour studied.

Cytological study of the root tips has given a clue to its causation. The stunted sterile segregants were found to have 22 chromosomes only, as opposed to 24, normal for paddy. This deficiency of two chromosomes is inferred to cause the changed growth as well as complete sterility. It can be seen that the absence of panicle formation can be caused only by a deep-seated cause like this, while lack of grain setting may be due to genetical or pathological causes. The chromosome counts were made carefully with different collections of root tips, done in plants grown in two seasons. Counts were made only in the clearest metaphase plates, and have been checked by independent observers. However, the pollen grains of heterozygous plants do not show dimorphism corresponding to the full and reduced chromosome complements. Confirmation of this explanation is being sought in the meotic stages in the meterozygote.

The inference is that originally, by nondisjunction in meiosis, a gamete with 11 chromosomes (a loss of one from the normal genom of 12.) was formed, and this on fertilisation gave rise to a normal looking plant with 23 chromosomes. This plant gave rise to 24 chromosomed; heterozygous 23 chromosomed; and

colour, with an apical thickening upto 14 μ and single germ pore at the apex, stalks persitent, up to 41×11 μ, hyaline or subhyaline; paraphyses hyaline or subhyaline, clavate, mixed with teliospores.

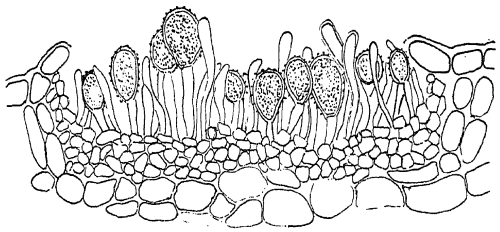

FIG. 1. Section through uredium × 335

On living leaves of *Acorus calamus* L. Ootacamund, 24th March 1948, T. S. Ramakrishnan and G. Rangaswami (type).

Soris uredosporiferis amphigenis, ovalis, isolatis, interdum aggregatis, 1 mm. longis, erumpentis, subepidermis, brunneis; uredosporis pedicellatis, subglobosis, ellipticis vel obovatis, 24×22 μ (22–33×19·5–25·0) echinulatis vel verrucosis, flavo-brunneis vel rubrei-brunneis; paraphysibus numerosis, clavatis, sub-hyalinis vel hyalinis.

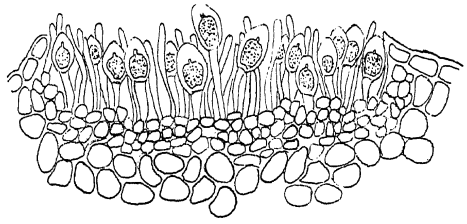

FIG. 2. Section through telium × 160

Soris teleutosporiferis conformibus, uredиis immixtis, amphigenis; teleutosporis pedicellatis, unicellatis, ovatis vel ellipticis 30×21 μ (27–36×16–25), flavo-brunneis, apice incrassatis, usque 14 μ, poris germinationis 1, pedicelli persistenti, hyalini vel subhyalini, usque 41×11 μ, paraphysibus clavatis, subhyalinis vel hyalinis.

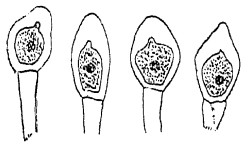

FIG. 3. Teliospores. × 335

In vivis foliis *Acori calami* L. Ootacamund, 24th March 1948, T. S. Ramakrishnan et G. Rangaswami.

Raciborski (Saccardo, 1902) has described *Uredo acori* on *Acorus terrestris* Spreng. from Java. Sydow, H. and P., and Butler (1906) have noticed the same rust on *Acorus calamus* from Gauhati, Assam; and Uppal *et al* (1934) have recorded it on the same host from Poona, Bombay. The rust under study has the uredial stage closely resembling that of *Uredo acori* Rac. already recorded, in spore shape and size though in the description of the fungus by Saccardo no mention is made of the presence of paraphyses. An authentic specimen was kindly supplied by Dr. M. K. Patel from Poona and paraphyses were noticed in this. The uredial stage of the rust under study is found to be identical with *U. acori*. The perfect stage of the fungus has now been observed. The telia and uredia are mixed together and occur on the same leaf. Therefore they are considered to belong to the same rust. The telial phase of the fungus shows it to be *Uromyces* and the rust is named as *Uromyces acori*.

Department of Mycology,
Agricultural College and Research Institute, Coimbatore,
T. S. RAMAKRISHNAN.
G. RANGASWAMI.
June, 23, 1948.

1. Saccardo, P. A., *Syll. Fung.*, 1902, **16**, 357. 2. Sydow, H. and P., and Butler, E. J., *Ann. Myc.*, 1906, **4**, 443. 3. Uppal, B. N., Patel, M. K., and Kamat, M. N., *Fungi of Bombay, Dept. Agri. Bombay, Bull.*, **176**, 1934, 16.

PISTILLODY IN SACCHARUM

FROM among the graminaceous plants occurrence of pistillody has been recorded by Anthony[1] and Leighty and Sando[2] in wheat. Isolated instances of pistillody were noticed at this Station by Dutt and Krishnaswami[3] in a few spikelets of the varieties Taboe Woelong and Shamsara as also in a seedling of Glagah × Co. 331, but in the instance recorded below pistillody seems to be a feature or a characteristic of this particular seedling and occurs in all the inflorescences and in all spikelets. The pistil parent of this seedling is *S. spontaneum*, L. (Uganda) which in itself is peculiar among *spontaneums* in that according to Dutt and Krishnaswami[3] it is protogynous.

During the flowering season of 1945-46, an instance of abnormality involving partial or complete transformation of the stamens into processes bearing stigmatic hairs was noticed in a hybrid seedling G. 5023. The malformation was noticed in all the arrows and in each and every spikelet and in all cases all the three stamens were affected, though variation was met with in the degree of transformation of the stamens.

In the upper portion of the arrow, there was complete transformation of the stamens into carpels. The extreme case was wherein all the three stamens were transformed into carpels. In structure these had a membranous ovary-like sac at the bottom with one or two stylar branches having feathery stigmatic hairs (Fig. 3). These bore no resemblance to stamens and could be judged to be transformed stamens only from their positions. In other cases, half of the anther was transformed into carpel while the other half retained its shape, though the contents in the sac were only a pulpy mass. In the transformed portion there

were one or two stylar branches with stigmatic hairs (Fig. 4). In this case a membranous structure slightly swollen and resembling an ovary was noticed in the bottom portion.

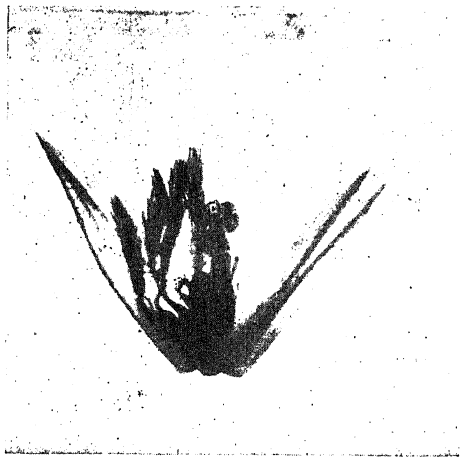

FIG. 1. Shows a spikelet with the glumes opened out and the essential organs *in situ*.

In the lower portion of the arrow, the anthers were normal in size but invariably had feathery stigmatic branches on top (Fig. 5). In others though the dehiscence was normal, the little pollen which was available was unhealthy and did not germinate *in vitro* or *in vivo*. In the middle portion of the arrow all the different degrees of transformation were met with in the same spikelet. This is illustrated in Fig. 2, while Fig. 1 shows the essential organs of the spikelet with the glumes opened out.

FIG. 2. Shows the different degrees of transformation of the anthers in the same spikelet.

When the arrow was selfed, there was no seed setting indicating that the little pollen available was not capable of fertilising the ovule. Normal seed setting was observed when foreign pollen was used, but it was always the normal carpel which produced the seed.

The above pistillody in G. 5023 was noticed during all the three flowering seasons from 1945-47. This would appear to be due to inherent genic factors and not to influence of environmental conditions.

Another interesting feature noticed in G. 5023 was that like its pistil parent, *S. spontaneum*, L. (Uganda), it is also protogynous. Even the few anthers that dehisce open only two days after the coming out of the stigmas. This coupled with the phenomenon of pistillody enables the variety being used as an ovule parent.

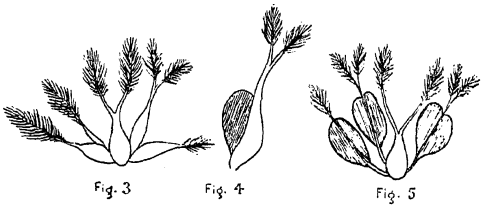

FIG. 3. Shows all the three stamens transformed into carpels. FIG. 4. Shows half the anther transformed. FIG. 5. Shows three normal anthers but with stigmatic branches on top.

A seedling of *S. spontaneum*, L. (Uganda) and *Sorghum rigidifolium* also showed such abnormalities though not to such an extent. Herein the anthers have been partially transformed, there being one or two stylar branches on top of the generally shrivelled anthers which are a pulpy mass containing no pollen grains.

Sugarcane Breed. Station, N. L. DUTT.
Coimbatore, J. THULJARAM RAO.
June 29, 1948.

1. Anthony, S., *Jour. Heredity*, 1918, 19. 2. Dutt, N. L., and Krishnaswami, M. K., *Proc. Assoc. Econ. Biol.*, 1939. 3. —, —, *Curr. Sci.*, 1943, **12**, 1. 24 4. Leighty, C. E., and Sando. W., *Jour. Heredity*, 1924, 16

CHROMOSOME NUMBER AND EFFECT OF COLCHICINE ON CHROMOSOMES OF *COLCHICUM LUTEUM*, BAKER

Colchicum luteum, Baker is a Lileaceous plant growing in Afghanistan, Turkistan and Western Himalayas—extending from Murree Hills to Chamba and Kashmir at an altitude of 4,000 feet to 7,000 feet on grasslands. It is an Indian substitute for the European *Colchicum autumnale* as the source of drug Colchicine.

The material was collected from Murree Hills. The corms were grown in December 1946 in pots containing sand which was irrigated regularly with Knops solution. The pots were kept in green-house. Corms produced roots abundantly in about two weeks time.

The root tips fixed were in Craf's fixative. Observations were made from paraffin sections 10 to 12 μ thick which were stained with Crystal Violet-Iodine.

conspicuous by the total absence of the pelvic.

Department of Biology,
Bhavan's College, D. VAIDYANATHAN.
Andheri. Bombay, *July* 22, 1949.

THE OCCURRENCE OF STARCH AND ITS IMPORTANCE AS A SPECIFIC CHARACTER IN *SACCHARUM*

DURING the course of the study on sett and shoot-root formation last season, it was noticed that sett-roots were formed late in the Burma form of *S. spontaneum* while in the variety Katha belonging to *S. Barberi* the sett-root formation was both early and profuse. It had been shown by Carlson[2] that shoots of roses grew much more rapidly and developed a more vigorous root system if the nodes of the cuttings from which they grew showed starch accumulation. Sections were therefore cut both in the case of Katha and Burma *spontaneum*; there was more starch accumulation in the stem of Katha than in Burma *spontaneum*.

Went (quoted by Onslow[4]) observed that much starch is present at first but it gradually disappears forming hexose. After growth ceases, the hexose is diminished and sucrose accumulates. Alfaro[1] and later Haddon[3] noticed that in cane grown in acid soils there was accumulation of starch while that grown on alkali soils showed no starch. This aspect of the question was later studied by Weller[5] who came to the conclusion that two distinct types of starch accumulations occur in the cane plant. The first type occurs only above the nodes in the first two or three layers of parenchyma cells surrounding the vascular bundles. He observed this in H. 109 grown in both acid and alkaline soils. The second type occurs in all of the parenchyma cells and he observed it only in Natal Uba. He further pointed out that these accumulations of starch were suggestive of causes of varietal variation in the rooting habit of cane.

It occurred to the present authors that why Went did not notice starch in the fully grown internodes was may be because he was dealing with only *S. officinarum* varieties and why Weller noticed starch in Uba was that this might be characteristic of *S. sinense*. A few varieties belonging to the species of *S. officinarum*, *S. spontaneum*, *S. Barberi* and *S. sinense* were examined and it was found that there was practically no starch in *S. officinarum* varieties. On the other hand there were relatively large quantities of starch in *S. Barberi* but only traces to small quantities in *S. spontaneum* while *S. sinense* came in between *S. Barberi* and *S. spontaneum* with regard to the accumulation of starch. The presence or otherwise of starch as seen in transverse sections of the four species of *Saccharum* is shown in the micro-photographs in Plate I. These sections were taken from the bottom-most internode.

PLATE I

Accumulations of Starch in the stem of *Saccharum* species

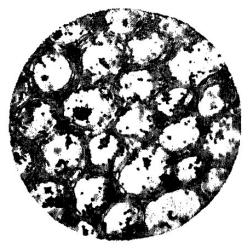

FIG. 1
Katha (*S. Barberi*)

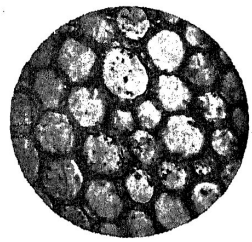

FIG. 2
Uba (*S. sinense*)

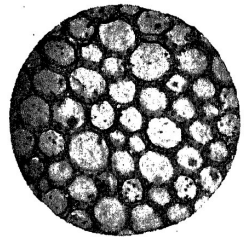

FIG. 3
Coimbatore (*S. spontaneum*)

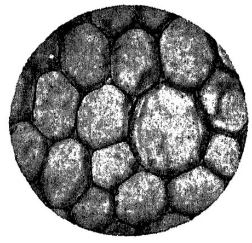

FIG. 4
Vellai (*S. officinarum*)

×150

The above observations were then extended to the other varieties in the Collection. Seventy-eight varieties of *S. officinarum* have been studied and in all of them there has been no accumulation of starch except in ten varieties in which traces or very small quantities of starch have been

observed in the top portion of the stem. Eightyfive varieties belonging to *S. Barberi* have been studied and in almost all of them a relatively large accumulation of starch has been noticed both at the base of the stem and at the top portion. Examination of 25 varieties belonging to *S. sinense* showed that in most of them the quantity is not so much as in *S. Barberi* but a fair quantity is present in all excepting 3 or 4 in which only traces have been met with. Twenty-six varieties belonging to *S. spontaneum* were studied and only small quantities of starch were noticed, though in 8 or 9 types a fair accumulation but lesser than in *S. sinense* and much less than in *S. Barberi* was noticed. Preliminary observations were also made on other genera and it was noticed that there was no starch accumulation in *Sclerostachya* and *Narenga,* while starch has been noticed in Guinea grass (*Panicum maxicum*), Napier grass (*Pennisetum purpureum*) and *Sorghum.* Eight types of *Erianthus* have been studied and fair to large quantities of starch accumulation were noticed.

The observations have been restricted to the fully formed portions of the stem. Sections were taken at two points (1) at the bottommost joint above the ground and (2) the joint at the top next above the dead leaf joint, *i.e.,* the oldest functioning green leaf. These observations were made on almost fully matured crop of about 11 months growth.

These studies are being continued. The indication at present is that the presence of starch in the fully formed internodes is a definite specific character for certain species of *Saccharum.* It is hoped to extend the studies to the numerous inter-specific and inter-generic hybrids at the Station to ascertain how this character is modified in these.

Sugarcane Breed. Station,
Coimbatore, N. L. DUTT.
July 26, 1949. R. NARASIMHAN.

1. Alfaro, *Ann. Conf. Cuban Sugar Tech.,* 1928. 2. Carlson, M. C., *Bot. Gaz.,* 1929, **87,** 64. 3. Haddon, E., *South African Sugar Journal* **10,** 629. 4. Onslow, M. W., "The Principles of Plant Biochemistry," 1931, 25. 5. Weller, D. M., *Hawaiian Planters Record,* 1929, **3,** 294.

CHROMOSOME NUMBERS IN SOME ANGIOSPERMOUS PLANTS

ACCORDING to the information of the authors, the chromosome numbers reported here are new.

*The morphological features of *Justicia adhatoda* Linn. is so different from other species that it was kept under a separate genus as *Adhatoda vasica* Nees. Its haploid chromosome number 17 as compared to 14 of other species confirms this separation.

MELIACEÆ		
Melia azadirachta Linn.	$2n=28$	Pathak & Singh
POLYGONACEÆ		
Rumex dentatus Linn.	$n=20$	,,
APOCYANACEÆ		
Allamanda grandiflora Hook.	$n=9$	Pathak & Tiwari
Tabernæmontana coronaria Willd.	$n=11$	,,
Thevetia nerifolia Juss.	$n=9$	,,
SIMURACEÆ		
Ailanthus excelsa Roxb.	$n=31$	Pathak & Srivastava
Balanites ægyptiaca Delice	$n=9$	,,
STERCULIACEÆ		
Pterospermum acerifolium Willd	$n=19$	,,
Sterculia colorata Roxb.	$n=20$	,,
ACANTHACEÆ		
**Justicia adhatoda* Linn.	$n=17$	Pathak & Pande
Eranthemum variegata Linn.	$n=21$	,,
Daedalacanthus nervosus T. Anders	$n=21$	,,
BIGNONIACEÆ		
Tabebuia pentaphylla Gomez	$n=20$	,,
Jacaranda mimosifolia D. Don.	$n=33$	,,
RUTACEÆ		
Murraya exotica Linn.	$n=9$	,,
EBENACEÆ		
Diospyros embryopteris Pers.	$n=15$	,,

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Kanpur, A. N. SRIVASTAVA.
January 3, 1949. K. K. PANDE.

CULTURAL WORDS OF CHINESE ORIGIN: MONSOON

THE following information has been summarized from Yule[1] and Burnell, almost in their own words: "Monsoon is the name given to the periodical winds of the Indian seas—The original word is the Arabic Mausim, season, which the Portuguese corrupted

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THE BREEDING OF SUGARCANE

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1. INTRODUCTION

THE main scientific problems which fall within the purview of the Sugarcane Breeding Institute, Coimbatore, are those connected with the breeding of improved varieties and thus relate chiefly to the raw material of the Sugar Industry, *viz.*, the sugarcane supplied to the factories. The sugar industry in India stands on a somewhat different footing as compared to other industries, as the bulk of the cost of the finished product, *viz.*, sugar, is represented by the price paid for the raw material which is nearly $\frac{2}{3}$ of the cost of production of cane sugar. As such, the protection which was granted to the sugar industry was one of protecting a particular branch of agriculture until such time as improvements in methods of cultivation and developments in research enable the agriculturist to increase his yield per acre while maintaining or increasing his profits.

The crux of the problem is, therefore, raw material, not merely because of the high proportion of its cost in the total cost of cane sugar, but principally because the quality and the output or yield per acre of the raw material were very poor, indeed, the poorest in the world. The yield of cane in the sub-tropical North India (which represents 80% of the total acreage under cane in India) was only 10 tons per acre against 70 tons in Hawaii, 60 tons in Java and 30 tons in Cuba. This yield has, with the spread of improved varieties of cane bred at Coimbatore, risen by 50%, but there is still a long road to travel if we are to compete on equal terms with other sugar producing countries and place our sugar industry on a sound basis. It is true that in Cane Competitions yields of over 60 tons per acre have been recorded in Uttar Pradesh and elsewhere in North India and over 100 tons per acre in the Deccan Canal Area of the Bombay State, but what is to be aimed at is high or at least fairly satisfactory average yield of cane over the main cane-growing areas. The potentiality of high yields of Co. canes in cultivation has thus been demonstrated by the high yields in Cane Competitions and the aim of satisfactory yield by the average cane-grower can be achieved by proper cane development. Cane Development Departments have now been set up in the chief sugarcane growing States and the Indian Central Sugarcane Committee has also sanctioned long term Cane Development Schemes, and progress in this behalf may now be hoped for.

In the present note only the technical or scientific problems are briefly touched upon. These problems are varied and of a complicated nature.

II. CANE-BREEDING PROBLEMS

The very first problem which the Institute had to tackle was whether the varieties that had to be crossed would flower under Coimbatore conditions and set seed satisfactorily. So far as the technique of crossing and raising of seedlings is concerned a satisfactory technique was evolved and is in vogue for the last four decades with slight modifications depending upon the combinations that have to be effected each year but the problem of flowering still remains. Quite a few varieties have not yet become available for hybridisation because they have not flowered so far while others are unavailable for effecting certain desirable combinations as the disparity in the time of flowering is such that they cannot be mated. A scheme on Sugarcane Physiology has now been in existence for the past few years devoted mainly to the study of the physiology of flowering in sugarcane and some details of the progress made in this direction are given in a later paragraph.

The second problem was whether the canes bred at Coimbatore will suit the rather rigorous climatic conditions of the sub-tropical North Indian regions where the bulk of the area is situated. To ensure the success of Co. canes in North India, Dr. Barber and Dr. Venkatraman took the unusual step of utilising the wild *S. spontaneum* in breeding and this paid rich dividends as the very first seedling of a direct cross between *S. officinarum* and *S. spontaneum*, *viz.*, Co. 205, was an immediate success in the Punjab. Only the Coimbatore form of *Saccharum spontaneum* and later Glagah, the Java form have been used at Coimbatore. A few seedlings have been raised from Burma spontaneum also. But there is such a wealth of *S. spontaneum* forms in India that this Institute has now organised an exploration for collecting the wild forms of *Saccharum* and allied genera from all parts of the Indian Union in its Spontaneum Expedition Scheme. An account of this important work is given in a subsequent section.

Another problem of some importance which presented itself was that no very satisfactory method was available for assessing the male viability. Attempts at germination of sugarcane pollen *in vitro* had failed and the storage of pollen in a viable condition was attended with its own difficulties. Ultimately a method for successfully culturing sugarcane pollen was evolved, but the storage of pollen is conditioned by the fact that howsoever well stored, like certain other graminaceous pollen, it does not retain its fertilizing capacity beyond 48 hours. On the pistil parent side, tests on the stigma receptivity were made and the time taken in fertilization determined.

The problem of evolving canes suitable for local areas in the various States is a perennial problem because for one reason or another varieties go out of cultivation; moreover better varieties are bred and come to replace the older ones from time to time. The breeding of better and yet better varieties is thus a continuous process. In the Punjab tract in North India Co. 205 gave place to Co. 285. The cane which proved to be almost an universal cane for the sub-tropical belt was Co. 213 and was in cultivation from East Punjab to West Bengal, and formed the backbone of the sugar industry for a number of years. It, however, fell a prey to red rot disease and had to be replaced by other varieties. Co. 312 and Co. 313 then came into the picture, but Co. 312 has also shown susceptibility to red rot and needs replacing. There has been during relatively recent years a reorientation in the type of canes for North India. It was felt that slightly thicker or medium thick canes could with advantage be cultivated in North India provided they could withstand the extremes of temperature. The advantage would be that with better cultivation and irrigation they could give much higher yields which would have been impossible with the thinner reed like older varieties. Special combinations were therefore devised and in due course canes like Co. 421 and Co. 453 which are somewhat on the thicker side as compared to Co. 213 and Co. 285 have come to occupy fairly extensive areas in North India. This process is being continued and the search for new parents from among the Co. canes themselves most of which are tri-species hybrids continues each year as more experience is gained.

The breeding of suitable varieties for the tropical States of Bombay and Madras was taken up at a relatively later stage as compared with the canes for North India and fortunately in Co. 419 an almost universal cane for the tropical conditions in Bombay, Madras, Hyderabad, Mysore and Orissa was evolved and shows very good growth and yield. Other recent canes are Co. 449 and Co. 467. Naturally the parents employed for breeding canes for peninsular India are very different from those employed for breeding canes for North India as in the canes for the South a preponderance of *S. officinarum* can with advantage be woven into the parentage. Care, however, is taken that a certain amount of hardiness is also introduced.

The interesting work on the intergeneric hybrids including the sugarcane × bamboo hybrids is now reserved more for academic studies in the Cyto-genetical Section excepting crosses with *Sorghum* for evolving early canes and those with *Sclerostachya* and *Narenga* for disease resistance.

Breeding for earliness and high sugar is an aspect which concerns the sugar factory most. High sucrose and earliness in ripening have been found

difficult to combine with satisfactory yield. However, Co. 313 among the earlier canes and Co. 527 among the relatively later series have fulfilled the requirements to some extent. Among the recent canes Co. 630, Co. 644, Co. 659 and Co. 686 combine in themselves early maturity and fairly high tonnage, but these are as yet in the experimental stage. In connexion with the selection of early ripening varieties studies on the anatomy of cane leaves have indicated correlation between cell size of leaf and maturity. The size of the stomata in both lower and upper epidermes and the bulliform cells in the upper epidermis have been noticed to be smaller in the early ripening varieties as compared to the late maturing canes.

Recently the formulation of breeding aims for production of varieties with certain specialised characters has become more necessary with the continually changing outlook both from the agricultural and factory points of view. Attention is now being paid to the production of (1) canes which do not have pith and are not hollow, (2) chewing varieties, (3) disease-resistant varieties, and (4) varieties with good manufacturing qualities. After an elaborate study of the varieties combinations have been devised which produce canes that show no tendency to pith formation or hollowness in the centre. The pithy portion does not contain juice and pithy stalks are less in weight. One other drawback with stalks having pith is that the canes tend to dry up quicker after harvest as also in the field when kept on in hot weather. There has been a demand for chewing canes both in urban and rural areas. This in some respects has been difficult of achievement for chewing qualities and the yield particularly under North Indian conditions are hard to combine. Canes like Co. 798, however, have been recently released for trial and may succeed at least in some tracts.

Attention is also being devoted to the production of varieties resistant to red rot. This aspect deserves serious attention since some of the commercial varieties are falling a prey to this disease. In the work on breeding of disease-resistant varieties with particular reference to red rot, crosses between highly susceptible varieties and those which are moderately susceptible have shown a great deal of variability in the matter of disease resistance and the data available indicate the need for caution. It is now felt that the best method of evolving red rot resistant canes would be to inoculate the seedlings and study them for red rot resistance and release only those which are found to resist the disease.

As regards the manufacturing qualities, a beginning has been made in the study of the chemical composition of the juice as it affects the quality of (1) gur as manufactured by the average cane grower and (2) white sugar

in factories. The prominent Co. canes in cultivation have been analysed for total nitrogen, protein nitrogen, ash and colloids. The various constituents of the ash, *viz.*, lime, phosphoric acid, sulphate and iron were also determined. It is proposed to continue this study to seedlings of known parents to see how far they contribute good and bad juice characters to their progenies.

III. Cyto-genetical Problems

A Cyto-genetical Section is an essential limb of any plant-breeding project. Studies on cyto-genetics of sugarcane have been conducted at Coimbatore by Drs. Janaki Ammal and N. Parthasarathy and now by Dr. Raghavan. The studies have revealed that cyto-genetically even the simplest of sugarcane material is highly polyploid with an equally high degree of genetical impurity. To this extent in sugarcane breeding there must always be a very large element of chance.

The main problem is to bring sugarcane breeding in a line with other crops which are within the operation of mendelian heredity. This can be achieved by simplification which in its turn may be expected to re-establish a fairly high degree of purity. One way of achieving this is through haploid parthenogenesis of which no sign exists so far. Another is by continued back crossing with forms which are likely to be the progenitors of sugarcane. This is also being done. But the problem is to bring about an elimination of all chromosomes other than those of officinarum basic complement. Study of the meiotic configuration in such back-crossed progeny has thrown light on the constitution of *S. officinarum*. There has also been found recently chromosome eliminations *en bloc* and this makes it possible for different chromosomal races to come into existence and it is suspected that this phenomenon also plays a very important part in sugarcane breeding. Cytoplasmic inheritance has also been noticed and it is presumed that in sugarcane breeding more importance has to be paid to the mother than to the staminate parent.

IV. Spontaneum Expedition Scheme

Shri R. R. Panje is in charge of the Spontaneum Expedition Scheme. The strenuous work of the actual exploration is now drawing to a close and the study of the botanical and agronomical characteristics of the over 200 forms as also of the exotic types imported from South-East Asia, the Middle-East and the African areas has been taken up.

On a very close study of the characters depends the utilisation of these forms in breeding work. The special value of the wild sugarcane lies in

the fact that apart from at least two sub-species, *Saccharum spontaneum* has several ecological races which are adapted to a variety of habitats, and these ecotypes are to some extent associated with a fairly wide range of chromosome numbers. Among the forms collected are giant types, thicker and broader-leaved than some of the cultivated canes; dwarf, bushy types; spreading types; rhizomic forms and types with certain unusual morphological characters. Observations on the distribution and the ecological adaptations of these forms in the original habitats against the behaviour of the trans-plants have given indications of the extent of utility of the forms in breeding. Selections of genetic stocks have been made from out of a wide range of useful characters, *viz.*, habit, growth-vigour, drought-resistance disease-resistance, tolerance to salt, sugar content, etc. Some of the selected forms are being tested for the heritability of the desirable characters. Work on vegetative and floral morphology, starch content, epidermal patterns and chromosome numbers has shown certain interesting trends within the species, though the complete picture will take yet some time to emerge.

The taxonomy of *Saccharum* and the allied genera needs a close scrutiny. The delimination of this genus from the allied genera has undergone changes and the question of the validity of certain genera is awaiting further research. A beginning towards this has been now made through studies on the morphology, anatomy, ecology and distribution, as also on the cytology and biochemistry of the forms and species within *Saccharum*. These aspects together with the botanical and agro-physiological assessment, the pre-testing of the genetic stocks and the building up of presumptive parents out of the wild material constitute by themselves a whole branch of research bearing on sugarcane breeding with a far-reaching applicable value.

V. SUGARCANE PHYSIOLOGY SCHEME

Studies on the physiology of flowering in sugarcane have been conducted at Coimbatore by Mr. N. D. Yusuf and now by the present Sugarcane Physiologist, Dr. M. V. Saradhy, and his Senior Assistant, Mr. R. Narasimhan. There is a lack of precise knowledge of the factors controlling development in the cane plant. Identical response to treatments which are unrelated or even opposite in nature and variance in the effect of the same treatment during different years have been noticed. For instance, the usually non-flowering *S. spontaneum* Burma, recorded favourable response to the 22 hours darkness treatment while later it gave favourable response to 22 hours continuous light treatment. As regards variance in results, early flowering was induced in a previous year, in POJ. 2725 in the 6 hours-day treatment, while in later experiments the same treatment delayed the flowering.

The experiments have now been graded at closer intervals. Photoperiods ranging from ¾ hour to 12 hours both in respect of extra light and darkness and in relation to (1) pre-initiation, (2) initiation, and (3) post-initiation stages of the floral primordia are in progress for the last two years. Sugarcane seems to be very sensitive or exacting in its photoperiod factor. In the pre-initiation stage any deviation of over 1 hour completely inhibits flowering. At the initiation stage the flowering is delayed while in the post-initiation stage there is not much effect. As regards the irrigation and manure factors, profuse irrigation seems to have an accelerating effect on flowering while the nitrogenous and phosphatic manures at the levels (100 lb. Nitrogen, 75 lb. P_2O_5) tried did not have much effect. These experiments are proposed to be continued with graded and increasing manurial doses.

As a pre-requisite to further studies on flowering, observations on the initiation and growth of the sugarcane inflorescence have been made. It has been found that the floral initiation takes place by about the end of August each year and is practically simultaneous in both early and late varieties. Though, as now found, the floral initiation is at about the same time, the factors which make a variety to flower early and another late in the season have yet to be determined. Observations on the growth of the inflorescence indicate that the inflorescence completes its growth in length at the short blade stage and the emergence of the arrow is the function of the elongation of the stalk. The growth of the inflorescence itself appears to be of the auto-catalytic type while the elongation of the stalk is exponential. Negative correlation seems to exist between the elongation of the inflorescence and stalk.

VI. Survey of Manufacturing Qualities

Shri K. V. Gopala Aiyar is in charge of the Chemistry Section and in addition to the rather routine work of analysing the juices of the very large number of sugarcane seedlings under test each year, has recorded valuable observations on the effect of soil conditions on the growth and quality of cane varieties as also the effect of planting in different months of the year on the maturity and growth of sugarcane. He is now conducting for the last four years a survey of the factory areas with a view to gathering information on the manufacturing qualities of the Co. canes in cultivation. This information when completed is proposed to be utilised in selecting suitable parents in the breeding programme so that parents which pass on to their progeny undesirable qualities in the juice may be dropped from the list of parents and only such as possess good qualities retained for crossing work.

There has been considerable improvement in the recovery of sugar per cent. cane obtained by the sugar factories in India in recent years. Side by side with this increase there is also a steady increase in the sucrose per cent. in the cane crushed, while the fibre has remained more or less at 15·50%. It may be said that the improvement in recovery is partly on account of the rise in the technical efficiency of factories and chiefly on account of the improvement in the quality of the Co. canes.

Juices of some varieties have on certain occasions been found to be refractory. In Bombay State difficulty was experienced by some of the factories regarding clarification of juice in POJ. 2878. It was associated with phosphate deficiency in some cases, though not always explained on that score. In Bihar, difficulty was encountered in filtration with the juice of Co. 313. The practice during the recent years has been to study as far as possible the seedlings in the test plots at Coimbatore before they are released to the State Testing Stations for the non-sugars in juice including colloids, ash, phosphoric acid, as also protein and non-protein nitrogen as these are the constituents which will affect the manufacturing qualities.

The non-sugars may well be expected to assume greater importance in the relatively inefficient open pan system of gur manufacture which is a cottage industry consuming more than 60% of the crop. Large varietal differences in gur quality have been noticed and the following juice characteristics would appear to be conducive to good quality gur; (1) a low level of colloidal matter (total colloids and also gums and pectin), (2) a low level of mineral matter, (3) a higher level of phosphates, (4) a smaller proportion of mineral matter present in the colloidal stage, (5) lower values of soluble SiO_2, Fe_2O_3, Al_2O_3 and CaO, and (6) a low level of non-protein nitrogen.

ON CERTAIN RECENT ASPECTS OF THE BREEDING PROGRAMME AT COIMBATORE

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INTRODUCTION

A fair measure of success has attended the cane breeding work at Coimbatore since the establishment of the breeding programme in 1912. A large number of hybrid canes (Co. varieties) have been released and the indigenous varieties in the sub-tropical North India and the thicker noble canes in the tropical peninsular India have been replaced by the improved varieties which now occupy over 90% of the acreage in India. Quite a few of them are in commercial cultivation in countries overseas as well. The sugar industry in India has been fairly stabilised which is the best evidence of the success of the breeding work.

The bulk of the sugarcane area in India being in the sub-tropical belt with its rigours of climatic conditions and short growth period, hardiness and satisfactory yield and early maturity were the factors which assumed importance in the earlier years of the breeding programme. The deliberate utilisation of the wild cane *S. spontaneum* (Coimbatore) resulted in the production of certain commercial types fairly resistant to drought and cold and certain diseases, the proof of which was manifested in the success of Co.205 and later Co.285, the direct progenies of the wild cane. The production of such early ripening varieties as Co.214, Co.223, Co.281, Co.299 and Co.396 is proof of the successful results achieved in this direction.

Considering the wide differences in soil and climatic conditions, the possibility of finding a single suitable variety for the whole sub-continent is remote and it is not surprising that a variety which is suited to one tract may not do so well in another. This is markedly so in sub-tropical India. The days of Co.213 which was a fairly universal cane are gone as it fell a prey to red rot and has been replaced. In tropical India, however, Co.419 has come to stay as a general purpose cane in view of its adaptability to varied soil conditions. Recently the formulation of breeding aims for production of varieties with certain specialised characters has become more necessary with the continually changing outlook both from the agricultural and factory points of view. Attention is now paid to the manufacturing qualities of the canes crushed by the factories. There have been demands for varieties which may be tolerant to saline and water logged conditions of soil, for varieties which have a solidity of core and varieties good for chewing purposes. Attention is also being devoted to the production of varieties resistant to red rot and

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smut, the two major diseases in India. This last aspect deserves attention since some of the commercial varieties are falling a prey to red rot disease in North India. The two varieties Co. 312 and Co.453 of late have shown susceptibility to red rot and need replacement.

RECENT PARENT STOCKS

In the breeding programme at Coimbatore the nobilisation of *S. spontaneum* was not carried far, but the seedlings obtained were again crossed among themselves or with other varieties, inter alia, with Glagah, nobilisations from Java like P.O.J.213, P.O.J.2725 and P.O.J.2878. This has resulted in all the Co. canes being tri-species hybrids having the characteristics of the three species *S. officinarum*, *S. spontaneum* and *S. Barberi*.

The nobilisation of *S. spontaneum* has not been carried far. So far only two forms (Coimbatore and Java) have been fully exploited in breeding at Coimbatore and pre-war Java respectively. Recently the United States Department of Agriculture have utilised in breeding the form from Turkmenistan for production of cold tolerant varieties. In view of the highly polymorphic nature of the species and its extreme adaptability and variability, there are potentialities of achieving further success with the use of *S. spontaneum* in breeding. This Institute has organised an expedition for the collection and study of the forms available in this sub-continent with a view to their ultimate utilisation in breeding. The exploration work has been completed for the major part of the Indian Union and more than 200 forms collected. These are under study for all the agronomical and biochemical characteristics. Types have been collected from places subject to salinity, water logging, high rainfall, drought etc., and these may open possibilities in the evolving of forms resistant to the various factors. Some of the collections are fairly rich in sucrose content and possess good tillering capacity (PANJA, 1951). A few of the forms selected on the basis of their desirable agronomical characters have been utilised in breeding to assess their value as parents. It is as yet too early to comment on the results obtained. A valuable addition to the *S. spontaneum* parent stocks are the forms which are protogynous. Protogyny was noticed in the Uganda form of S. spontaneum (DUTT and KRISHNASWAMI, 1943) and since then more forms which show this character have been discovered during the course of the work of the Spontaneum Expedition Scheme. There are now as many as twenty varieties of *S. spontaneum* which show this tendency. The value of these varieties lies in the fact that advantage can be taken of their protogynous nature and they can be used as pistil parents.

The main varieties used for breeding during recent years are the Co. canes of the relatively later series. In the choice of the parents, consideration is given to all the desirable characters of a variety as also to the performance of the progeny as judged from experimental crosses first done on a small scale to ascertain the nature of seedlings obtained. Only when the cross is thus considered successful is it repeated on a large scale. During recent years the parents in wide use are Co.301, Co.453, Co.464, Co.508. Co.527 and Co.617. There are also certain seedlings which are not quite fit enough for raising to the status of Co. canes and for economic distribution, but are quite useful as parent stocks.

The main consideration in the use of Co.301 is that it is not pithy and has solid core and is also of fairly erect habit. Co.464 has been utilised for its character of resistance to red rot and quite a few of the recent releases are of this parentage. Co.453 is a derivative of Co.285 which was the main parental stock during the earlier years of breeding work. Its advantages over Co.285 are its higher sucrose value, higher yield with comparatively

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less of fibre. It has been one of the most productive parents and is a good source for obtaining erect, high yielding types. Co.508 and Co.527 have been the mainstay in recent breeding work for evolving early maturing varieties. The former has been found to be exceptionally good in this respect and in addition is also a useful parent for imparting solid core to the progeny. Co.617, like Co.453, is a derivative of Co.285 and has been utilised in breeding for its characteristics of erect habit, good yield and fair resistance to drought and red rot disease. However, comparatively low sucrose content is its main drawback. Two other varieties Co.649 and Uba Marot have replaced Co.331 as parent material in the programme for evolving late ripening types.

One of the forms of the wild species *S. robustum*, viz., 28 N.G.251, obtained from U.S.A. has been tried in breeding but with very limited success. Reports from U.S.A., Australia and Hawaii indicate that "on the whole results from *S. robustum* as a breeding material have been more encouraging than those from *S. spontaneum*". The seedlings of 28 N.G.251, however, were noticed to be poor in sucrose content with a tendency to lodging habit, which is a character of the parent. A few more forms have recently been obtained through the courtesy of the United States Department of Agriculture and these are proposed to be exploited in breeding during the years to come.

Some sweet *Sorghum* varieties of Africa as also some tetraploid *Sorghums* obtained from the United States Department of Agriculture have been under use in breeding during the last few years. The progeny obtained have varied so much from year to year that it is difficult to estimate the usefulness of these as parent material. On the whole the seedlings are not quite satisfactory from the yield and sucrose points of view and it is doubtful whether any of the seedlings will be a commercial success. Three Co. canes of Sorghum parentage have been released for trial at the State Research Stations.

During the last few years, through the courtesy of the respective Experiment Stations, a number of commercial varieties have been obtained from U.S.A., Hawaii, Mauritius, South Africa and Barbados, and these are proposed to be utilised in the breeding work.

BREEDING TRENDS

1. *Breeding for earliness*

As stated above, this has been one of the main objectives in the breeding programme ever since the initiation of breeding work at Coimbatore in view of the short growth period in North India. Also such early ripening varieties were needed to start the factory crushing. The earlier evolved varieties like Co.281 and Co.313 were useful for early crush. Co.313 especially was the mainstay in the white sugar belt of Bihar and sustained the sugar industry of the State. But one defect with these early varieties was their low yield and in view of the fact that comparatively higher yielding midseason or late varieties were available and in view of the system of cane payment (by weight of cane) prevalent in this country, it was found difficult to induce the cultivators to grow the early ripening varieties. It became essential that early varieties with fairly good yield should be bred. It may not perhaps be possible to combine in early varieties, tonnage as high as the midseason types but, during recent years some advance has been made in increasing the yields of early ripeners. The later Co. releases viz., Co.630, Co.644, Co.659, Co.686 combine in themselves early maturity and fairly high tonnage, but these are as yet in the experimental stage and have not been released for large scale cultivation.

The most successful parent during recent years for breeding for early maturity is

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Co. 508 and very many of the recent Co. releases from Coimbatore are of this parentage. The most useful combinations in this respect are Co.508 × Co.453 and Co.508 × Co.617.

In connexion with the selection of early ripening varieties even in the young stage of the crop (3 months), studies on the anatomy of cane leaf have indicated correlation between cell size of leaf and maturity. The size of the stomata in both lower and upper epidermis and the bulliform cells in the upper epidermis have been noticed to be smaller in the early ripening varieties as compared to the late maturing ones. This finding, when fully confirmed, would aid in the selection of suitable varieties with different periods of ripening even in the nursery stage of the seedlings.

2. *Evolving non-pithy varieties*

Sugarcane varieties differ in the amount of pith in stalk. Some have a solid core while others are hollow in the centre. There are gradations ranging from whitish streak to hollow cavity. The presence or absence of pith is a varietal character though it may be slightly modified by environmental conditions and cultural and manurial operations. The pithy portion does not contain juice and pithy stalks are less in weight than non-pithy ones. One other drawback with stalks having pith is that the canes tend to dry up quicker after harvest as also in the field when kept on in hot weather when the amount of pith increases forming a fair size cavity thus depressing the yield to a great extent. This has been the drawback with the two varieties Co. 331 and Co. 453. These varieties are midseason late in maturity and are harvested during February, sometimes in March, when the hot weather sets in. One of the programmes in the breeding work at the Institute, of late, has been an attempt to breed canes with a solid core.

The extent of pith in Co. varieties has been estimated qualitatively (DUTT, KRISHNASWAMI and HUSSAINY, 1946) and the varieties classified into non-pithy, moderately pithy and pithy. To find out the nature of inheritance of this character from particular parents, progeny tests were conducted (DUTT and RAO, 1951) on twenty-one different combinations and one hundred seedlings studied in each cross. In the selection of the crosses, the following combinations were kept in view: (1) pithy × pithy; (2) non-pithy × pithy; (3) pithy × non-pithy and (4) non-pithy × non-pithy. While the first combination, naturally, yields only pithy seedlings, in the other cases, even the introduction of one non-pithy parent results in considerable decrease in pithiness. In the last combination, the seedlings are non-pithy. The decrease in pithiness is generally better manifested when the non-pithy parent is a pollen parent.

From the point of view of tendency to pith formation, the parental stocks at Coimbatore can be classified as below:

1. Pithy varieties: Co. 285, Co. 331, Co. 349, Co. 421, Co. 453, Co. 617, Uba Marot and P.O.J. 2878.
2. Moderately pithy varieties: Co. 213, Co. 312 and Co. 313.
3. Non-pithy varieties: Co. 244, Co. 281, Co. 301 and Co. 508.

The varieties Co. 244, Co. 301 and Co. 503 in most cases transmit their character of non-pithiness to the progeny even in cases where highly pithy types like Co. 349 and P.O.J. 2878 are used in combination. Co. 453 as a parent transmits its pithy character to the progeny even when mated with solid cored pistil parents. The same is the case with Co. 617 and Uba Marot used as pollen parents. Hence these varieties should be used with caution when evolving of non-pithy varieties is the objective.

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The best combination for production of non-pithy seedlings are (1) Co. 508 × Co. 244, and Co. 508 × Co. 301.

It has thus been possible, by a judicious combination of parents to breed varieties with solid core.

3. *Chewing canes*

There has always been considerable demand for chewing canes both in urban and rural areas. The characteristics that go to make a chewing cane are different from those of a factory or gur making cane. The rind has to be more or less a separate entity by itself and has to peel off intact. The sugar content may be in the form of glucose since all that is needed is sweetness, no matter whether it is in the form of sucrose or glucose. The fibre content has got to be low, much below the minimum needed for a factory or for gur making. In view of all the above characteristics contained in the thick noble canes *(S. officinarum)*, a number of these varieties are still being grown both in tropical and sub-tropical India mainly for chewing purposes.

With a view to evolve canes which will be good as chewing varieties, E.K. 28, B. 6308 as also some *S. officinarum* varieties have been tried as parents in the breeding programme. But it has been found that the parentage is no criterion as often varieties, approximating to the ideals mentioned above have been obtained from the combinations effected for other economic studies. Six varieties have so far been released as fit for chewing purposes and they are Co. 400, Co. 401, Co. 603, Co. 634, Co. 652 and Co. 798. The first two did not show any promise as the yield was very low. Co. 603 approximates to the ideals of a chewing variety. The recently released Co. 798 is likely to be of promise and is being watched.

4. *Breeding for disease resistance*

The two major disease of sugarcane in India are the red rot and smut and during the last few years the evolving of varieties resistant to the two diseases has been one of the main items in the breeding programme. The studies include ratings of parent varieties used in breeding and progeny tests to assess the nature of transmission of this character to the progeny. The work is done with the help and active co-operation of the Head of the Division of Mycology, Indian Agricultural Research Institute, New Delhi.

The standard method adopted in India for studies on red rot resistance is the "plug inoculation method" perfected at the Division of Mycology, Indian Agricultural Research Institute, New Delhi (CHONA, 1950). Canes are inoculated in the field in September with 16–20 days old culture of the virulent strain No. 24. This strain which is a light race has been used in the Coimbatore experiments also as the tests at New Delhi had shown that it is more virulent than the dark physiologic races.

In order to assess the ratings of parent varieties with a view to their effective utilisation in breeding, it was thought desirable to undertake progeny tests. As a preliminary to this, Co. cane varieties which are themselves seedlings of earlier Co. canes and their parents were studied. Fifty-six varieties of Co. 213 parentage (which is highly susceptible to red rot), seventeen of Co. 331 parentage (highly susceptible), twenty-one of Co. 349 parentage (highly resistant), twenty-six of Co. 301 parentage (highly resistant) and thirteen of Co. 281 parentage (moderately resistant) were tested. The first named has been tried for three years, those of Co. 301 and Co.331 for two years and those of Co. 281 and Co. 349 parentage for one year. The data show a great deal of variability in

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the transmission of disease resistance by the parent cane variety to its progeny. The majority of the seedlings of the highly susceptible parents Co. 213 and Co. 331 were found to be moderately resistant and relatively few as highly susceptible as the parents. On the contrary the majority of the seedlings of Co. 349, a resistant parent, were resistant or moderately so. The majority of the seedlings of Co. 231 and Co. 301 were moderately resistant, as the parents themselves. The data indicate the need for caution in arriving at any definite conclusions till the experiment has been conducted for a number of years (DUTT, and HUSSAINY, 1951).

Recently certain red rot resistant varieties were obtained from the United States Department of Agriculture and are being tried in breeding work. The genera *Sclerostachya* and *Narenga* which are reported to be resistant to the disease have also been utilised in breeding.

It is now felt that the best method of evolving red rot resistant canes would be to inoculate the seedlings that go to the Final Trial Plot and study them for red rot resistance and release only those which are red rot resistant. This procedure will apply also to evolving varieties resistant to smut.

5. *Breeding for pest resistance*

Breeding for resistance to pests presents many complications as little is known of the factors which influence the degree of resistance and environmental conditions and cultural practices also play their part. The best method of assessing the resistance of varieties is to estimate it in the field and use in breeding such of them as would impart resistance to the progeny. An indirect approach in this direction has been the establishment of correlation between certain anatomical characters and pest resistance. The degree of resistance of a variety to the top borer (*Scirpophaga nivella* F) has been found to be conditioned by the hardness of the mid-rib which is a manifestation of the lignification. Similarly resistance to the stem borer *Diatraea* sp. is correlated with the anatomical characters of the rind. Such studies have thrown light on the utilisation of varieties as parent stocks (RAO, J. T., 1947).

Other instances in sugarcane of the correlation of certain plant characters to resistance or susceptibility to insect pests are of (1) mite *(Parapetranychus indicus)* and (2) sugarcane leaf hopper *(Pyrilla perpusella)*. The attack of mites was noticed at Pusa, Bihar, in clumps of *S. spontaneum* and spread later to some other sugarcane varieties in the vicinity. Forms of *S. munja* and *S. arundinaceum* growing in the same area were found to be free from the attack throughout the season. An examination of certain plant characters associated with the attack of mites indicated the probability that the presence or absence of stomatal grooves on the under-surface of the leaves might be responsible for this variation in susceptibility. While forms of *S. spontaneum* and varieties of sugarcane that were attacked have stomatal grooves and spinous outgrowths protecting them on the under-surface of their lamina, forms of *S. munja* and *S. arundinaceum* which were throughout free from attack, have no such stomatal grooves or spinous outgrowths. It was suggested that the presence of stomatal grooves between the veins affords suitable shelter for the mites and the spinous outgrowths afford suitable hold for spinning their webs and thus explain the susceptibility of sugarcane varieties and forms of wild *Saccharums* having these features, in contrast to the immunity of those forms showing an absence of such characters (KHANNA, K. L. and PAMANATHAN, K. R., 1947). At Coimbatore also incidence of mite was noticed on sugarcane varieties and there does

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appear to be some correlation between the presence of bristles and stomatal grooves and the susceptibility of sugarcane varieties to the mite. The mite in question has, however, been identified as *Schizotetranychus andropogoni* (RAO, G. N., 1952). In the case of Pyrilla the varietal behaviour of sugarcane showed that narrow and short-leaved varieties were more resistant than those with long and broad leaves. It was also found that in the resistant varieties the tissue tapped by the insect for its food was protected by a shield formed by the fusion of vascular sheath and the solrenchymatous ribs below it while in the susceptible varieties such protection was not available (KHANNA, K. L., SHARMA, S. L. and HUSSAINY, M. Z., 1950).

6. *Chemical composition of juice in relation to manufacturing quality*

A beginning has been made in the study of the chemical composition of the juice as it affects the quality of (1) gur as manufactured by the average cane grower and (2) of white sugar in factories. The prominent Co. canes in cultivation have been analysed for total nitrogen, protein nitrogen, ash and colloids. The various constituents of the ash, viz., lime, phosphoric acid, sulphate and iron were also determined. It is proposed to continue this study to seedlings of known parents to see how far they contribute good and bad juice characters to their progenies.

A few points that have emerged in the relationship of the constituents of the juice to the quality of gur manufactured may be of interest. The gur was manufactured from these varieties under fairly uniform or standard conditions. The strike was made exactly at 120° C. irrespective of the fact whether the syrup at that temperature answered the empirical test or not. The rate of boiling was also kept uniform by observing the temperature rise each minute from 105° C. to the point of strike at 120° C. The time taken for the syrup to cool before it was transferred to the mould was also observed. It is found that in point of colour, hardness and crystalline structure, Co. 312 and Co. 421 have given very good quality gur, while Co. 453, Co. 467 and Co. 331 have formed softer gur lacking the crystalline structure and hardness of good gur. Gur from Co. 285, Co. 290, Co. 313, Co. 356 and Co. 475 is slightly inferior to that obtained from Co. 312 and Co. 421.

Poor quality of gur is very often associated with high total and organic non-sugars, high colloids, high ash and low phosphoric acid content in juice. The total and organic non-sugar content of the juices of Co. 331, Co. 453 and Co. 467, which have formed poor quality gur, are comparatively higher than those in Co. 312 and Co. 421, which have given better quality gur. Striking contrast is seen in the proportion of organic non-sugars to sucrose and this ratio is comparatively higher in Co. 331, Co. 453 and Co. 467 being 17.86%, 19.59% and 15.11% respectively. In Co. 312 and Co. 421, which have formed good quality gur, it is only 12.26% and 8.04% respectively. The colloid content in juice of Co. 453 which has formed poor quality gur is as high as 0.62%. However in Co. 467 and Co. 331, which also have formed poor quality gur, the colloid percent juice is only slightly more than in Co. 312, and Co. 421. The data for the ash content of good and bad quality juices also fails to reveal the association of low ash content with better quality juices, as in Co. 312, which forms good quality gur, the ash content is as high as 0.69% while in Co. 331, Co. 453 and Co. 467, it is 0.58%, 0.52% and 0.45% respectively. Regarding the phosphoric acid content also, it is high in Co. 453 with 0.089% while in Co. 312 and Co. 421 it is 0.050%, and 0.064% respectively.

Similar observations were noted in the case of the juice of *spontaneum* SES 205 A which did not set and form crystalline gur at all. In this the ratio of organic non-sugars

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to sucrose is as high as 24.66 and the colloid content is also high being 0.70 % in keeping with the poor quality juices. However the ash content of the juice is only 0.4 % and the P_2O_5 content 0.124 %, quite contrary to the general characteristics associated with poor quality juices.

One striking feature of good quality juices is seen in the rapid rise in temperature from 105° C. to the point of strike. Under our pan conditions, juices which have given good gur require only about three minutes to rise from 105° C. to 120° C. while in poor quality juices the time taken is as much as 8 minutes. Comparatively shorter interval of time for the syrup to cool when transferred to the mould is also characteristic of good quality gur. In Co. 421 it is as low as 3 minutes 10 seconds, while in Co. 312 it is 8 minutes. Poor quality juices take a longer time to cool and crystallise.

As for the white sugar manufactured in factories a survey of factories and factory areas is in progress for the past three years and will be completed during the present crushing season.

Future trends

Other special breeding aims which have to receive attention during the years to come are resistance to (1) lodging, (2) waterlogging and (3) salinity. It is hoped that suitable breeding stocks will be available from among the *S. spontaneum* collections for breeding types resistant or at least tolerant to the above factors.

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DISCUSSION

MR. DE SORNAY observed that the authors stated that one hundred seedlings of each of twenty-one crosses had been studied. He considered that the number of seedlings was rather small to provide really a representative sample.

MR. GRASSL said that if the same female parent had been used in all crosses the numbers might be adequate. He also referred to the excellent work done in collecting two hundred clones of *S. spontaneum* in India.

DR. BRANDES also wished to congratulate the Indian authorities on their work but expressed the opinion that it was more important to collect clones of the noble canes first.

DR. WARNER agreed with DR. BRANDES on the advisability of collecting the noble cane clones first, as these are unable to survive in the wild state, and will disappear from cultivation with the advance of civilisation.

MR. GRASSL observed that part of the breeding programme was directed towards the production of canes for chewing purposes and wondered if any other breeding stations had undertaken similar work.

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B. 2—DIFFERENT TYPES OF MALE-STERILITY IN SUGARCANE

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INTRODUCTION

Bi-sexuality of the spikelets and the impractibility of adopting emasculation in the sugarcane flower, have not stood in the way of combining two different varieties in a cross and getting the hybrid progeny. This has been possible because of the varying degrees of male sterility exhibited by some of the sugarcane varieties. According to Venkatraman (1917) ensuring their use as pistil parents the percentage of open anthers in a variety is an indication of its relative degree of male fertility and on this basis varieties could be classified into potential 'Fathers' and 'Mothers'. In addition to the above and perhaps more important is the quality (fertile or infertile) of the pollen shed by the varieties, as ultimately it is the complete absence of fertile, viable pollen that would go to make a dependable mother. The breeding value of male sterile varieties is obvious and on their availability and utilization depends the production of hybrid canes. The term 'male sterility' is used here in a broad sense covering all those cases wherein there is minimum or no chance of self fertilisation.

MATERIAL AND OBSERVATIONS

A large number of varieties that have been employed at this Institute as female parents have been studied and it is observed that they differ among themselves regarding the manner in which they exhibit male sterility. The different types studied could be broadly grouped into the following categories :—.

(1) *Non-dehiscence of anthers* : This type of sterility is associated with pure mothers, which have cent per cent closed anthers. The anthers in these varieties are formed normally and may not differ in size, shape, and colour (though in some cases they are typically yellow) from the normal fertile, open anthers, only in these cases the anthers do not dehisce, but form a solid mass without any slit either at the tip or on the sides. 'Selfing' is out of question in these varieties, though the possibility of their giving rise to parthenogenetic derivatives is not ruled out, as has often the case with P. O. J. 2725. Many of the varieties belonging to *Saccharum officinarum* and *Saccharum sinense* groups, intergeneric hybrids of Vellai x Narenga, Co. 421, Co. 424, Co. 866, C. P. 29/103, P. O. J. 100 and P. O. J. 2725 fall under this group. This is a case of environmental sterility since the per cent of open or closed anthers in a variety may

vary from place to place and this has been noticed not only from place to place but also during different seasons. By subjecting Co. 421 a pollen sterile variety to 15 hours light Yusuf (1945) produced healthy pollen with 10% gern.nation.

(2) *Production of defective pollen* : This condition is most commonly met with in sugarcane varieties. In this case a certain percentage of the anthers dehisce but the pollen produced is mostly defective, as could be readily judged from fertility and viability tests —the former by starch —Iodine and the latter by germination in artificial culture. Occasionally it has been noticed that only one lobe of the anther has a slit, while the other remains closed. The pollen grains formed by these varieties are aborted, smaller in size and of varying shapes and the deformities could clearly be distinguished in the dry pollen condition. Varieties that can be classified in this group are Co. 270, Co. 281, Co. 290, Co. 360, Co. 413 Co. 527, P.O.J. 2878, C.P. 29/116 and others.

(3) *Agglutination of pollen grains* : In the variety Co. 213, the spikelets open normally and about 40% of the anthers also dehisce. But the pollen instead of shedding, remains glued together inside the anther sacs and roll in lumps, when teased out. Though a small percentage of the pollen grains in these lumps react starch positive to Iodine, yet they do not function normally as they are not free moving, but form an integrated mass. This phenomenon known as agglutination of pollen grains has been noted in Ragi (*Eleusine corocaua)* (Rangaswamy and Krishnaswamy, 1931). Other varieties in which this condition has been observed are Co. 650, Co. 971 and M. 108/30. This is a case of germinal sterility occasioned by defects in the pollen material.

(4) *Protogyny with poor pollen fertility* : The occurrence of protogyny in certain forms of *S. spontaneum* has already been reported (Dutt and Krishnaswamy 1943 ; Mukherjee 1949 and Rao 1953 unpublished). It has now been noticed that a tendency towards a protogyny is discernable even in certain cultivated canes. In an attempt to employ certain varieties like Co. 419, Co. 449, Co. 475, Q. 28 and some others as fathers, it has been observed that invariably on all days irrespective of climatic variations anther dehiscence and pollen availability were always late and poor in these varieties, stigmatic branches emerge out far ahead of the anthers and there is a clear interval of ½ an hour to 1½ hours between the two stages of development. Pollen fertility in these varieties is less than 50 per cent. A study of the spikelets from a few arrows from the field in these varieties, has revealed that in nature, there is prolific germination of foreign pollen on their stigmatic surfaces, long before their own pollen becomes available. Thus in this group in addition to low pollen fertility there exists protogyny which further renders the varieties effectively

auto-sterile. The sterility in this case is due to difference in the period of pollen shedding and stigma receptivity.

(5) *Protogyny combined with non-emergence of anthers from a majority of the spikelets* : Co. 603 is an usefull ovule parent and figures in the parentage of many promising Co. varieties. In this variety the flower opening is not perfect. The tips of the stigmatic branches protude first out of the spikelets and even they do not emerge out fully. But the emerged portion is found to be quite receptive as observed by germination of pollen *in situ*. A day or two elapses before the anthers emerge. But the anther emergence itself is confined to only about 30 per cent of the spikelets in the entire arrow. The anthers that emerge do not either dehisce or produce viable pollen. Thus in Co. 603 male sterility is achieved effectively by the suppression of the emergnce of anthers from the majority of the spikelets, infertility in the few that emerge, in combination with protogyny. This association seems to be the most specialised among the types so far discussed, as the abnormality causing sterility is not only confined to the sex cells but also extends to the non-functioning of the floral organs.

Thus in sugarcane varieties both environmental sterility and geneic sterility are noticed. These are helpful in the utilisation of such varieties as pistil parents.

SUMMARY

The phenomenon of male sterlity in sugarcane and its importance as a necessary adjunct to successful breeding is stressed. Depending on the nature of sterility observed and studied in a large number of varieties five different categories have been distinguished.

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BREEDING

B.1—LATEST IMPROVEMENTS IN SUGARCANE BREEDING ADOPTED AT COIMBATORE

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INTRODUCTION

In an earlier paper (Dutt and Raghavan, 1950), a review of the breeding technique as adopted at Coimbatore with particular emphasis on recent trends was given. Since then, certain improvements have been effected in the breeding technique which are likely to have far reaching effects in efficient breeding as also in the simultaneous testing of seedling varieties at Coimbatore for tropical India and at Karnal (Punjab—I) for sub-tropical conditions without loss of time. In this paper is presented the salient features of the technique adopted.

CROSSING TECHNIQUE

In sugarcane breeding for evolving commercially useful varieties, open crosses have been done while for genetical studies, controlled cross ing using paper bags or lanterns have been in vogue. It was, however, found that bagging of arrows interferes with seed setting. Attempts were, therefore, made in India and Hawaii to isolate arrows by artificial rooting of the canes so that the arrows can be taken to a place free from foreign pollen and the desired controlled crosses effected. Venkatraman and Thomas (1926) successfully rooted canes by the method now popularly known 'as tile potting'. In this the basal portion of canes are treated for root development by applying moist soil and sand which is kept in position by two tile pots. The soil is watered at frequent intervals. After a fortnight when rooting is anticipated, the canes are cut below the tile pot and the later put into a bigger pot with soil. The tile pot is then removed. The seed setting was noticed to be normal. One drawback in the method is that the flowering of the particular stalks cannot be certain and as such a large number of stalks have to be tile potted. This is more so in the case of shy flowers. Tile potting after clear symptom stage may or may not result in effective rooting at the node. Another difficulty is that sometimes the rooting is slow, depending on the varieties, and it is not possible to know whether the stalk has rooted without disturbing the tile pot.

Verrett, Kutsumai and Das (1925) found that cut canes kept alive for several weeks and completed their blooming and pollen shedding in a normal manner, when kept in a solution of sulphurous acid (So_2) 1 part in 2,000. It was later noticed that the arrows of some varieties dried up

in the solution. A combination of phosphoric and salphurous acids (150 ppm. of So_2 and 85 ppm. of $H_3 Po_4$) proved more effective. This method is now adopted in Hawaii and other countries. It has an advantage over the 'tile pot' method, in that the cane can be cut even after clear emergence of arrows and only a limited number of stalks just sufficient for crossing need be isolated. This method has been tried under Coimbatore conditions and observed to be only partially successful. The solution needs changing every day and the pH has to be constantly adjusted. Even so some of the tassels dry up and the seed setting is not perfect either.

Since the necessity for artificial rooting and isolation of arrows is of prime importance in controlled breeding involving inter-generic crosses, and for cyto-genetical studies, efforts have been made to evolve a more efficient method of isolation. Recently it was noticed that thin plastic films are being utilised for successful rooting of herbaceous plants and trees. One of them named 'Alkathene' [a product of Imperial Chemical Industries (India) Ltd.] was tried for artificial rooting with very encouraging results. The method consists in taking pieces of alkathene and tying one end at the node to be rooted. Soil is put in the improvised bag of alkathene and water added. The other end of the bag is also tied. Roots start developing from 6th day onwards and profuse rooting results in a few days. In view of the transparent nature of the material, the rooting can be seen. No watering is necessary. The stalks, after rooting, can be cut and planted in a big pot and the arrow utilised for hybridisation. One of the greatest advantages with this method is that the rooting can be done even in the topmost 2 or 3 nodes below the arrow dispensing with the major portion of the stalk. It would not be much of exaggeration when it is said that the 'arrow can be carried in the pocket' for crossing operations, so easy of handling will it be. The rooting can be done after tip emergence of the arrow and there is no chance of failure. Mass isolations by this method have been tried with hundred per cent success. The isolated arrows are noticed to be normal in the matter of pollen production and seed setting.

Thus the above method eliminates all the disadvantages encountered in the other two methods of isolation, combining the advantages of both. It is expected that this method would to a great extent simplify the task of the breeder in his attempts to do controlled breeding work.

SOWING OPERATIONS

In former years, country-made earthenware pots have been in use for raising seedlings. In view of their uneven shape and bottom, there was non-uniform stand of the seedlings and fairly heavy mortality in the pans. Preliminary experiments (Dutt, Rao and Davis, 1948) have shown

the superiority of glazed, uniform pans over the earthenware ones in the matter of health, vigour and uniform growth and distribution of the seedlings. In view of this, the sowings are now done in glazed pans. Concrete platforms have been constructed for taking the pans in favour of the bomboo ones in use for over four decades which give an uneven surface. These two improvements have decreased the mortality rate of seedlings (due to water stagnation) and uniformly grown seedlings result.

In view of the light nature of sugarcane fluff, the seeds are sown in pans behind closed doors to prevent contamination. This entails the first watering of the pans in the shed itself and carrying the pans to the platforms for keeping in the open. This involves a lot of labour and difficulties in practice, sometimes resulting in the breakage of the heavy, sown, glazed pans and loss of valuable seed material. To offset these difficulties, the sowing is now done in the open on the concrete platforms with the pans in their places duly labelled. The flying of the fluff is prevented by placing 6" high concrete rings over the pans which effectively cut off light breeze. If the wind is rather heavy, a screen of alkathene is put over a number of pans and sowing done inside. The watering is conveniently done through hose pipes which again has minimised labour charges.

After sowing, the pans need frequent watering at the rate of 3 or 4 times a day till germinations result and then once or twice a day. The labour involved and the correct and efficient method of watering is dispensed with by covering the pans with alkathene sheets. These being impervious to water retain the moisture inside with the result that the waterings are considerably minimised. This does not affect the germination of the seedlings as has been noticed in comparison with controls.

For effective germination and to give warmth to the seeds to stimulate germination, horse dung mixture is being used in the seedling pans Experiments conducted with leaf mould mixture have given encouraging results and if proved useful, will reduce the cost of purchase of horse dung.

NURSERY STAGES AND SEEDLING SELECTIONS

The practice in vogue at the Institute in the selection of seedlings in the nursery stages is as below :

The seedlings in pans are transferred to what is known as 'First Ground Nursery', the selection being based on vigour only. The spacing in the nursery is 6"×6" apart. The seedlings stay in the nursery for about 3 months after which by a process of selection based on vigour and tillering, the selected ones are shifted to the 'Second Ground Nursery' wherein the spacing between seedlings is 2' on all sides and where they stay for 10 months. From the second Ground Nursery, vegetative propagation starts and the seedlings are planted in one 20' row or two 10' rows.

The above nursery method has been far from satisfactory though it has served admirably well for the past four decades. While transferring from the First Ground Nursery to the Second, the 3 month old seedlings which often attain 2—3 feet in height are uprooted, the tillers trimmed (rather cut) leaving only 6" stubbles (as in ratoons) and planted in pits. This gives a 'shock' to the plant and perhaps a set back in its further progress of growth. It has been felt for sometime that some change in the procedure might be adopted which will minimise this disadvantage to the plant.

The following method is being adopted now and has been found to work satisfactorily. When the seedlings in pans are about a month old, individual ones meriting selection on the basis of vigour are transferred to small tile pots of 8" × 2" one in each. These pots are kept in shade for a few days for the plants to revive and then removed to the platforms again. The seedlings stay in the pots for about 1½ months and when tiller formation starts are removed from the pot and planted directly into the field each seedling 2' apart. Thus there is continuous growth without any set back. Data collected for comparison purposes from such transplanted seedlings and the control (normal method) have revealved the superiority of the 'transplanted' seedlings in the matter of growth and thickness of stalks. This method, modified to suit the conditions, is in vogue in some countries.

One other and important advantage of the above method is that planting material is available in the seedlings within a short period of one year from sowing, for simultaneous testing at Coimbatore for tropical conditions and at Karnal (Punjab—I) for sub-tropical conditions. Till now the planting material available by the old method was hardly sufficient for trials at Coimbatore. It is now proposed to carry out the trials simultaneously at the two places. This new technique is being brought into effect this year itself and will enable 300 to 500 new seedling canes to be tested at the Sugarcane Sub-Station, Karnal for North Indian subtropical conditions and at Coimbatore for tropical conditions.

PLANTING DURING OCTOBER

The usual month of planting the Test plots, following the local practice, has been February of each year. The varieties are analysed for sucrose content during November, December and the following January, selections made in February and the new releases sent to the various State Experiment Stations during the second week of February each year. It has been found that the midseason ripening and late ripening varieties are not being tested properly for their maturity period for which the canes have to be in the field for another couple of months or so. But the selections have to be finished by January to enable planting material being sent

to the Testing Stations especially in Northern India by the last week of February which is already late for planting in view of the incoming hot weather.

To obviate these disadvantages, it has been decided to do the planting in October by which canes would have made full one year growth by next October and it would be possible to carry out detailed chemical analysis and decide the maturity period of varieties.

PACKING OF CANE MATERIAL FOR OVERSEAS TRANSPORT

The method adopted at Coimbatore for sending planting material of cane varieties for overseas countries is to pack them (about 6 one foot bits) in moist charcoal in tins or wooden boxes of 15″ × 3″ × 3″. The weight of a tin is on the average 12 lbs. This served the purpose well for surface shipments which usually take a month or two for reaching the destination. With the increased facilities now available for transport of material by air, the packing arrangement has got to be simplified and the weight of the parcels reduced. Experiments have been conducted by packing cane setts in ordinary newspaper, wax paper, cellophane paper, pliofilm and alkathene. It has been found that alkathene is superior to the rest and perhaps the best available material for packing of canes. Cane setts packed in alkathene have remained fresh upto a period of 1½ months and 80% of the buds have remained in good condition and capable of sprouting. Cane setts sealed in good alkathene tubes and packed in cardboard box made an ideal elegant parcel for transport by air, weighing only 2 lbs.

The above are the main improvements in the breeding technique which are being adopted. It is hoped that these will be conducive to more efficient breeding and evolving of improved varieties.

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INTERNATIONAL SOCIETY OF SUGAR CANE TECHNOLOGISTS
NINTH CONGRESS, INDIA—JANUARY, 1956.

SOME RECENT FEATURES OF CANE BREEDING TECHNIQUE AT COIMBATORE.

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PLANNED PLANTING OF ARROWING PLOT FOR ADJACENT ROW CROSSING

It is a long standing practice at Coimbatore to have a separate arrowing plot for crossing purposes. Previously the only thought given to the relative position of the various varieties in the plot was to plant the female varieties on the side from which the wind blows so that the pollen of the male varieties is not carried by wind to the female varieties. The change now made is that varieties which come into flower at the same time and possess a similar growth vigour are grouped together. Among these the male sterile 'mother' variety is planted in the central row and on either side of it two male fertile 'father' varieties with whom the former was intended to be crossed are planted. This method of grouping and planting is being followed for all desired parents starting from those, that flower in the first week of October to those that arrow in the last week of November, thus covering the entire crossing season. (Diagram 1)

When the canes grow and begin to flower, half the number of arrows of the pistil parent in the central row and a corresponding number of arrows of the pollen parent on its right side are brought together and tied in such a manner that the former are just immediately above and encircle the female arrows. The remaining number of arrows in the rear side of the pistil parent are tied in a similar manner to the arrows of the male on its left. Partitions made of bamboo matting are placed between the two groupings for protecting the desired combinations from unintended contamination.

In the above method natural free crossing is allowed to take place, with the varieties *in situ*. Occasional gentle agitation of the arrows ensured free mingling and thorough distribution of pollen. Seed is collected from both the female and male arrows. The method is quite simple and has proved to be of great practical value for effecting a record number of parental combinations with the minimum labour and expense.

ISOLATION OF LIVE CANES IN 'ALKATHENE'

The Coimbatore method of effecting controlled crosses by isolating the parents by 'tile potting' is well known (Venkatraman and Thomas, 1926). It has now been found that *Alkathene could be used with decided advantage in the place of tile pots, for artificial rooting on standing canes. The method consists in putting an improvised bag

*Alkathene is a polythene film marketed by Imperial Chemical Industries (India), Ltd.

PORTION OF THE ARROWING PLOT TO INDICATE PLANNED PLANTING FOR ADJACENT ROW CROSSING

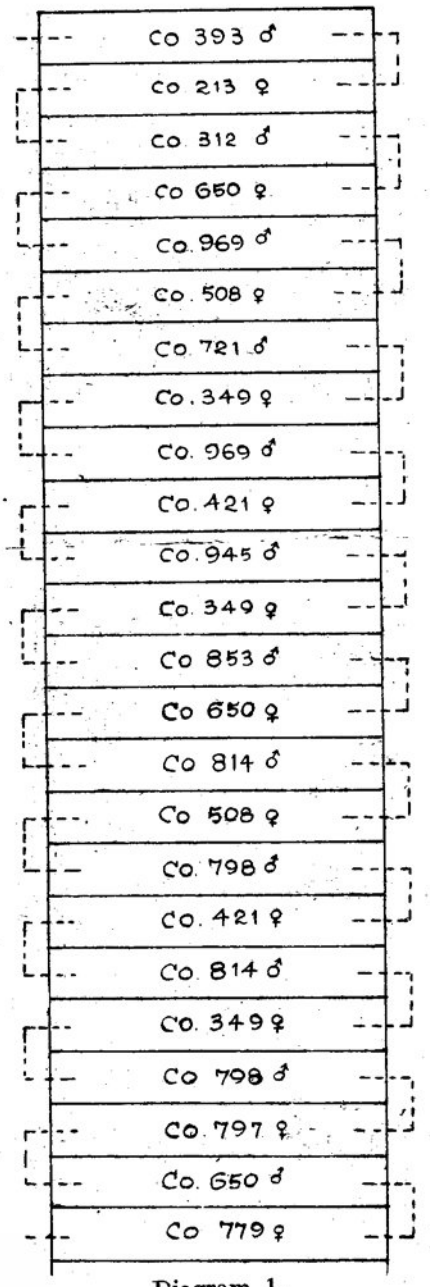

Diagram 1.

of Alkathene to cover two top nodes of a standing cane, and filling it with moist soil or sphagnum moss and tying at both ends (Fig. 1 and 2).

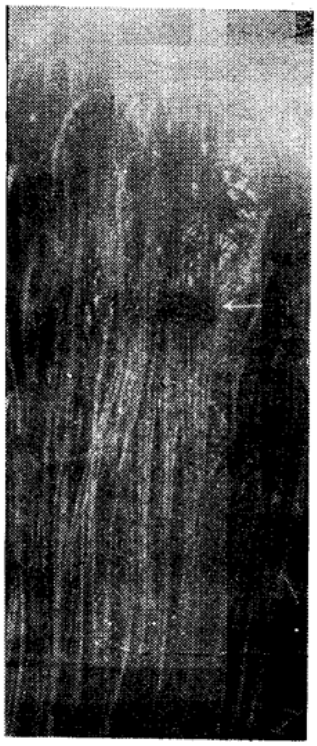

Fig. 1. Alkathene bags put up at the top internodes for inducing rooting.

Fig. 2. Rooting of canes by alkathene bags and tile pots.

The new method dispenses with the cumbersome procedure of tying two halves of the tile pot together and keeping it in position round the cane. The Alkathene rooting bags could be put up at the top nodes without needing any support, and the rooting was not only quicker, but the percentage of root eyes sprouted at that level of the cane was also high. By such 'high level' rooting the cane when isolated could be 'midgeted' to a convenient height of 3′ to 4′ for crossing purposes (Fig. 3). The ease of handling arrows for controlled breeding work, rendered by the new method, would be appreciated when it is considered that sometimes a cane in arrow is of such great height, that even the tallest ladder is not able to reach it and a special 'Pollen stick' had to be used as shown in Fig. 4.

The greatest benefit derived from the new technique, was that Alkathene very effectively preserved the moisture in the medium. When once the Alkathene bag was put round the cane filled with moist soil, there was no need to water for a second time at all. Further, the plastic film being transparent, the formation of roots could be watched to decide the stage and time for cutting the rooted cane.

Mass isolations by this method were tried with cent per cent success. It was seen that the canes could be rooted even at the tip

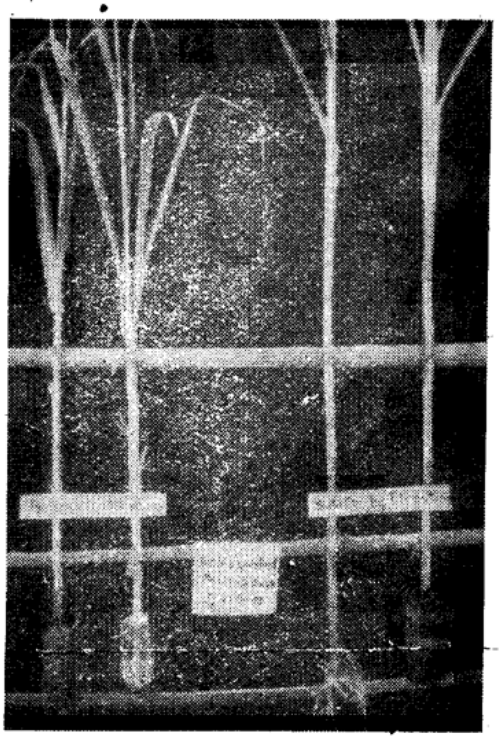

Fig. 3. Isolated arrows available at a convenient height for hybridisation.

Fig. 4. Technique of hybridisation with the special 'pollen stick'

emergence stage of the arrow, and the same isolated in time for controlled crossing.

*TRAYON BAGS

Previously muslin bags used to be employed for controlled crossing and for safeguarding the crossed arrow from foreign pollen. Recently special trayon paper bags fitted over thin bamboo strip cages have been used as shown in Figs. 5 and 6. The trayon bags are quite strong and do not tear easily. The other advantage is that they are transparent and allow light to pass through. The occurrence of moisture, high humidity, temperature, fungal growth and the consequent poor seed setting which were invariably associated with the use of cloth and other paper bags were noticeably absent in the case of trayon bags.

SOWING OF SEED IN FLATS

A few modifications have now been made in the method of sowing of sugarcane seed. Previously the seed used to be sown in the Sowing Shed and the seed pans were then removed to the bamboo platforms.

*Trayon is a cellophane type paper manufactured by Travancore Rayons Ltd., Trivandrum.

The platforms are now of cement slabs and therefore absolutely of a uniform level. The seed pans are kept arranged on the platform and

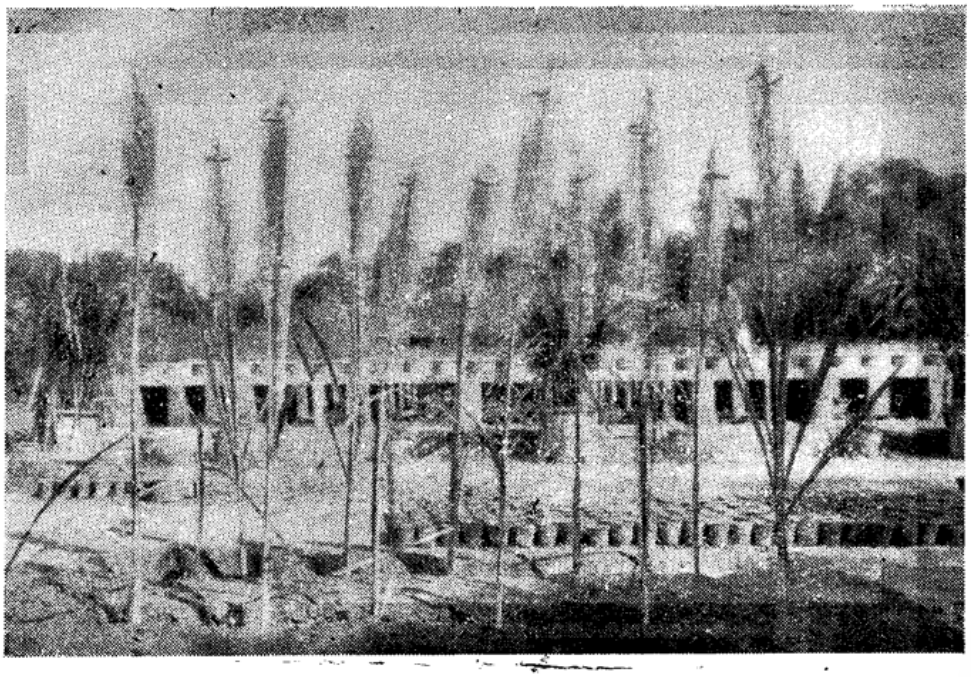

Fig. 5. Trayon cages on isolated canes.

are not removed to the Sowing Shed for sowing and then brought again to the platform. Separate cement rings are provided which fit just above the seed pan and each individual pan is sown. The cement ring prevents the blowing of seed from one pan to another by the wind. In former years country made earthenware seed pans were used. A few years later these were replaced by Glazed pans and still later by cement pans. It has now been found that if brick walled flats are made on the cement platforms, the seed germinations and the health and vigour of the seedlings are better than when they are raised in earthenware pans, or glazed pans or cement pans or cement concrete flats. The bricks have to be changed every year. The success is perhaps due to the porous nature of the fresh bricks which allow aeration and drainage of water.

ELIMINATION OF FIRST GROUND NURSERY

As per the old method, seedlings germinating in seed pans (1½ months old) were transplanted in the field in what was known as the first ground nursery. After 3 months, vigorous seedlings used to be uprooted, leaves trimmed, tops cut and transplanted into the second ground nursery. It was felt that two transplantings within a short period of 5 months acted as a set back and affected the growth of the seedlings. The first ground nursery has now been eliminated. Seedlings

from the seed pans when they were about 6" high, were transplanted individually into the tile pots. There they grew for a month and

Fig. 6. Sugarcane arrows in the field covered with trayon cages.

when the seedlings began to tiller, i.e., when the 'B' shoot began to emerge, they were ready for transplanting into the field. The seedlings were removed from the pots with the root system and soil intact and transferred to previously prepared pits, 2' apart in the field. It was found that barring 1½ months in seed pans and 1 month in tile pots, the seedlings remained for full 12 months in the field nursery enabling proper evaluation of their characteristics and selection by next February. Moreover, the intrinsic value of first year characters like tillering, growth vigour, habit, etc. could be properly assessed as the seedlings were allowed to enjoy continuous growth without disturbance at any stage.

The growth vigour as compared to the seedlings transplanted by the old method is shown in Figs. 7 and 8. The tillering was far more satisfactory and the height and girth of individual stalks was also much

Fig. 7. Seedlings transplanted from pots.

better. Immediate advantage was taken of this availability of large amount of planting material at the seedling stage itself. Half the material in the selected seedling was planted at Coimbatore and the other half sent to the Institute's sub-station at Karnal to test their performance under sub-tropical conditions where the bulk of the cane area in India even now lies.

It may be mentioned in passing that potting seedlings in the early

stages is practised in other countries as well (Mangelsdorf, 1953) though not with the same ends in view as ours. For us getting sufficient

Fig. 8. Seedlings transplanted from first ground nursery

planting material for simultaneous testing and selection of suitable commercial canes for both the sub-tropics and tropics was the main objective.

The growth of the seedlings in the new method was much better as compared to the old method. The tillering was far more satisfactory and the height of the canes was also good. Immediate advantage was taken of this availability of sufficient planting material.

RAPID PROPAGATION AT THE YOUNG SEEDLING STAGE ITSELF

Mainly with a view to saving planting material of available seedlings from the attack of mosaic, the technique of multiplying the material available from seedlings at the younger stage itself has been evolved. There is a secondary spread of mosaic at Coimbatore and unfortunately some of the best seedlings had to be removed and destroyed because of the attack of mosaic. The device now used in about 20% of the total number of seedlings is that when the seedlings have to be transferred to the field from the tile pots, each seedling has been separated into the available tillers with their individual roots and planted as separate units. It was noticed that even if the mosaic attacked 60 to 70% of these canes, at least 30 to 40% were still available and thus the seedling was not completely lost to the Station. Incidentally this method came in very handy for obtaining large amount of plant-

ing material from the seedlings (vide Figs. 9 and 10). This enabled

Plant

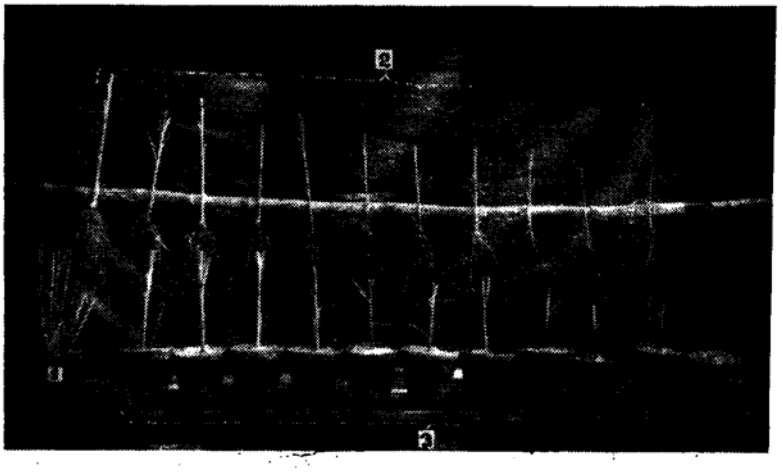

Fig. 9. 1. A seedling in pot with 11 tillers. 2. Tillers separated showing roots. 3. Individual tillers planted in tile pots.

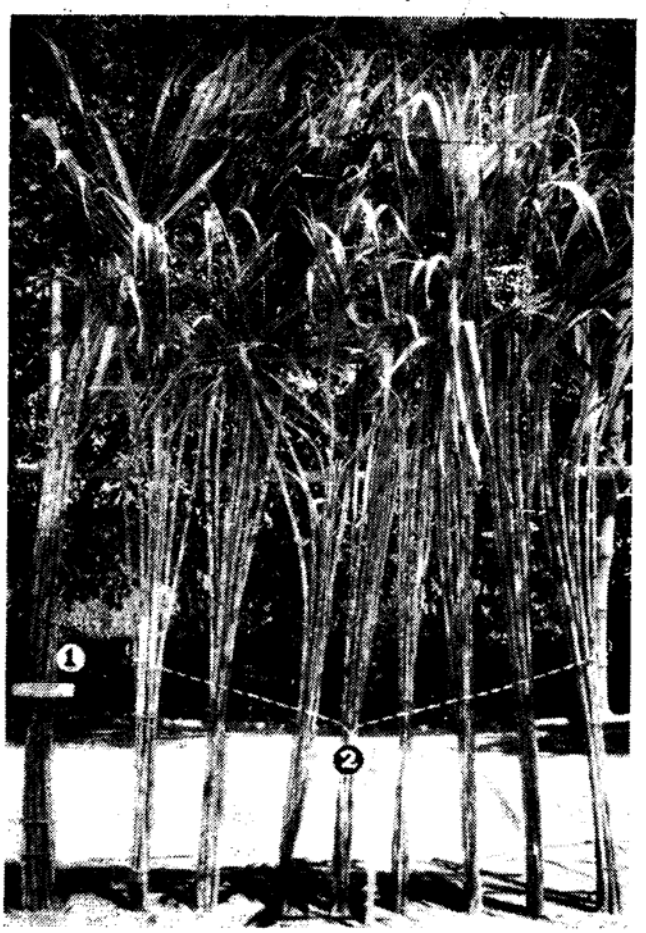

Fig. 10. 1. Planting material available from a single seedling. 2 Planting material available by the method of tillers separation.

the testing of planting material at the earliest available stage simultaneously at Karnal and at Coimbatore, that is to say, both under the sub-tropical and tropical conditions.

The tiller separation method described above agrees in principle with the 'Seblang' method developed in Java (Dillewijn, 1950) for rapid propagation of sett planted material. But this is apparently the first case where promising new varieties raised from seed are subjected to this tiller separation treatment and their worth and usefulness as commercial types assessed very early.

DESPATCH OF SEEDLINGS BY AIR

The testing of the seedling canes from the ground nursery stage at the sugarcane Sub-Station, Karnal, has been mentioned above. The existence of air mail service has helped in carrying the seedlings themselves. Previously the best that could be done was to send seedlings by train all the 1,800 miles. The seedlings had to be trimmed and kept watered during the long journey of nearly five days. Now 1½

Fig. 11. Seedlings packed in coconut fibre for air parcel.

month old seedlings from flats are taken with the adhering soil and wrapped in moist coconut fibre. An eight pound parcel contains 2,400 seedlings and reaches Karnal the next day. Figures 11 and 12 illustrate the way seedlings are packed and sent.

USE OF ALKATHENE IN CANE PARCELS

The use of Alkathene for isolating live canes has been described in section above. Alkathene has come in handy in yet another im-

Fig. 12. Seedlings ready for despatch by air.

portant way. The old method of packing cane for foreign despatch was to use moist charcoal as the packing medium (Venkatraman, 1920). This has been replaced altogether by enclosing the canes in Alkathene tubes. The cane material has remained fresh upto 1½ months in Alkathene tubes and 80% of the buds were quite fresh and healthy.

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