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The Production and Testing of Sugar-Cane Seedlings

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SUMMARY

An account is given of the technique applied to the production and testing of sugar-cane seedlings in Queensland.

From the crossing point of view, to ensure an excellent arrowing season the crops must have made reasonable growth before the wet season, the wet season should be long and uniform, and autumn and early winter conditions should maintain reasonable growth and allow emergence of arrows. A simple lopping procedure is adopted to delay arrowing.

Data on pollen viability, abundance of pollen and arrowing are given for the varieties maintained as parent material, and the relation of these features to breeding practice is discussed. The main blood lines in use in Queensland are spontaneums at various stages of nobilization, S. robustum, sorghum hybrids, and nobles.

The solution method of holding arrows for crossing, and the associated use of lanterns, are described.

Pre-storage drying of seed is usually by an electric dryer. The fuzz is stored in small tins at 32-40° *F. until required for planting within the ensuing year.*

Seed is germinated in sterilized soil in flats in glasshouses and the seedlings thinned out to 400-500 *per flat of about* 270 *sq. in. When* 3-4 *inches high the seedlings are transplanted to pots outside the glasshouse, and when* 9-12 *inches high are put out into the field.*

Seedlings are selected from either the plant or the ratoon crop, and selection is carried out in the field, where comparison of certain characters as between seedling plots and standard canes can be readily made. The measure of stooling in the original seedling stool is the number of sticks of millable cane at the time of selection. Brix figures are obtained from hand refractometer readings from extracted juice.

Selected seedlings are planted in 40*-sett plots; further selection is made in the plant crop and is mainly on a visual basis. From* 20 *to* 40 *seedlings at each station then go into a "yield-observation" trial for two seasons, and the next lot of selections are incorporated in Latin square or randomised block trials and in disease resistance and district trials before being distributed to farmers or rejected for disease susceptibility or other cause.*

INTRODUCTION

The author has had an intimate association with sugar-cane seedling work in Queensland over a period of 11 seasons, commencing in 1937, and since he has now relinquished his direct interest it was thought desirable to record details of technique and to review in passing some of the achievements of the last decade. This paper is concerned only with the production and testing of seedlings by the Bureau of Sugar Experiment Stations and has no reference to the excellent work being done by the Colonial Sugar Refining Company Limited at Macknade in North Queensland.

Eleven years is not a long period in the breeding of new varieties of such a crop as sugar cane, and it is only to be expected that varieties produced since 1937 would not yet bulk largely in the varietal census of the State. The process of developing, testing and propagating a particular cane is very slow; one has only to call to mind two recently risen new varieties, Q.28 and Trojan, to have this brought home forcibly. Both are comparatively new canes to the commercial grower and quite new canes as major varieties, yet Trojan (a Colonial Sugar Refining Company seedling) was bred in 1933 and Q.28 in 1935. In addition to the inherent slowness in the development of new canes, the work of the Bureau had to start afresh in 1937, since the number of synthesized parents was then very low, there had never been any extensive testing of new combinations, the crossing technique was not very efficient, and the selection procedure was unsatisfactory. At the present time a large number of synthesized parents embodying different bloodlines is available, a very wide range of new combinations has been examined, the crossing technique has been standardized, and the selection procedure, while still in a state of flux and subject to alteration, gives promise of proving satisfactory.

The seedling production activities of the Bureau are carried out in close association with the established Experiment Stations. Each of these is equipped with a glasshouse, compost pit, steam sterilizing outfit, benches and all the other apparatus necessary for raising delicate seedlings in large numbers. The Bundaberg Station (*see* Fig. 1) in latitude 25° S. is the most southerly, and with the Mackay Station in the central district at latitude 21° S. receives all its seed or fuzz from the northern Station. This is at Meringa, near Cairns (latitude 17° S.) and as well as providing fuzz for the other two stations grows a large number of seedlings itself and raises several thousands for planting in the wet belt at Babinda. A fourth Experiment Station being developed at Ayr will also raise seedlings.

THE ARROWING OF CANE

It is well recognized that the amount of arrowing of a particular variety of sugar cane varies considerably from district to district and also from year to year in the same location. In Queensland, where the sugar belt runs from the sub-tropical zone (the southern limits of cane in this State are at latitude 28° S.) to well into the tropics at Mossman (lat. 16° 30′ S.) just north of Cairns, the overall effect of decreasing latitude is very marked. Varieties such as P.O.J. 213 and

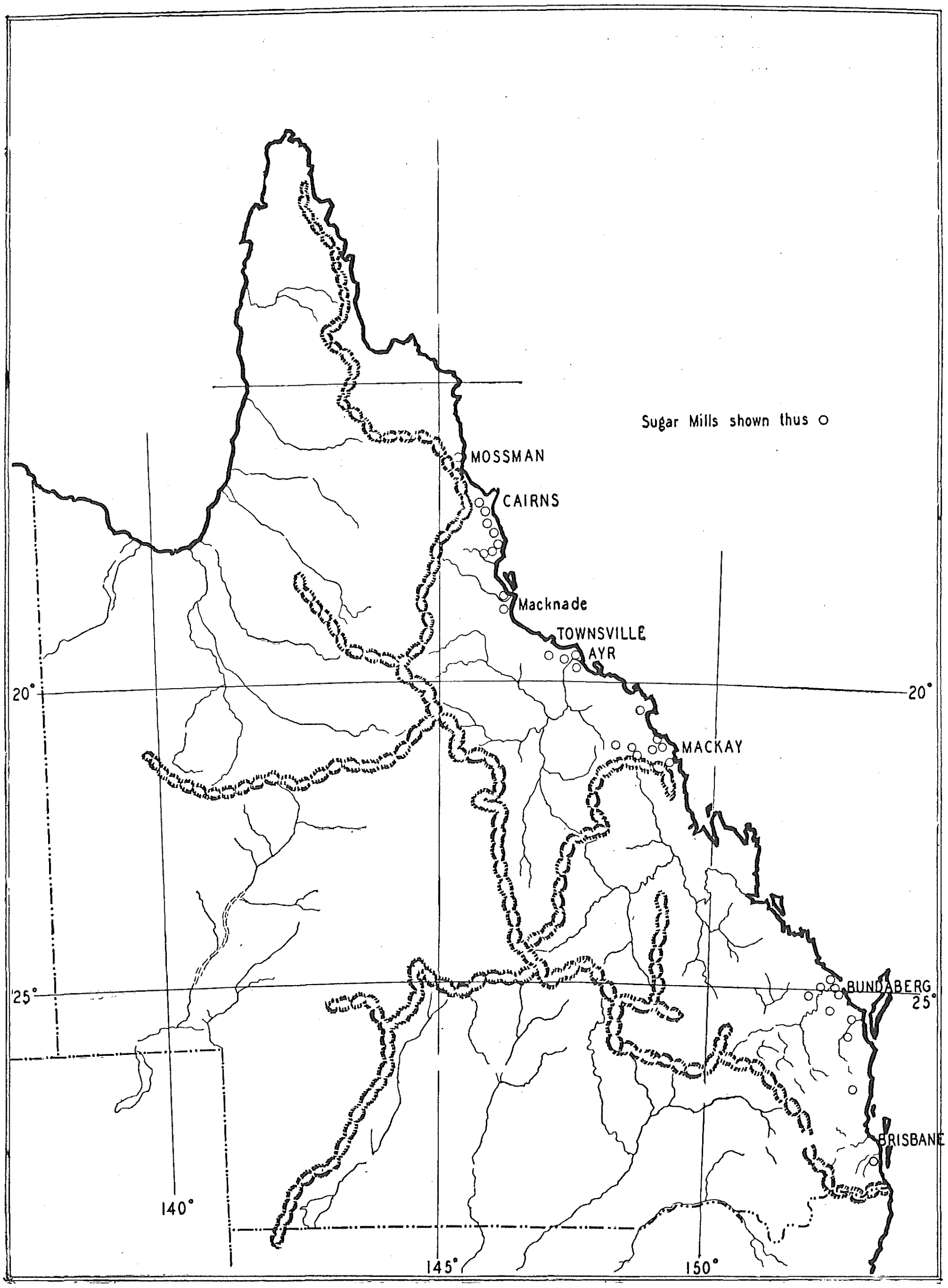

Figure 1.
Map of Queensland, showing location of raw sugar mills and localities mentioned in the text.

P.O.J. 2878, which rarely arrow at all in southern Queensland, will arrow practically every season in the north and virtually every stalk will flower. Other canes, such as Badila, Mahona and M.1900S, which were never known to arrow when they were grown in the south, produce arrows fairly regularly in the north. This effect is, of course, well known in other parts of the world and for that reason cane seed-producing centres are confined to the tropics. The precise reasons for differential arrowing are not known, but it would appear that there is some over-riding factor responsible. This may be the different temperature levels or the more marked seasonal changes in the south or, on the other hand, may be the combination of factors usually grouped together in the term " climate."

In addition to the gross variations in arrowing induced by differences in latitude, there are also the variations occurring in different parts of the one district and sometimes in different parts of the one farm. Aspect and elevation frequently have a profound influence on the arrowing in practically adjoining fields. In the Bundaberg district, for instance, the undulating coastal area of the Woongarra is broken by a hill, locally known as The Hummock, which is about 320 feet in height, and cane is grown to within 100 feet or so of the summit. The southern and eastern slopes of the hill are exposed to the sea breezes coming in across Hervey Bay and show much more pronounced arrowing than the other sides. Similar effects are seen in the other cane-producing areas, though the apparent reason is not usually so obvious. The differences between localities in the one district have to be considered in establishing the arrowing plots for the breeding work, and if the experiment station does not happen to be in a particularly favourable area the plots have to be sited elsewhere. This has had to be done to some extent for the breeding work in Queensland.

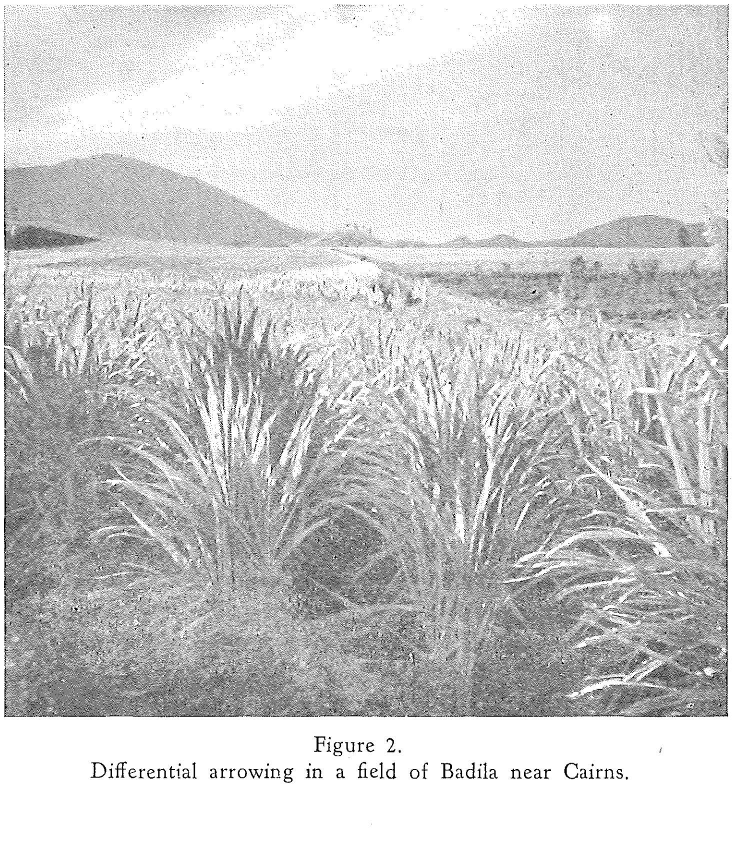

Figure 2.
Differential arrowing in a field of Badila near Cairns.

Differences in arrowing can also occur in various parts of the one field. Occasionally this may be attributable to a lower water-holding capacity of the soil in the parts arrowing most freely or the earliest; on the other hand, excessive moisture may often have the same effect. Figure 2, showing a field of Badila in North Queensland, illustrates how arrowing has occurred abundantly in a shallow wash-filled gully while the rest of the field has not flowered. Even in blocks where soil conditions are apparently uniform, it is frequently found that stools on the headlands arrow before those further in the field, and on occasions those more exposed stools are the only ones to arrow. In North Queensland, it has been observed that the stools on the southern and eastern edges of the paddocks usually arrow first. The headland effect does not seem to vary with the width of the headland and is often as pronounced against headlands of the minimum width, which is about 12 feet, as against main roads and railway enclosures over two chains wide.

The year-to-year variation in the one locality can be very great. In a comparatively poor arrowing year, the variety C.P. 29/116 in southern Queensland will not show a single arrow, yet in the succeeding year every field may be in flower. In the Mackay district, about 4° north of Bundaberg, some seasons yield very few flowers, while in others the crops are a sea of arrows for mile after mile. In the far north similar contrasts occur. The poor seasons hinder breeding work in that many desired crosses may not then be possible, but the good seasons give an abundance of arrows of most useful parents and may give a few of such very shy arrowers as B.208 and Clark's Seedling (H.Q.426). It must be borne in mind, however, that though a good arrowing year may yield a plentiful supply of arrows of most varieties, there may be one or two canes which do not respond to the general conditions and fail to produce as many arrows as in another year.

It may be mentioned here that mere numbers of arrows do not always give a true indication of the favourableness or otherwise of the arrowing in a particular variety from the crossing point of view, for the time factor is of great importance. The crossing season is somewhat restricted in North Queensland, and the production of arrows by a variety after practically all other canes have ceased flowering restricts the crossing range as effectively as does a lack of arrows. For instance, in the years 1943 and 1945, the variety S.J.4 showed a very marked seasonal variation in time of arrowing. In years of good arrowing this cane may be termed a reasonably early arrower (*i.e.*, crosses can be made with it by the middle of May), and this was so in 1943. Two years later, however, though the arrowing was still sufficiently frequent to allow its use in several crosses, the first arrows were not available until the second week in June, by which time some of the early arrowing canes had finished flowering.

The annual variation is apparently influenced by wet-season conditions prior to the arrowing, but just what factors are involved has not been worked out for Queensland centres, nor, as far as is known, for any other cane-breeding centre. The coastal area of North Queensland has a very pronounced summer monsoonal wet season, the precipitation ranging from 50 to 120 inches during January, February

Table 1

ARROWING AND RAINFALL AT MERINGA, 1937 to 1946 SEASONS.

Year	Rainfall	Nov.	Dec.	Jan.	Feb.	Mar.	April	Total Dec. to April	Total Nov. to April	Arrowing
1936–37	Rain in inches	0.8	7.6	8.4	4.7	16.4	4.9	40.0	40.8	Poor
	Wet days	2	19	18	15	20	6	78	80	
1937–8	Rain in inches	2.7	2.5	18.8	18.9	2.7	0.5	43.4	46.1	Poor
	Wet days	12	8	14	18	9	6	55	67	
1938–9	Rain in inches	3.0	2.4	26.1	36.9	34.7	9.3	109.4	112.4	Excellent
	Wet days	13	11	19	14	19	22	85	98	
1939–40	Rain in inches	1.6	0.2	12.7	18.9	34.4	7.3	73.5	75.1	Excellent
	Wet days	7	2	14	21	25	17	79	86	
1940–41	Rain in inches	2.3	0.6	12.2	24.2	15.4	18.7	71.1	73.4	Excellent
	Wet days	5	5	25	19	23	26	98	103	
1941–42	Rain in inches	4.1	3.3	3.2	12.0	3.8	8.4	30.7	34.8	Mediocre
	Wet days	14	16	11	20	13	19	79	93	
1942–3	Rain in inches	1.8	18.5	5.3	26.6	3.9	1.6	55.9	57.7	Excellent
	Wet days	11	24	14	24	14	14	90	101	
1943–4	Rain in inches	0.3	2.9	5.1	23.3	10.8	1.8	43.9	44.2	Poor
	Wet days	7	11	14	22	24	9	80	87	
1944–5	Rain in inches	1.2	4.7	21.6	26.0	47.6	4.8	104.7	105.9	Good
	Wet days	5	11	19	17	23	17	87	92	
1945–6	Rain in inches	0.8	8.4	17.1	24.6	7.7	0.7	58.5	59.3	Very poor
	Wet days	12	13	21	23	10	8	75	87	
1946–7	Rain in inches	0.3	2.0	1.5	13.8	9.3	2.3	28.9	29.2	Good
	Wet days	7	14	9	21	24	13	81	88	

and March, and observations have shown a general positive correlation between years of heavy wet-season and good arrowing; exceptions, however, even during the past decade have been so marked that it is obvious that the primary factor is not rainfall or wet days, as such, during the summer months. A correlation between heavy wet seasons and good arrowing has been reported from Barbados (McIntosh, 1938; British West Indies Central Sugar Cane Breeding Station, 1938 to 1944), but this is somewhat tempered by the note that arrowing is generally very satisfactory on that island.

Records of rainfall and numbers of wet days at Meringa in the pre-crossing months of November to April, together with arrowing notes for the seasons 1937 to 1947 inclusive, are set out in Table 1. Arrowing in North Queensland usually commences in most commercial canes during the first or second week in May; and, since evidence of arrowing can usually be found by splitting open the apical growing point some six weeks prior to this, the conditioning of the canes for arrowing must occur some time before the middle of March. The use of the term " conditioning " implies an influence operating over a period and it is quite possible that the initial impetus to arrowing may occur some weeks before. Should the influence be a soil moisture factor, it is necessary to go back some weeks again in order to assess the value and effect of the rainfall at the start of the wet season. Therefore, figures given in the table include not only the wet season months but also the two immediately before, and April, which is immediately after; the reason for the inclusion of April will be explained shortly. It is obvious from the table that heavy wet seasons at Meringa will give at least good, and usually excellent, arrowing seasons; what is not so obvious is the reason for the recording of " excellent " and " very poor " (for 1942-43 and 1945-46 respectively) during seasons of much the same rainfall, though it is noticed that in 1942-43 the soil would have been saturated from December until March, while in the other year there was no heavy rain until January and detailed records show that the heavy March falls occurred early in the month and subsequently a drought developed; the canes had also been very unthrifty and backward following the dry spring, and heavy grub infestation had caused further losses. The figures for April are of interest in certain years (*e.g.*, 1944-45, when 4.8 inches fell on 17 wet days in that month). This showery weather and consequent lack of sunlight did not affect the earlier arrowing canes, but arrows in the later varieties, though fully formed in the spindles, either failed to emerge or else emerged much later than usual. This later emergence is shown very clearly in a comparison (Table 2) between the dates of the first crosses made with certain canes in 1943 and in 1945, both years of good arrowing. It is an empirical comparison, but it is the regular practice to use the first normal arrows to be found in the district, and each variety was represented by fairly large plantings.

Table 2

DATES OF FIRST CROSSES.

Year	Badila	Korpi	Oramboo	Q.27	Q.44
1943	June 14	May 31	June 8	June 8	May 31
1945	July 5	June 28	June 28	July 2	June 15

Very dry weather during April and May has a deleterious effect on the supply of arrows, since many stalks in which the apical bud has developed into a young arrow will not develop further and the arrows will never emerge, or, if they do, will be malformed and generally useless for crossing purposes. It would appear that, for an excellent arrowing season from the crossing point of view, the crops must have made reasonable growth by the time the wet season comes, the wet season should be reasonably long and uniform, and conditions during the autumn and early winter months should be such as to maintain reasonable growth and allow the emergence of arrows, but not so favourable as to lead to excessive vegetative growth.

Experiments overseas (Venkatraman, 1928 *et seq.;* Yusuf, 1945; van Dillewijin, 1946) have shown that time of arrowing can be controlled to some extent by varying the length of day, providing the canes are reasonably free, or very free, arrowers. This method, however, is not very suitable for inducing shy arrowers to produce flowers, and is hardly applicable on a large scale, since it involves a great deal of labour with no guarantee of satisfactory results. In Queensland some preliminary experiments with a solution of acetylene as used for inducing flowering in pineapples (Mangelsdorf and Lennox, 1936) did not show response in shyly arrowing canes and no further work was done. However, over the past few years a good deal of work has been carried out in delaying the arrowing of comparatively free arrowers, which usually have finished arrowing before the bulk of the other canes are ready for crossing. These early canes include many of the commercial canes from southern Queensland (such as Q.42, P.O.J.2725 and C.P.29/116) and, in addition, some very important parental varieties which arrow very early indeed: most notable of these are the hybrids from the Turkmenistan, cold-resistant spontaneums.*

The method used to delay arrowing consists in lopping the leaves on one or two occasions during the growing season. The procedure is very simple and can be followed quite satisfactorily by unskilled labour. The leaves are bunched and grasped by the hand upright about the spindle; leaves and spindle are then cut through with a sharp cane knife at a point three or four inches above the youngest exposed dewlap. The net effect is that the spindle and young leaves are cut short while a progressively greater amount of blade is left intact on the older leaves. With some varieties, one lopping causes sufficient delay in the arrowing; with others a second is necessary. The reduction of photosynthetic working area which the lopping entails leads to a stunting of the twice-lopped canes; but single loppings, which are normally made at the beginning of the best growing weather, generally have little effect on growth. The optimum time and number of loppings can be determined only by trial with each particular variety. Lopping is now standard practice with several varieties in the Meringa breeding plots; but, to guard against unexpected vagaries in the arrowing, only half the stalks of any particular cane are lopped, the remainder being left untouched.

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* *Saccharum spontaneum.*

Table 3

Effect of Lopping on Arrowing at Meringa.

Variety	Block	Treatment	Dates of Lopping	Size of Plot	Date of Counts	Old Arrows		Young Arrows		Flags		Normal Tops	
						No.	%	No.	%	No.	%	No.	%
P.O.J.2725	C	Lopped	29/2/44	1 chain	25/5/44	4	4	21	23	8	9	58	64
		Lopped	29/2/44 and 3/4/44	1 chain	25/5/44	1	1	7	7	3	3	97	89
		Control	—	1 chain	25/5/44	90	78	9	7	2	2	15	13
P.O.J.2725	A.2	Lopped	30/1/45 and 1/3/45	5 chains	22/5/45	3	1	63	7	293	35	488	57
		Control	—	4 chains	22/5/45	411	62	116	17	45	7	94	14
P.O.J.2364	A.4	Lopped	31/1/45	2 chains	22/5/45	62	27	89	37	45	18	46	18
		Control	—	2 chains	22/5/45	236	84	23	8	12	4	10	4
C.P.29/116	C.3	Lopped	31/1/45	1 chain	22/5/45	0	0	0	0	20	13	130	87
		Control	—	1 chain	22/5/45	0	0	62	43	28	20	52	37

A considerable amount of experimental work was necessary to establish the full value of lopping, and many counts of the arrowing in comparable treated and untreated plots were made. Figures for a few of the plots are set out in Table 3. These counts were made on May 22 and May 25—that is, on dates which, in their respective years, represented the first few days of the crossing season. As shown by the untreated plots, P.O.J.2725 arrows very early in the season, and by the time any number of other canes are available for crossing some 60 to 80 per cent. of the stalks of this variety have arrowed and are therefore useless; the 40 to 20 per cent. of young arrows, flags and unarrowed stalks remaining would have to provide all the arrows required for a large number of desired crosses and, without the lopped plots, would very likely be insufficient. The lopped plots of P.O.J.2725 show a much greater reserve of young arrows for the provision of arrows later in the season. The double lopping of P.O.J.2725 in 1944 was apparently too severe, since the percentage of arrows available for use at the beginning of the season was too low. The variety P.O.J.2364 shows an excellent response to lopping, but care has to be exercised with this cane since, unless well grown (and it is not a vigorous cane in North Queensland), arrowing is likely to be inhibited altogether. The figures for C.P.29/116 show some response by that variety, but these early counts do not emphasize the fact that though this variety is a fairly free arrower all arrows are produced within a very short period, with consequent severe restriction of the crossing range. Lopping delays the arrowing, but it also spreads it over a longer period, a consideration often of more importance to the breeder than the actual delaying. Co.290 is another variety whose crossing life in a season may be considerably extended by judicious lopping.

MATERIAL FOR CROSSING

Stocks of canes used for crossing purposes are maintained at the Northern Experiment Station, Meringa, some 12 miles south of Cairns, and at Freshwater, about five miles north of Cairns (*see* Fig. 3). Both plots are only a few feet above sea-level, but other differences are sufficiently marked to cause wide variation in the arrowing habits of a particular variety in the different plots. The soils at Meringa Station vary considerably in depth and texture, ranging from friable red loams to heavy grey clays, and originally supported a rather poor open forest. They are not subject to flooding, though frequently waterlogged for long periods during the wet season; during spring and early summer they often become very dry. The plot at Freshwater is situated near a small permanent lagoon on a very deep alluvial soil, typical of the Barron River flood plain. It is subject to flooding, when the waters may cover it for a week or even more, but it does not suffer from drought, except in most unusual seasons. It is regarded as good Badila land, that variety being somewhat exacting in its demands for good soil and adequate moisture; in comparison, Badila is not generally successful around Meringa, where hardier canes have to be cultivated. Rainfall figures for the two centres show that Meringa has a lower average rainfall and fewer wet days in the year; and, though the differences between figures may not appear to be highly significant, the general impression is that Freshwater is a wetter place than Meringa. During the monsoonal

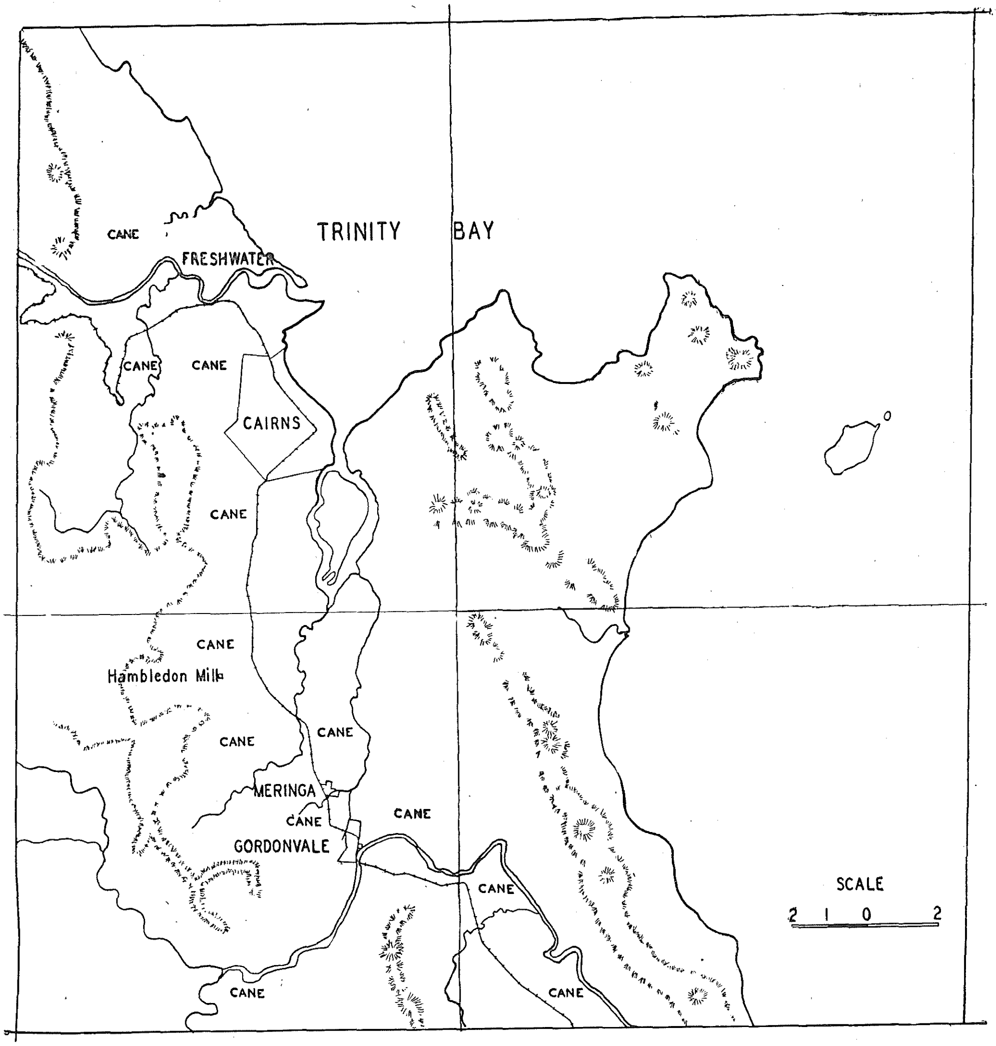

Figure 3.
Sketch map of Cairns district, showing location of Freshwater and Meringa.

wet season both localities are affected in much the same way by the heavy rains, but as autumn approaches a marked difference in average humidity becomes apparent. Meringa is situated approximately eight miles in a direct line from the sea, and mountains up to 3,000 feet or more effectively prevent the sea breezes from unduly affecting the local humidity. Freshwater, however, is only a mile or so from the coast, is on a flat plain, and is fully exposed to the moist winds coming across Trinity Bay from the open sea; the average humidity is very much higher there, particularly during the critical later summer and early autumn months. Sufficient temperature data for adequate comparison are not available for the two centres, but it is of interest to note that the mean maximum recorded at Meringa is some four degrees above that at Cairns and that the early summer days, though hotter at Meringa, usually have a lower humidity than in the city. The diurnal range of temperature is an average of seven to eight degrees greater at Meringa than at Cairns during autumn and winter.

It is by no means certain which climatic factors or combination of factors are actually responsible for variations in the percentage of stalks arrowing in a particular variety in different situations, but whatever may be the cause plantings at Freshwater fairly consistently produce more arrows than those at Meringa, and even when this does not happen arrows emerge at Freshwater earlier than on the Station. As illustrative of the differential arrowing in favour of Freshwater, it may be noted that Badila frequently arrows at Freshwater when it does not at Meringa, and the same thing has been noted with the varieties S.C.12/4, S.W.499 and Co.290. The only record of B.208 arrowing in North Queensland within recent years was at Freshwater.

The plots at Freshwater and Meringa provide the bulk of arrows for the crossing, but in addition a number are cut each season from commercial crops in the district, and on occasions neighbouring mill areas have also provided arrows. Many of the standard North Queensland canes (such as Badila and H.Q.426) are not free arrowers, and it is fortunate that many fields of these varieties are available, since the chances of getting arrows every year from the comparatively small and restricted plantings which could be made in Bureau plots would be very remote.

A list of the named varieties growing or recently grown at Meringa and/or Freshwater is set out in Table 4, together with particulars of parentage, pollen viabilities, abundance of pollen, arrowing and general remarks.

Pollen viability is an estimate of the average percentage of pollen grains showing the presence of starch. The test is made by dissecting anthers from mature flowers (*i.e.*, those due to open the following day) and staining the pollen grains in a weak solution of iodine in potassium iodide (1 gm. iodine, 1 gm. potassium iodide in 100 ml. of distilled water). Samples representative of the variety are taken, but malformed or abnormal arrows are avoided, except under special circumstances. Grains regarded as viable are firm, smooth and rounded, and the contained starch is stained darkly by the iodine. Non-viable grains are often shrunken and empty and are not stained by the iodine. The viability is expressed as a percentage of the total pollen grains after several microscopic fields have been counted. Several hundred grains are examined at each test, and, depending on the previous knowledge of the cane, several to many samples are taken each season. The percentages obtained are necessarily approximate, and for ease in reference are grouped into the following classes :—0-2, 2-5, 5-15, 15-30, 30-50, and over 50 per cent. viable pollen. It has been found that varieties yielding less than 5 per cent. viable pollen may be used as females with strong males, though there will be a small proportion of selfs; any cane showing more than 30 per cent. viable pollen is usually quite successful as a male. The varieties testing between 5 and 30 per cent. are a problem, since as females they usually produce a high proportion of selfs and as males are not very satisfactory. The behaviour of Badila is unusual, because, though its

Table 4

POLLEN PRODUCTION AND ARROWING HABITS OF VARIETIES IN NORTH QUEENSLAND.

Variety	Parentage	Pollen Viability per cent.	Pollen Abundance	Arrowing. Time and percentage	Notes
Akbar	Co.270 × 27M.Q.1122*	0—15	—	Early; high	——
Atlas	P.O.J.2364 × M.1900S	0—50	Variable	Early; high	Marked variation in pollen viability from season to season.
B.147 ..	——	30—50	—	Very low	Very shy arrower.
B.208 ..	——	30—50	Abundant	Very low	Arrows very rarely.
B.726	Ba.11569 × ?	—	—	—	Has not arrowed.
B.2935 ..	Ba.11569 × Ba.6032	—	—	—	Has not arrowed.
B.H.10/12 ..	B.6835 × B.4578	—	—	—	Has not arrowed.
Badila ..	——	0—30	Abundant	Late; low	Shy arrower; self-sterile.
Black Cheribon	——	—	—	—	Has not arrowed.
C.H.64/21 ..	Uba × D.74	0— 2	—	Variable; high	Arrowing period is very short.
C.P.807 ..	U.S.1643 × ?	0— 2	—	Very early; high	Arrowing period is very short.
C.P.29/116 ..	P.O.J.2725 × C.P.1165	2—50	—	Early; high	Arrowing period is very short. Generally male. See text.
C.P.38/778 ..	P.O.J.2725 × Amu Darya 59	15—50+	—	Very, very early	Has to be lopped to delay arrowing.
C.P.38/782 ..	P.O.J.2725 × Amu Darya 59	15—30	—	Very, very early	Has to be lopped to delay arrowing.
C.P.38/907 ..	P.O.J.2725 × Amu Darya 60	—	—	Very, very early	——
C.P.39/339 ..	E.P.C.155 × P.O.J.2878	0	—	Very, very early	Has to be lopped to delay arrowing.
C.P.39/424 ..	P.O.J.2725 × E.P.C.573	15—30	—	Very, very early	Has to be lopped to delay arrowing.
Cato	Badila × Q.813	0— 2	—	Mid-season; medium	——
Co.270 ..	Co.206 × B.3747	0— 5	—	Early to mid-season; medium high	Short arrowing period.
Co.281 ..	P.O.J.213 × Co.206	0—30	—	Early; high	Marked seasonal variation in pollen viability.
Co.290 ..	D.74 × Co.221	0—50	Scanty	Mid-season; high	Short arrowing period.
Co.301 ..	P.O.J.1499 × Co.213	15—30	—	—	——
Co.356 ..	P.O.J.2725 × Sorghum durra	50	Abundant	Early; high	Progenies examined lead to doubt with regard to sorghum parentage.
Co.364 ..	P.O.J.2725 × Badila	0— 5	—	—	Shy arrower.
Co.419 ..	P.O.J.2878 × Co.290	0—30	Scanty	Variable; variable	Marked seasonal variation in pollen viability.
Co.421 ..	P.O.J.2878 × B.3412	0—50	—	Early; high	Marked seasonal variation in pollen viability.
Co.515 ..	P.O.J.2725 × Sorghum durra	0	—	Early; high	Short arrowing period; sideshoots sometimes give second crop of arrows. Very poor vigour.
Comus ..	Oramboo × Q.813	30—50+	Abundant	Mid-season; medium	Long arrowing period.
D.1135 ..	D.103 × ?	15—50	Scanty	Mid-season; medium-low	Shy arrower with long arrowing period.

Table 4

POLLEN PRODUCTION AND ARROWING HABITS OF VARIETIES IN NORTH QUEENSLAND—continued

Variety	Parentage	Pollen Viability per cent.	Pollen Abundance	Arrowing. Time and percentage	Notes
D.166/34	P.O.J.2878 × Sorghum	0—50	—	Mid-season; medium	Some doubt with regard to sorghum parentage.
D.1.52	Black Cheribon × Batjan	—	—	—	Has not arrowed.
Daniel Dupont	—	0— 2	Scanty	Low	—
E.K.28	P.O.J.100 × E.K.2	0—50+	—	Mid-late; medium	Usually a good male.
Endor	—	—	—	—	Has not arrowed.
Erianthus arundinaceus	—	—	—	—	Shy arrower.
Eros	P.O.J.2878 × 31M.Q.228*	0—30	—	Early-mid; high	—
Ewa 371	—	50+	—	Late; low	Irregular arrower.
Glagah	—	50+	—	Very early; very high	Very short arrowing period.
H.89/88	—	—	—	Medium; low	—
H.Q.409	N.G.24 (Goru) × ?	5—30	Scanty	Mid-season; low	Used as male.
H.Q.426	N.G.24 (Goru) × ?	0— 2	Scanty	—	Very shy arrower.
H.Q.458	N.G.24 (Goru) × ?	—	—	—	Very shy arrower.
Hawaiian canes:					
26C.148	Yellow Caledonia × ?	30—50	Abundant	—	Frequently does not arrow.
26C.149	Yellow Caleodnia × ?	0— 2	—	Late	Frequently does not arrow.
H.109	Lahaina × ?	5—30	—	Medium	—
H.456	H.240 × ?	5—15	—	Low	Frequently does not arrow.
M.301	—	5—15	—	—	Unreliable arrower.
20S.16	—	50+	Abundant	Early; high	—
W.4	—	0—50	—	Low	Shy arrower; usually a strong male.
28—4291	Uba × H.456	0	—	Early-mid-season; high	—
31—1389	P.O.J.2878 × 26C.270	0—2—30	—	Early-mid-season; high	Usually female.
31—2484	P.O.J.2878 × (Uba × H.456)	0—50	—	Early; high	Variable pollen tests.
31—2806	P.O.J.2878 × H.9811	0— 2	—	Early; high	—
32—1063	P.O.J.2878 × 28—4399	—	—	Mid-season; high	—
32—3575	28—4898 × 26C.270	15—30	—	Mid-season	—
32—8560	Co.213 × P.O.J.2878	—	—	Mid-season; medium	—
Hind's Special	S.spont. and noble ?	50+	Abundant	Mid-season; high	Does not always arrow.
Jason	P.O.J.2878 × 28M.Q.674*	0—50	—	Early; medium	Marked seasonal variation in pollen viability.
Juno	H.Q.409 × Korpi	0— 2	—	Mid-season; medium	—
Kassoer	Black Cheribon × Glagah	0	—	Early; medium	Frequently does not arrow.

Table 4

Pollen Production and Arrowing Habits of Varieties in North Queensland—continued

Variety	Parentage	Pollen Viability per cent.	Pollen Abundance	Arrowing. Time and percentage	Notes
Katha ..	——	0—15	Scanty	Medium ; high	——
Kavangire ..	——	0— 2	—	Early-mid-season ; high	——
Korpi	——	0— 2	—	Medium-late ; low	Frequently does not arrow.
Loethers ..	——	—	—	—	Has not arrowed.
M.1900S ..	——	5—50+	Abundant	Late ; low	Good male.
Mahona ..	——	0— 2	—	Late ; low	Unreliable arrower.
Malabar ..	——	—	—	—	Shy arrower.
Merthi ..	——	—	—	Mid-season ; medium	——
Nanemo ..	——	0— 2	—	Medium-late ; medium	——
N.G.16 ..	——	0—15	Scanty	Mid-season ; medium	Usually a good female.
N.G.24 (Goru)	——	0—50	—	Late ; low-medium	Shy arrower ; usually a good female.
28N.G.82 ..	——	0—2—30	—	—	Unreliable arrower ; *S. robvstum.*
28N.G.201 ..	——	—	—	—	*S. edule.*
28N.G.218 ..	——	2—5—15	—	Early-mid-season ; medium	Unreliable arrower ; *S. robustum.*
28N.G.251 ..	——	50+	Abundant	Late ; low-medium	*S. robustum.*
28N.G.253 ..	——	50+	Abundant	Late ; low-medium	*S. robustum.*
28N.G.289 ..	——	0—50+	—	Early ; low	Unreliable arrower ; usually female.
27N.G.6 ..	——	—	—	Early-mid-season	——
Neptune ..	29M.Q.305* × M.1900S.	30—50	—	Early-mid-season ; high	——
Oramboo ..	——	0—50	Not abundant	Late ;low	Unreliable arrower ; usually female ; season to season variation in pollen viability very high.
Otamite ..	——	—	—	—	Has not arrowed.
Petite Senneville	——	50+	—	Late ; medium	——
Pindar ..	Co.270 × 33M.Q.157*	—	—	—	——
Pompey ..	——	0—5—50	—	Mid-late ; low	Unreliable arrower ; usually male.
P.O.J.100 ..	Black Borneo × Loethers	0— 2	—	Early mid-season ; medium-high	——
P.O.J.213 ..	Black Cheribon × Chunnee	0— 2	—	Early mid-season ; high	——
P.O.J.234 ..	Black Cheribon × Chunnee	0— 2	—	Early-mid-season ; medium	

Table 4

POLLEN PRODUCTION AND ARROWING HABITS OF VARIETIES IN NORTH QUEENSLAND—continued

Variety	Parentage	Pollen Viability per cent.	Pollen Abundance	Arrowing. Time and percentage	Notes
P.O.J.2364 ..	P.O.J.100 × Kassoer	0— 2	—	Early ; high	Not a reliable arrower ; lacking in vigour.
P.O.J.2714 ..	P.O.J.2364 × E.K.28	0— 2	—	Mid-season ; high	Has not set seed in N.Q.
P.O.J.2722 ..	P.O.J.2364 × E.K.28	0— 2	—	Mid-season ; high	—
P.O.J.2725 ..	P.O.J.2364 × E.K.28	0— 5	—	Early ; high	Reliable arrower.
P.O.J.2727 ..	P.O.J.2364 × Batjan	0— 2	—	Early-mid-season ; high	—
P.O.J.2747 ..	Lahaina × P.O.J.2628	0— 2	—	Early mid-season ; high	—
P.O.J.2875 ..	P.O.J.2364 × E.K.28	0— 2	—	Mid-season ; medium	—
P.O.J.2878 ..	P.O.J.2364 × E.K.28	2—50	Not abundant	Mid-season ; medium	Marked seasonal variation in pollen viability.
P.O.J.2883 ..	P.O.J.2364 × E.K.28	0— 2	—	Mid-season ; high	—
P.O.J.2940 ..	P.O.J.2722 × E.K.28	2—50+	Abundant	Mid-season ; medium	Usually a strong male.
Q.2	—	0—30	Scanty	Mid-season ; low	—
Q.10	—	0—15	—	Mid-season ; low	—
Q.13	—	0— 2	—	Mid-season ; low	—
Q.20	Badila × S.C.12/4	0— 2	—	Mid-season ; low	—
Q.21	—	50±	—	—	—
Q.25	P.O.J.2875 × H.Q.409	0—15	—	Mid-season ; medium	Usually a good female ; not reliable arrower.
Q.27	—	0—30	Not abundant	Mid-late ; low-med.	—
Q.28	Co.290 × Q.1098	5—50	Not abundant	Mid-season ; medium-high	—
Q.29	—	30—50+	Not abundant	Mid-late ; low	—
Q.30	Black Cheribon × 28N.G.251	50	Abundant	Mid-season ; high	Some years self-sterile.
Q.31	Oramboo × H.Q.409	50±	Abundant	Mid-season ; medium-low	
Q.32	Badila × Q.813	15—30	Not abundant	Mid-late ; low	—
Q.33	Badila × S.C.12/4	15—50+	Abundant	Mid-late ; medium	Usually a good male.
Q.34	Badila × S.C.12/4	15—50+	Abundant	Mid-late ; medium	—
Q.35	N.G.24 × W.4	0—30	Scanty	Mid-late ; medium-low	Usually female.
Q.36	P.O.J.2878 × S.C.12/4	30—50+	Abundant	Early mid-season ; high	—
Q.37	P.O.J.2878 × S.W.499	0— 2	—	Late ; low	—
Q.38	S.C.12/4 self	50+	Abundant	Early ; high	—
Q.39	P.O.J.2878 × Badila	50+	Abundant	Late ; medium	—
Q.41	Co.515 × P.O.J.2940	15—50	Not abundant	Mid-late ; low	Usually not a good male.

Table 4

POLLEN PRODUCTION AND ARROWING HABITS OF VARIETIES IN NORTH QUEENSLAND—continued

Variety	Parentage	Pollen Viability per cent.	Pollen Abundance	Arrowing. Time and percentage	Notes
Q.42	Co.281 × Q.33	0— 2	—	Early mid-season; high	—
Q.44	—	0— 2	—	Mid-late; medium	—
Q.45	P.O.J.2878 × S.C.12/4	—	—	Late; low	—
Q.47	Co.290 × P.O.J.2878	0— 2	—	Mid-season; medium	—
Q.49	Co.290 × P.O.J.2878	—	—	—	Not a free arrower.
Q.50	P.O.J.2725 × Co.290	—	—	—	Not a free arrower.
Q.52	—	0— 2	—	—	—
Q.53	Korpi × Q.39	—	—	—	Rarely arrows.
Q.813	Badila × ?	50+	Scanty	Late; low	Unreliable arrower.
Q.1098 ..	Badila × ?	50+	—	Mid-season; medium	—
R.P.8	B.208 × D.145	—	—	—	Has not arrowed.
S.C.12/4 ..	—	50+	Abundant	Mid-late season; low	A good male.
S.J.2	Badila × ?	—	—	—	Rarely arrows.
S.J.4	Badila × ?	0— 2	—	Mid-season; medium-high	—
S.J.7	Badila × ?	—	—	—	Rarely arrows.
S.J.16	Badila × ?	—	—	—	Rarely arrows.
S.J.28 ..	N.G.24 × ?	—	—	—	Rarely arrows.
S.W.499 ..	—	0—50+	—	Mid-late season; low-medium	Usually a good male, but pollen viability varies from year to year.
Saretha ..	—	0—15	—	Early mid-season; medium	—
S. spontaneum Burma	—	—	—	Very early	Rarely arrows.
S. spontaneum Tank ..	—	50+	—	Very early; high	Arrowing season is very short.
Tanna, striped	—	—	—	—	Has not arrowed.
Toledo ..	Noble × spont.	—	—	—	Has not arrowed.
Trojan ..	Co.270 × 27M.Q.1124*	0— 5	Scanty	Late; low-medium	—
Uba	—	0— 2	—	Mid-season; medium	—
Uba Marot ..	Noble × spont.	50+	Abundant	Mid-season; medium-high	—
Vesta	P.O.J.2878 × 31M.Q.228*	—	—	Late; low	—

* "M.Q." canes are seedlings bred by the Colonial Sugar Refining Company at Macknade, North Queensland.

pollen test is high, it is practically self-sterile and can be used as male or female. Most of the other strong males in the Bureau collection are markedly self-fertile. Pollen viability is a very important factor to be considered in the planning of crosses, but considerations of the pollen test have to be waived at times when an important combination must be attempted, or when it is imperative to use a particular variety. The variety Co.290, for instance, has been a very important commercial cane in southern Queensland and from time to time has yielded very promising seedlings, but the arrows often do not mature their seed, so that, though the pollen test is fairly low (sometimes as low as 2-5 per cent.), the cane must be used as a male. P.O.J.2878 is another important parent whose pollen viabilities frequently place it between the male and the female range; it is then used as either male or female, but the possibilities of poor fertilization on the one hand and selfs on the other must always be borne in mind.

It has been found that normal arrows of a particular variety usually give very much the same pollen test throughout any one season; but at times variations have been noted between tests in different years, so that in one year a cane may be used as a female and in another as a male. A careful study of pollen viabilities over the seasons 1937 to 1947 did not reveal any correlation between the tests obtained and the arrowing; an excellent arrowing year, for instance, does not give a higher percentage of viable pollen, nor does the reverse hold in a poor year. Variations within the one variety occur independently of those in other canes. Seasonal variability in pollen tests may be illustrated by a few examples :—Badila, which usually produces pollen with a 15-50 per cent. viability, tested only 2-5 per cent. in 1947; C.P.29/116, normally 30 to more than 50 per cent. viability, tested 2-5 in 1940 and was used as a female; Oramboo usually acts as a female, but in 1945 gave pollen testing 30 to 50 per cent. viable; S.W.499, a consistently good male over several years, produced no viable pollen at all in 1944 and very little in 1947.

This variability makes it unwise to rely on pollen tests from a previous year in setting up crosses and enforces a system of continual sampling and testing, but it has the tremendous advantage that a cane showing a fairly wide variability can be used in a wider range of crosses than if it were constantly giving the same test. The example of change of viability in the variety C.P.29/116 just quoted is of interest in that the low test was obtained during the first year that the cane arrowed in North Queensland; in the following years it consistently showed a high percentage of viable pollen. Venkatraman (1928-1935) noted that varieties which subsequently become good males frequently yielded low pollen viabilities during the first and sometimes the second flowering after introduction into the breeding station at Coimbatore, India. C.P.29/116 may have shown a similar "settling-down" effect.

The use of varieties as males for crossing does not depend on pollen viability alone, since quantity as well as quality of the grains has to be taken into consideration. A comparatively poor tester may, by the bulk of pollen it produces, make a very efficient male, whereas comparatively high testers (such as H.Q.409) are often unsatisfactory males owing to the small number of pollen grains produced. Table 4 sets out the relative abundance of pollen, the average pollen viability, and notes as to the amount of arrowing normally to be expected in North Queensland. Only named canes are included in the table; it can be seen that the collection does not compare in extent or variety with some in other countries, but it does provide a fairly wide range of parental material. It is, of course, being added to each year. A discussion of the individual varieties would be redundant, but some notes on particular canes and a resume of the work with various bloodlines in use in Queensland are given below.

The cold-resistant spontaneum from Turkmenistan is represented by three F_1 and two F_2 hybrids obtained from the United States Department of Agriculture in 1940. They are not vigorous canes in North Queensland and their poor growth, combined with the extremely early arrowing, made it very difficult to secure crosses with them. The lopping of canes in order to delay arrowing had to be done at the correct time or the canes either failed to arrow or produced only abortive arrows. Eventually a few arrows of 38/782 and 39/424 were obtained in time to pollinate the early arrowing P.O.J.2725, and 124 seedlings were planted out in the field at Meringa in 1945. The next year a cross was effected between C.P.39/778 and P.O.J.2725. Selections were made from these seedlings and yielded parental canes approaching commercial types. These were crossed with several other canes, amongst which were C.P.29/116, Comus, Eros, P.O.J.2875, P.O.J.2878, Pompey, Q.37, Q.44 and Trojan; the progenies should yield some promising types. The emphasis with the Turkmenistan bloodline is on the development of varieties which will be resistant to the comparatively mild frosts of southern Queensland, will ratoon satisfactorily when cut early in the season, and will mature early. In order to select seedlings with these characteristics, it is proposed to make plantings of fairly large numbers on the Atherton Tableland, a high agricultural area in the hinterland of Cairns, subject to regular frosts during winter, and with a much shorter growing season than the warm coastal plain.

Shortage of staff and labour has precluded large-scale testing of other spontaneums in Queensland, but several spontaneum bloodlines at various stages of nobilization have been used. Crosses made with *S. spontaneum* Tank showed that this strain needs a great deal of dilution before a commercial cane can be expected. *S. spontaneum* Burma, which is regarded as the largest strain in the species, is a very vigorous cane and should provide valuable crossing material. It has, however, arrowed only twice in the several years it has been in North Queensland and then so early and unexpectedly that no crosses could be made. The pollen showed some viable grains and arrows were saved, yielding a small family of seedlings which have not yet arrowed. Other spontaneums are represented in the hybrids Hind's Special and Uba Marot. The former is possibly (Mangelsdorf, 1930) a natural hybrid between a noble or part-noble cane and the native Philippine form of *S. spontaneum*. It is not a reliable arrower, and though producing abundant pollen of high viability does not fertilize well, so that very few seedlings from it have reached the field. Uba Marot is apparently also a natural hybrid from a noble cane, but the spontaneum parent is probably the local strain from India (Stevenson, 1940). This extremely vigorous, hardy cane arrowed fairly freely, but despite the abundance of high-testing pollen does not produce much seed in the females with which it is combined. Mauritius experience was that seedlings by this cane were low in sugar, but only a small range of families has been examined here and no conclusions can be drawn. Agriculturally, Uba Marot is a most desirable type, and if the sugar content were higher there is no doubt it would itself be grown commercially in this State.

Higher dilutions (*i.e.*, increased nobilizations) of some spontaneums are represented by such varieties as Co.270, Co.281, Co.290 and several of the higher numbered P.O.J. canes. Some of these canes have themselves become important commercially in Queensland but many are destined to play even more spectacular roles as the progenitors of new canes. Co.270 itself is not a commercial cane here; it is thin and gives a poor cover (*i.e.*, has a sparse top), its sugar content is low, and it is a type not at all favoured by farmers, yet it has yielded some particularly fine canes. One of these, Trojan, is rapidly increasing in favour in the far northern mill areas; it is particularly suited to the wetter districts and has given very satisfactory cane and sugar yields. Co.270 has not always set seed well at Meringa and not many families have been tested to date. Co.281 is another variety which has never become a commercial cane in Australia, but it has yielded some promising seedlings. One of these became Q.42, which is useful as a special-purpose cane in frosty areas; it is an early maturing variety. Co.290, which has been a very important commercial cane, features in the parentage of Q.28, the most popular cane in the Mackay district, and several of the newer Q. canes. The combination of Co.290 with certain P.O.J. canes has been very successful, but the range of usefulness of Co.290 as a parent has by no means been fully exploited. The P.O.J. canes, particularly P.O.J.2878, are very important as commercial producers, and, as in the case of Co.290, they will probably be even more important as parents. Their diverse genetic make-up, and the excellent individual characteristics which they are capable of transmitting in large part, ensure a wide range of variation in the seedlings and a high proportion of selectable canes in most progenies. Their transmission of unfavourable reactions to diseases such as downy mildew and Fiji disease is, however, a serious fault.

It will be noted from the table that sorghum is featured in the parentage of a few canes. Co.356, which is reputed to have sorghum as a male parent, has shown no evidence of it in the progenies examined and has been abandoned as a source of that bloodline. Co.515, on the other hand, is undoubtedly a sorghum hybrid; it has a very short growing season and the arrow resembles that of its male parent very closely. It is not very vigorous and only one cross was obtained before it was lost. This yielded Q.41, which is more vigorous than its female parent and could be used freely in crosses. It is still under test.

A few crosses have been attempted with *Erianthus arundinaceus*, but without success. This large perennial grass is very vigorous at Meringa and it was thought to be worth a trial as a parent. It would, of course, need considerable dilution before a commercial cane resulted.

There are four clones of *S. robustum* listed in the table, as well as Q.30, which is a half-robustum and was the only source of that blood available in 1937. It has been tested in numerous combinations and many thousands of its progeny have been examined. It has not proved very promising as a parent, due chiefly to the dominance of poor stooling and waisted internodes. In the meantime, crosses had been made with three of the robustums (28N.G.218, 251 and 253) and a range of varieties. 28N.G.218 has not proved as satisfactory as the other two canes for the transmission of vigour, and the majority of crosses have been made with 28N.G.251 and 253, especially the former. The combination of Badila with 28N.G.251 yielded tall vigorous seedlings with excellent agricultural characteristics and very good cover, but the stooling was rather light. The hardness of rind, so desirable in North Queensland as a means of keeping the beetle borer in check, is a marked feature of these canes, as of many other robustum seedlings. Further nobilization of the 28N.G.251 blood has produced several seedlings which give promise of becoming satisfactory commercial canes, though they are still at a comparatively early stage of selection and have yet to pass through disease resistance trials. One of the most promising strains to date is the Badila x 28N.G.251 combination on to Korpi.

The change from dependence on noble sugar canes to the widespread cultivation of only partly noble seedlings has tended to be slower in Queensland than in other sugar producing areas. This has possibly been due to the fact that the noble Badila has proved so suitable for cultivation in North Queensland. It is now declining in popularity, but still is the most important cane in the State from the tonnage point of view and with a yield of over one million tons per annum is still one of the most important noble canes cultivated anywhere in the world. Whatever the reason for the delay in the changeover, the fact remains that as late as 1934 purely noble canes were responsible for 90 per cent. of the cane produced in the State; in 1947, though Badila yielded 28 per cent. of the total, non-noble canes produced more than 50 per cent. In 1934, Queensland-bred seedlings, all of which were derivatives from noble canes, produced 21 per cent. of the crop; by 1947 they produced 42 per cent., of which the non-noble seedlings were responsible for two-thirds. The point to be emphasized is that purely noble canes and seedlings from them are decreasing in popularity in Queensland as in other parts of the world, and that crosses between noble parents are becoming very much less important than other types of combinations. This does not mean that nobles are of no further use as breeding canes; but it does mean that in order to produce commercial canes they have to be combined with strains embodying wild blood.

THE PRODUCTION OF SEED

Virtually all cane-crossing work in Queensland is carried out with both males and females standing in a dilute solution of sulphurous and phosphoric acids. The solution method was originally developed in Hawaii (Verret and Mangelsdorf, 1932) and has many advantages over the other systems which have found favour at various times at other cane-breeding centres. Its chief advantages lies in a tremendous saving of time and labour, the making of certain crosses which inaccessibility might otherwise render impossible, and the concentration of all crossing work in the one locality, even the one field, so that the crosses may be easily supervised and carefully watched. The chief disadvantage is that occasional varieties do not set seed when left in solution, or, if males, may die before completion of pollination. However, the non-setting female canes form only a small proportion of the total and can be handled as individual crosses set up where the canes are growing in the field; the males can usually be replaced by new ones at intervals during the course of the cross. The saving of time and labour by this method is very important in Queensland, since otherwise it would be impossible to make a full range of desired crosses. The arrowing is variable from season to season and locality to locality: the main crossing plots are 20 miles apart, and, in addition, arrows may have to be taken from commercial fields, which may be up to 60 miles away. Were all females left growing *in situ* the normal programme of 100 or so crosses would take much more supervision than could be exercised with the facilities available. The solution method in comparison with others makes possible more than double the number of crosses, and, furthermore, allows a much closer supervision of each cross in this increased number.

A considerable amount of experimental work was undertaken before the solution method was adopted as standard practice in Queensland. The first few trials indicated the possibility that .03 per cent. sulphur dioxide solution, as recommended by Hawaiian workers in 1927 (Verret *et al.*) gave an undue proportion of deaths before the arrows had ripened their seeds, and in a series of crosses set up in 1937 the strength of the sulphur dioxide solution was reduced and phosphoric acid added in increasing amounts. The following solutions were tested :—

(1) .02 per cent. sulphur dioxide.
(2) .015 per cent. sulphur dioxide plus .009 per cent. phosphoric acid.
(3) .01 per cent. sulphur dioxide plus .0175 per cent. phosphoric acid.

Observations were continued until harvest at 28 days after the initiation of the experiment. There was little difference between the arrows in the various solutions, except that a pinkish tinge, deepening with the increase in concentration, showed in those in the phosphoric acid. At harvest there was no trace of green in any leaves on the main stalks, but sideshoots were a normal colour in all solutions. A total of 27 arrows was used, consisting of six of P.O.J.2878 and 21 of Q.37, a P.O.J.2878 seedling. Germination results showed that the setting of seed had been excellent but that in both varieties solution No. 3 had given the poorest results. Average germinations per 10 gm. of fuzz were :—

Solution	P.O.J.2878	Q.37
1	3,500	875
2	3,400	1,225
3	2,000	390

It was not clear from this whether the reduction in concentration of sulphur dioxide was responsible for the poorer results with solution No. 3, but subsequent experience led to the adoption of a solution of .01 per cent. sulphur dioxide and .01 per cent. phosphoric acid, with satisfactory results.

Coincidental with the work on the concentration of the solution, it had to be proved that the solution method was itself suitable for use under Queensland conditions. To settle the issue a series of crosses was made during the years 1937 to 1939. Each combination was made in duplicate, one cross with both males and females standing in solution, and one with the males in solution but the females left growing in the field. The duplicate crosses were made at the same time and given comparable treatment. The majority of solution crosses, however, were made at Meringa, while the field crosses were made at either Meringa or Freshwater. The comparison of solution and field crosses with over 30 different combinations, and the success in a number of solution crosses without field controls, left no doubt that the solution method would give quite satisfactory results in the production of seedlings. Of the comparable pairs, 15 yielded as many seedlings per unit of fuzz in the solution crosses as in the field, and seven were better in the solution. In several instances when one of a pair exceeded the other in yield of seedlings, the poorer yielder still produced more than sufficient seedlings for planting out. These results showed that the solution method could safely be adopted, but it had to be borne in mind that certain varieties might react unfavourably in solution and would still require field crossing to obtain seedlings if their pollen test were low.

The arrows for use in the solution method have to be selected with care. They must be cut with a considerable length of stick attached, and, so that they may be stood in a drum of solution, the sticks must be reasonably straight. Where a desired female cane has been badly lodged, it has been found advisable to make the cross on the spot rather than risk breakage of the sticks in transport or during the cross. Stalks which are showing any evidence of drought effect, due either to low soil moisture content or to root damage by grub infestation, cannot be used, since they will not remain alive in solution sufficiently long for the ripening of the seeds. Likewise, stalks damaged by beetleborer or infected with red rot (*Physalospora tucumanensis*) must be avoided for the same reason. The arrows themselves should be normal in formation and in their emergence from the topmost leaf sheath. Occasionally arrows of some varieties will not emerge naturally, and it is only after the sheath is split and the young arrow exposed that any flowers mature. This happens quite frequently with Co.290, which, incidentally, is one of the most unsatisfactory varieties to handle.

The habits of individual varieties, and whether they are to be used as males or females, decide at what stage the arrows should be cut for crossing. Some varieties, such as Q.813, do not mature flowers until the arrow has been exposed for some days, whereas others, of which P.O.J.2940 is a good example, mature flowers as the arrow emerges. The majority of varieties in use in North Queensland open their flowers one to three days after the arrows commence to emerge. Arrows to be used as males must be cut when sufficient flowers have matured to provide abundant pollen for the following morning. In the case of females, flowers already open when the arrows are cut must be removed, owing to the risk of their having been fertilized by extraneous pollen ; alternatively, the arrows are taken before any flowers have opened. In practice, it is preferable to leave the female arrows until a few flowers have opened and then remove them, since it is then certain that another lot of flowers will be ready for fertilization in the cross on the following day. If no flowers at all have opened there is always the risk that a slight error in judgment might lead to the grouping in the one cross of arrows whose flowering dates will collectively cover many more days than the individual arrows, so prolonging the period of fertilization.

Arrows are transported to the crossing paddock on a motor truck or utility. Where the journey is comparatively short, the stalks are tied loosely together into a bundle with the arrows free and held upright, or nearly so, by a man standing on the tray of the truck. Arrows can be brought along headlands and over comparatively rough ground by this method, but the vehicle must travel very slowly. For lengthy transport on good roads the stalks and arrows are placed in a wooden box (*see* Fig. 4) measuring 12 x 12 inches and 12 feet 6 inches long inside. It is

Figure 4.
Utility truck with arrow box attached.

fitted with a lid and holds from 25 to 50 arrows, depending on the thickness of the canes. The vehicle can travel at normal speeds without any damage to the arrows if they are placed in the box with the butt ends of the sticks towards the front. Careful arrangement in the box so that no leaves or arrows are twisted or tangled allows the transport of arrows over distances of 60 miles or more, and regular collecting trips two or three times a week are made over the 20 miles from Freshwater to Meringa. The arrows arrive in perfect condition, generally with the attached leaves fully turgid.

The crossing paddock, referred to above, is an area of level ground lightly timbered with regrowth forest adjacent to Meringa Experiment Station. Provision has been made on the Station itself for the crossing, but the shelter trees have not yet made sufficient progress to allow of the transfer. The trees in the paddock vary from about 20 to 40 feet in height, are fairly evenly scattered, and, while providing protection from strong winds, are not so dense as to prevent the rapid drying of the arrows after dew or rain. While realizing the importance of some protection for the arrows, it was not known whether the shading effects of the trees would outweigh the obvious advantages, and one of the first experiments of the period under review was designed to answer this question. A series of three crosses of the combination S.J.4 x Q.30 was set up with one unit in open sunlight on the Station lawn, one in the forest, and the third under a dense, well-grown mango tree. The crosses had identical treatment during the pollination period and were ripened together under the same conditions. They were sown at the same time, each cross being duplicated in the flats. Germination figures for 10 gm. of fuzz averaged 500 seedlings for the cross in the open sun, 700 for that in the forest, and 1,450 for that under the mango tree. The shade during crossing obviously did not have any harmful effect on seed-setting. It definitely caused the pollen from the females to be released over a longer period than in the open, and it is probable that the protection of the delicate stigmas from the direct rays of the sun allowed a better setting of seed.

The two gallons of solution for each cross are contained in a four- or five-gallon steel drum with the top removed. The drum is coated with a black bitumastic paint of the type commonly used for coating the under parts of motor cars; this forms a tough, insoluble skin which is resistant to the weak acid of the solution and provides reasonable protection for the metal underneath. Tins are usually repainted at the end of each season, since the sharp cut ends of the stalks often break the film of paint and so allow corrosion of the metal. Generally the solution remains perfectly clear in the tin, but on occasions a milkiness develops. The cause of this is not obvious, but the trouble can be controlled by applying further coats of paint. Arrows kept in tins which show this precipitate do not mature as satisfactorily as those in clear solution. The black colour of the tins does lead to some heating of the solution on warm sunny days, and a rise in temperature of as much as 10° F. has been observed. This is detrimental to the keeping qualities of the arrows, and care is taken to shade the tins from the direct rays of the sun.

The arrows, whether straight from the field or from the carrying box, are stood in solution as soon as possible after reaching the crossing paddock, and are kept there until they can be arranged in crosses. All flowering stalks in the one cross are cut to the same overall height. This is usually about 12 feet, though wild canes and poorly grown canes may be much shorter. The males are cut to such a length that the dehiscing parts of the arrows are either the same height or an inch or two higher than the receptive flowers of the females. The older leaves are severed near the dewlaps with a very sharp cane knife, seven or so of the younger leaves, counting the flag or tiny topmost leaf, being left with blades entire. It has been found that the seeds set and ripen quite satisfactorily with this small number of attached leaves, and the amount of water transpired is reduced compared with that taken by a full top of, say, 12 or 14 leaves. In addition, there is the fact that the older leaves are more easily damaged in transport and after a few days in solution generally wither and die. Arrowed stalks are not usually shot at the eyes when cut for crossing, but should they be so the shoots are left intact when setting up the cross. The young shoots grow particularly well in solution and provide valuable photosynthetic tissue when the leaf blades on the main stalk are becoming less active.

A female group of four arrowed stalks of the same length and with the arrows at the same stage of development is the desideratum for each cross. Such a group will generally yield 60 to 80 gm. of dried fuzz at harvest, with a possible total of

Figure 5.
Single crosing stand in light forest, Meringa.

25,000 seedlings or even more. However, frequently it is not possible to put four arrows of the one female in a cross, and the numbers of arrows have to be adjusted accordingly. The number of males used varies for each cross. On the one hand are males with large arrows producing abundant pollen over the full period of pollination for the particular females; on the other, males which produce pollen for a day or two only and have to be renewed several times during the course of the cross. A single arrow of a variety such as Q.39 or S.C.12/4 will frequently pollinate a full cross of four female arrows, while Co.290, H.Q.409 or D.1135 may need up to 20 arrows per cross. It is desirable that only the one combination be made on the one stand, since there is always the likelihood of pollination between females, but this is not always possible. On occasions, as during the war years and particularly in 1943, the shortage of labour necessitated the setting up of crosses in which a strong male was used to pollinate arrows of several females on the one crossing stand. The practice was discontinued as soon as possible, and seedlings from these crosses are being closely examined before a final decision is made as to their parentage. Careful records, of course, are kept with regard to the other females which may be in contact with a particular cane during pollination. Occasionally a male variety which is particularly desirable from the breeding point of view may produce only a few arrows; its crossing range can then be extended by using these arrows to fertilize a number of females in the one cross. The same stricture as regards parentage of the offspring applies here.

Figure 6.
Crossing lanterns in use in light forest, Meringa.

Each combination made, then, is normally kept separate from the others in its own drum of solution and with the arrows tied to its own stand of sawn, or light bush, timber (*see* Fig. 5). The crosspiece of the frame, which is about nine feet long, is attached at each end to a vertical upright and is about four feet six inches to five feet from the ground. The arrowed stalks standing in the tin of solution are tied with twine to the middle of the cross-piece. The females are tied first and the males, already cut to the correct height, are massed around them, particularly on the side facing the prevailing morning breezes. The massing of the arrows is important for success in the crossing. Not only does it minimise the chances of stray pollen from males on other stands coming in, but it also ensures that the pollen from the males in the cross is shed on and amongst the female arrows.

The risk of pollination from other crosses necessitates the separation of the stands in order to reduce it to a minimum. Two methods are in use at present: one, separation by the spacing of the crosses; the other, by the use of "lanterns" of lightweight cotton cloth.

Experiments in which female arrows were placed at intervals around a group

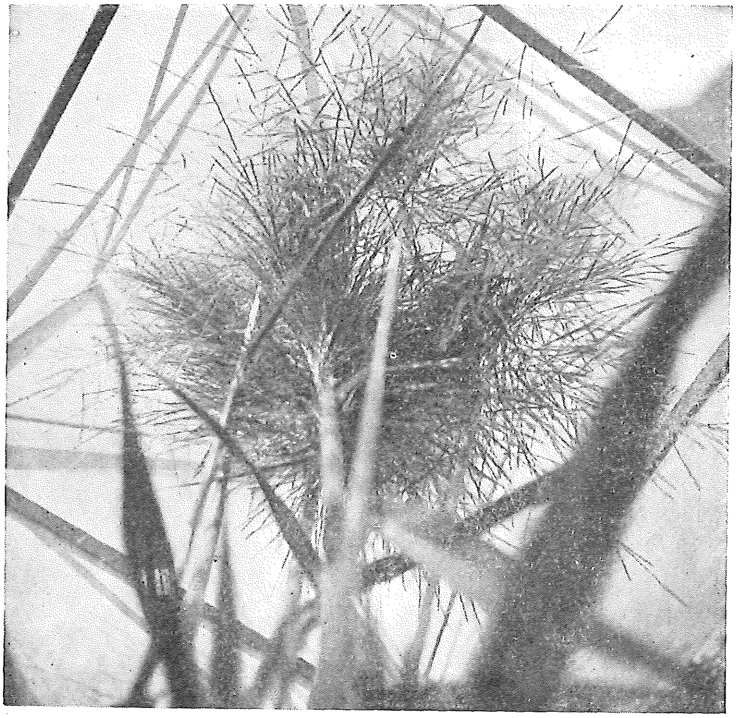

Figure 7.
Looking up into crossing lantern, showing mingling of male and female arrows.

of strong males have shown that in a canefield (*i.e.*, in a situation where arrows are exposed to all air currents) pollination occurs freely within a radius of approximately eight yards from the males but decreases sharply as the distance increases. At 10 yards there is little pollination except on the windward side, and even this ceases within a few yards. The distance of one chain adopted as the standard interval between crosses in the forest would, therefore, appear to be safe even if the males were not massed about the females; the massing is an added protection. The idea of lanterns for crossing work in the field is not new (McIntosh, 1935; de Sornay, 1938), but it does appear that the use of lanterns as an adjunct to the solution method is not generally practised at any other cane-breeding centre. The lantern used (*see* Figs. 6 and 7) consists of a light wooden framework covered with a thin cotton voile. The lanterns themselves measure three feet by three feet by four feet in depth and the material extends for a further two feet in the form of a skirt. They are mounted on frames which hold the top of the lantern a little over 14 feet from the ground, a height just sufficient for the handling of arrowed stalks 12 feet long. It was found that there was no drift of pollen (as judged by the lack of seed-setting when females were placed in lanterns adjacent to strong males) from one lantern into another, either through the material or down one lantern and up another, and the lanterns can be mounted in batteries of a convenient number. At present, there are 20 lanterns in continuous use during the crossing and when the work is established on Meringa Station itself the number will be increased to enable practically all crosses to be handled. The lanterns have obvious advantages :—the crosses can be concentrated in a comparatively small area, thus facilitating servicing and supervision ; the arrows and solution have to be carried only short distances ; the arrows are very well protected from wind and bird life ; and the massing of the arrows in the confined space ensures satisfactory pollination. The disadvantages of the lanterns are comparatively unimportant, the chief being the extra care needed in handling the arrows within the lanterns and the fact that bent stalks cannot be used.

The actual pollination takes from eight to 14 days, depending on the variety. The opening of the flowers and the consequent exposure of stigmas and release of pollen from the anthers occur at much the same time for all varieties on a particular day, but the time may vary considerably from day to day. Extensive observations have not been made with regard to the opening of flowers of female varieties, but it would appear that they behave in much the same fashion as those in the males. The females are difficult to observe without causing some movement or disarrangement of the arrows ; the males, on the other hand, signal the opening of the flowers by the release of pollen. Should the males be left relatively undisturbed, the release of the day's supply of pollen is a gradual process and may be spread over several hours ; if the air is perfectly still, without any movement of the arrows, the pollen will often remain in the anthers until it is too old to be viable. Fortunately, practically all the pollen produced by an arrow in a day can be released at the one time by shaking, or by a smart tapping of the stalk. The sudden dehiscence of a large number of anthers in good males releases a faint cloud of pollen, which drifts away on the slightest breeze. The massing, mentioned above in discussing the setting up of the cross, is necessary so that the pollen will float or stream on to the stigmas of the female and not move uselessly away. Most winter mornings in North Queensland are clear and bright following a fairly cool night with heavy dew, and under these conditions the pollen may be released by tapping at about 8 o'clock or soon afterwards. Arrows in the shade are generally slightly later, though the thin material of the lanterns causes very little delay. Usually the pollen clouds are obtained before the regular south-east breezes spring up, but if the breezes are particularly early the clouds may not be seen at all. Wet days, which are generally characterized by light showers and continued high humidity, are unsatisfactory from the crossing point of view, since anther dehiscence is subnormal and fertilization often poor. Continued wet weather, when the arrows may not dry out for several days, often results in death of the arrows through fungal attacks. A sample of the pollen from a cloud will give the best estimation of the viability of the grains which are actually reaching, or have a chance of reaching, the stigmas of the female, but the sampling (usually done with a microscope slide smeared with glycerine, and tied to the end of a long stick) is too laborious for routine use. The maceration method, plus observations on abundance of pollen, has proved to be very simple and reasonably reliable with most varieties.

After all flowers have opened and pollination is complete, the female arrows are removed to the ripening rack. This is merely a stand (Fig. 8) to which the females may be tied while the seeds mature and ripen. Since there is no pollen

Figure 8.
Ripening rack; crossing lanterns in the background.

present in these arrows and the stigmas are past the receptive stage, females from different crosses can be placed very close together; usually there is room for three lots of females in each drum of solution. It takes from 14 to 28 days from the completion of pollination to the picking of the seeds.

During both the pollination and the ripening stages, the solution is changed every second day, and at the same time a short length is cut from the bottom of the stalks, so as to expose a fresh surface. The regular changing is important if the seeds are to ripen successfully, but an occasional gap of three days between changes does not appear to do very much harm. Although it would thereby be possible to avoid the changing and cutting-off on Sundays, it was, however, continued; otherwise there was such an accumulation of this servicing on certain days as to interfere seriously with the setting up of new crosses. It was found that, with the standard solution of .01 per cent. sulphur dioxide and .01 per cent. phosphoric acid, an interval of four days between successive changes and cuttings was too great for general use, and even if allowed to happen only occasionally appeared to have adverse effects. Solutions are always changed when heavy showers have caused considerable dilution. In the cutting-off, the arrowed stalks are held vertically, a slice taken off the bottom with a specially sharpened cane knife, and the stalks then immediately placed in the fresh solution. In some crosses the arrows of different varieties elongate at different rates, and to preserve the massing different lengths have to be removed from the bottom of the stalks at each cut-off, but generally a slice of half an inch or so is quite sufficient : there is no attempt to remove a node at each cut-off. The amount removed is controlled to a large extent by the necessity for still having at least two feet of solid stalk attached to the arrow when the seeds are picked (*i.e.*, after possibly 19 cut-offs). The reason for this is that the arrows will not keep or ripen the seeds normally unless borne on a solid stem. At one time it was considered that it might be necessary to cut the new surface under water in view of the possibility that bubbles of air might interfere with the transpiration flow if the cut were made in the air. However, absorption tests showed that the interval between cutting and immersion was not sufficiently long for any appreciable movement of the flow to occur. It was fortunate that it did not prove necessary to cut-off under water, for it is a laborious, time-consuming job and many arrows are likely to be broken.

The number of solution crosses handled annually at Meringa averages just over 100, involving the use of more than 400 female arrows and a much greater number of male arrows each year. Records have been kept of the behaviour of every female arrow in solution, and it is apparent from this extensive experience that losses of arrows in solution are slightly greater than of those left growing in the field, but rarely do the losses interfere with the crossing programme. The losses referred to here are not those due to accidental breakages by birds or animals, or damage during the servicing of the crosses, but are those characterized by a premature drying and breaking up of the arrow, with the fuzz so formed showing an abnormal adherence of the flowers to the panicle branches and very few, if any, viable seeds. On occasions (such as in 1945, when there were 30 wet days in a total of 60 of actual crossing), the branches of some arrows disintegrate through fungal attacks, but usually there is no evidence of pathogenic or even saprophytic organisms in the dying arrows. It may be mentioned here that spraying the arrows with a mercurial preparation such as " Uspulun " did not result in any control of the wet-weather rotting. The premature breaking-up of the panicle branches appears to occur independently of atmospheric conditions, though the number of arrows affected varies from season to season. There is also frequently a variation as between the early and the late part of the season in the one variety, and between different varieties. Hawaiian work has shown that this effect of premature shedding may be caused by sulphur dioxide, but usually only after a period of six to seven weeks; in Queensland, the losses occur within three weeks or so of cutting, and quite often within a few days. On somewhat rare occasions the same effect is seen in arrows left growing in the field. The seasonal effect is well illustrated by figures for losses in females for several years selected at random :—1940, 101 arrows died in a total of 520; 1944, 48 in 302; 1945, 43 in 433; and 1946, 30 in 438. The year 1940 was the worst on record, but despite a loss of nearly 20 per cent. of the arrows only three crosses were lost; the loss of even a single cross is unusual. Frequently the loss of an arrow or even two arrows in the one cross still leaves sufficient viable seed for all requirements. While there is some extra work involved in handling at least four arrows in every cross as insurance against such losses, it is not so great as would appear at first sight, since crosses with two females need quite as much attention as those with four. In comparison with field crosses (*i.e.*, crosses in which the females are left uncut in the field), the solution crosses do not show an unduly high proportion of losses. Losses among field crosses can be of almost the same magnitude as those in solution crosses, though due to different agencies. Practically all losses in solution are due to the premature dying mentioned above, while the field crosses suffer losses from bird damage and breakages caused by winds. Furthermore, owing to the difficulty of adequate inspection in a field of cane there are frequently some losses due to shedding of the ripe seed. The ideal arrangement for reducing losses to a minimum would consist of lanterns erected over canes growing in the field, but shortage of labour precludes the adoption of this method in Queensland.

The variation in losses in a single variety during the season is often quite marked, deaths in the early part of the season generally being more plentiful than in the later part. This is shown most obviously in early-flowering varieties such as P.O.J.2725 and P.O.J.2364, and may be due to the higher average temperatures in the first two weeks of the crossing. It has been found that increased sulphur dioxide in the solution does not prevent these early-season losses.

Varieties differ widely in their losses in solution, ranging from Co.290, which only rarely ripens seed in solution, to S.J.4, which in tens of crosses has not lost an arrow through premature dying. The variety Co.290 is deserving of special mention, since it is an important parent. It suffers so many deaths in a normal season that its use as a female in solution has virtually been abandoned, though in certain years (the drought year 1946 was one) it does ripen seed normally. Co.290 also suffers considerable death of arrows in the field in some years, so the solution cannot be entirely to blame for deaths in crosses. It is fortunate that Co.290 yields viable pollen, though the amount produced is small and many arrows have to be used in each cross. P.O.J.2364 and P.O.J.2725, and in some years P.O.J.2878, have frequent losses, as also do several of the seedlings used in the crossing. Korpi and Oramboo have odd losses, while Badila, Pompey and S.J.4 have few. As an illustration of the varietal range, the figures of losses for the nine important females of 1941 may be quoted :—

—	Crosses		Arrows		
	No. made	No. lost	No. used	No. lost	Per cent. lost
Badila	10	0	44	3	7
Co.270	6	0	27	0	0
Korpi	11	0	46	4	9
N.G.16	5	0	19	2	10
P.O.J.2364	7	2	35	17	49
P.O.J.2725	5	0	21	2	10
P.O.J.2878	11	1	54	15	30
Pompey	5	0	18	0	0
S.J.4	13	0	52	0	0

The seeds produced by normal arrows in solution are indistinguishable from those from arrows growing in the field. They have the same plumpness, and, judging by germinations both before and after storage (*see* page 52), have the same viability. The ripening of the seed is indicated by the fluffing-off of the flowers. Singly or in pairs they float away in the breeze, and a delay of a few days in picking can lead to the loss of all the seed, particularly if the arrows are exposed to the wind. The silky hairs at the base of the florets become more obvious as the seeds approach ripeness, and the silvery appearance they impart to the fluffing arrow is in marked contrast to the dead lack-lustre characteristic of arrows which break up prematurely. The arrows are usually picked when the first few florets at the top of the main axis and at the extremities of the upper branches have started to fluff. Occasionally an arrow which has opened its flowers over a longer period than usual will fluff at the top while the seeds at the bottom are still immature, but generally the commencement of fluffing means that all seeds in the arrow have at least reached the firm dough stage and, though they may shrivel slightly on drying, will germinate satisfactorily. The solution method, as pointed out before, allows the concentration of the fertilized female arrows in a sheltered place, so making them readily accessible for the close supervision necessary to pick the arrows at the right stage. With so many arrows so close to each other, great care has to be taken that drifting flowers from one female do not become caught in the arrows of another. One of the simplest precautions is to arrange the arrows themselves at least four or five feet apart (though the stalk-butts may be in the same drum or solution) across the direction of the prevailing breezes. With such an arrangement and due care, there is little chance of contamination of the crosses by flowers from other females, and the bagging of the heads is not necessary. In harvesting the cane seed, the branches of the ripened arrow or arrows are gathered in the hand and thrust into a bag of cotton voile, measuring 17 inches by 2 feet 8 inches. The mouth of the bag is closed by a draw-string and the protruding stalks of the arrows severed with a sharp knife. The material of the bag is a light, cheap voile, woven sufficiently closely to prevent the seeds and husks embedding themselves in it, yet sufficiently open for some circulation of air for the drying of the fuzz. The identity of the cross in each bag is put beyond doubt by including with the fuzz the label which has been tied to the females throughout the crossing.

THE PACKING AND STORAGE OF SEED

Only a small proportion of the seed is planted at Meringa in the year it is produced; the remainder is packed for transit to the other Stations, or for storage. Whether for immediate or subsequent planting, however, the fuzz has to be separated from the larger panicle branches, since these interfere with the growth of the seedlings in the flat, act as foci of infection for fungal growth, and may lead to damage to seedlings when excess plants are being removed. The fuzz on at least the lower part of the arrows taken from the ripening rack is firmly attached to the panicle and has to be dried further before the fuzz can be separated. Should the weather be fine, the bags of ripe arrows are hung in the sun, and the fuzz can usually be stripped from the arrow stalks after two days. However, showery days are fairly common during the ripening of the crosses, and an electric dryer has been found indispensable for most seasons. This consists of a wooden box measuring six feet long, one foot wide and three feet deep. It is fitted with an iron rod, from which the bags of fuzz are suspended, and baffle plates to ensure adequate circulation of air. An ordinary household electric fan drives air through a grid of electrically heated wire into a funnel which delivers the warm stream through an 8-inch opening into the box. The first baffle takes the air to the bottom of the bags, and the movable second baffle is adjusted according to the number of bags. The temperature of the air-stream can be controlled by altering the speed of the fan and the current through the grid. Thermometers are fitted through the wooden lid of the box, and the air is maintained at a temperature above 90° F. but never in excess of 100° F. Since the daytime temperatures on the wet days when the dryer is in operation rarely exceed 85° F., and are usually several degrees lower, the increased temperature in the dryer is sufficient to dry out the fuzz. This artificial drying may take from three hours to two days, depending on the state of the arrows when picked; the right stage for picking is indicated by the ready separation of the flowers from the panicle branches. Some of the flowers separate freely by shaking, but generally the majority of them have to be stripped from the arrows. The fuzz from the bags is then shaken on to a large sheet of paper in a still room, obvious pieces of arrow stalk removed, and the fuzz packed into special tins.

These are $4\frac{1}{4}$ inches square by 3 inches deep, with a circular lever-lid at the top. They are of heavy tin plate and are lined with paraffin wax to prevent rusting. Square tins have an advantage over cylindrical tins of the same capacity, in that they pack more easily and occupy much less space. Each tin holds up to 25 gm. of ripe fuzz. Since a dry atmosphere is essential for the maintenance of seed-viability during storage, 5-10 gm. of dry powdered calcium chloride, tied in a small square of calico, are included with the fuzz in each tin. To prevent possible ingress of moisture, it is the usual practice to seal the lid with paraffin wax. Details of the contained fuzz are printed in paint on the tin, making an easily read, permanent label.

As mentioned above, practically all the fuzz (except that from breeding crosses) is put into store, but before discussing the experiments which showed how it could be done, the reasons for storing the fuzz may be outlined. The matter of the most suitable time for putting the seedlings out into the field has received considerable attention in Queensland, and the conclusion has been reached that, in general, an endeavour should be made to plant them at about the same time as the commercial plantings of cane are made. The original seedlings are then growing during the same seasons as they will be when they become commercial canes, and undesirable characteristics, leading to an early discard, are frequently shown before further propagation. At Meringa, the commercial plantings are made in the autumn and spring, and seedlings are planted out in both these seasons; at Mackay, all seedlings go into the field in autumn or early winter; at Bundaberg, canefields are planted in spring or late summer, and the seedlings are put out in spring. The crossing season finishes in July (*i.e.*, in winter), usually a few weeks too late for sowing for planting out in the following spring, so the fuzz is stored for sowing the year after crossing; if for autumn planting into the field, the fuzz is sown in summer; for spring planting, it is sown in the middle of the year.

The ability to sow the fuzz at the most suitable time at each Station is an important advantage of successful storage; added benefits are the insurance given against a very bad arrowing season causing a complete break in the seedling raising programme, and the fact that seedlings from a particular cross, which may be obtainable only at long intervals, may be grown in successive years.

In addition to ascertaining the required conditions for prolonged storage of cane fuzz, it was necessary to learn whether the fuzz should be forwarded to the other Stations before or after storage. Accordingly, a series of experiments was initiated over the years 1937 to 1939 with those aims in view. The first preliminary experiment, using fuzz of the self-fertile variety Q.38, was commenced in 1937, when tins of fuzz were stored for either four or nine months. In half the tins the ordinary atmosphere had been displaced by dry carbon dioxide; some tins were stored at room temperature, some at 55° F., and some at 32° F. Tins kept at room temperature for the shorter period experienced some days when the temperature exceeded 90° F. and nights during which temperatures were correspondingly high; but those left for the longer period were stored through a tropical summer and wet monsoon. Pre-storage germination yielded 800-900 healthy seedlings per 10 gm. of fuzz, but germinations after storage, particularly at room temperature, showed that many of the seeds, though capable of sprouting, did not produce normal healthy seedlings. Counts of seedlings from most fresh fuzz showed that practically every seed which shot produced a healthy, vigorous seedling. With the stored fuzz, there was considerable mortality amongst the seedlings after germination; they were not thrifty and died at varying intervals. For this reason, two counts of seedlings were made in all the storage experiments, the first at 10-12 days after sowing, and the second at 3-4 weeks. The second figure is, of course, the only significant one from the point of view of numbers of seedlings available. It was found that the substitution of carbon dioxide for the ordinary atmosphere had no effect on the keeping qualities of the fuzz. Table 5 sets out the germinations obtained in this initial experiment.

Table 5

Storage Temperature	Germination Counts per 10 gm. Fuzz			
	4 months		9 months	
	11 days	23 days	11 days	26 days
Room	625	450	40	8
55° F.	700	625	550	525
32° F.	725	675	650	—

The difference between the pre-storage count of 850 and the initial counts after cool store may not be significant, but the drop in numbers of surviving seedlings, as indicated by the count at 23 days, is quite significant for the fuzz stored at room temperature for four months, and even more so for that stored at room temperature for nine months; the latter is a failure. In comparison, the fuzz stored at the lower temperatures shows a much higher proportion of healthy seedlings, and the final counts after storage for nine months show that more than 60 per cent. of the seeds have maintained their germinating capacity and viability. It should be pointed out here that over 500 seedlings per flat is still too many for adequate growth and the seedlings in these flats would have to be thinned out.

Germination experiments commenced in 1938 with selfs from Co.356 and Q.30 again included tests in an atmosphere of carbon dioxide and at lower than room temperatures, and also included tins which were left at room temperatures for several days before storage, as well as a series not germinated until a few days after their removal from storage. These delays simulated the time taken for fuzz to reach the southern Stations after despatch from Meringa and were intended to settle the question of whether fuzz should be sent before or after storage. As in the previous experiment, carbon dioxide was without effect, and counts of this series are not included in the table of germinations at seven months summarized in Table 6. The fresh Co.356 fuzz gave 4,300 seedlings per 10 gm.; the Q.30 fuzz, 204.

Table 6

FUZZ STORAGE EXPERIMENTS.

Fuzz	Storage Temperature	Germination Counts per 10 gm. Fuzz			
		On Removal from Store		After 4 days Delay	
		At 10 days	At 20 days	At 10 days	At 18 days
Co.356	Room	1800	100		
	55° F.	2100	1850	2800	2800
	32° F.	2700	2450	3400	3250
	55° F. (delayed)	3300	3200		
	32° F. (delayed)	3000	2900		
Q.30	Room	15	0	1	0
	55° F.	150	135	170	150
	32° F.	150	150	170	160

There is no doubt that storage at room temperature in the sealed tins with calcium chloride does not preserve the vitality of the seed, and that it would not be possible under these conditions to retain fuzz from one crossing season for germination in the following year. Cool storage—whether at 55° F. or 32° F. does not appear to matter—will definitely maintain the majority of seeds in good condition and so give an abundance of healthy seedlings. The figures for the counts made after a delay following storage, or after storage following a delay, actually show an increase in the number of seedlings, which may or may not be significant; the important point is that neither period of delay causes any reduction in germination.

At the present time it is the practice to store nearly all the fuzz in a cold room, the temperature of which ranges from 32° F. to 40° F., and forward the tins to Mackay and Bundaberg Stations as required. Fuzz is not left in store beyond the one year, though some seedlings have been grown successfully from fuzz stored for a period of 20 months.

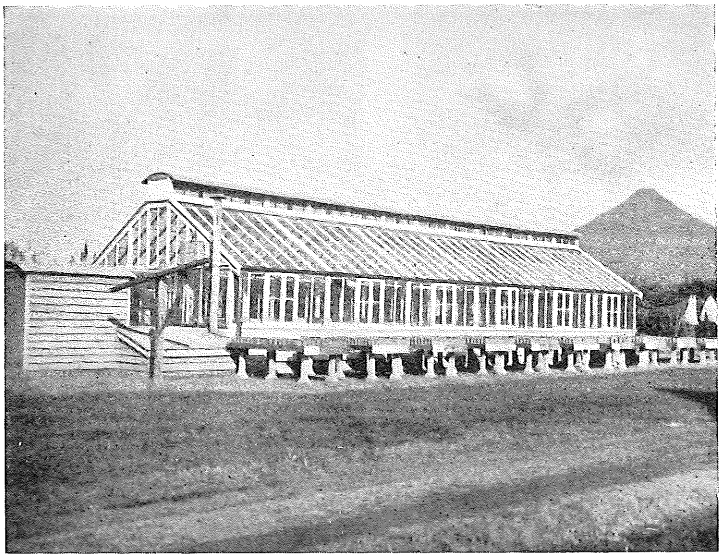

Figure 9.
Glasshouse and some of the seedling benches at the Northern Experiment Station, Meringa.

GERMINATION OF SEED

Each Experiment Station germinates the fuzz for its own requirements of seedlings, and the glasshouse and ancillary equipment is much the same at each centre. The techniques are similar, the only marked variation being the use of shades inside the glasshouse when sowings are made in summer.

The glasshouses are of concrete, wood and glass and are fitted with hot-water systems operated by household-type boilers. The Meringa glasshouse is the largest and measures 18 feet by 60 feet; it has a gabled roof and ventilation windows along the ridge (Fig. 9). The houses at the other Stations are smaller. Care is taken that the air temperatures in the houses do not exceed 100° F. for any length of time, and that adequate humidity is maintained, but the management of the seedling glasshouses does not present any more difficulty than for any other crop, the only point being that glasshouses are rare in the tropics and overheating is more likely than in more temperate zones. Excessive temperatures are prevented by the use of sprays, adequate ventilation and hessian screens. At the lower ranges of temperature, it has been found that 50° F. for a short time during the night does no harm to the seedlings, but these low temperatures can retard them seriously if at all prolonged. There are seasons when the Meringa boiler is not used at all; on the other hand, at Bundaberg, where frosts may occur during the raising of the seedlings, the boiler is lit every night.

As a first step in the sowing of the fuzz, flats of galvanized iron reinforced with wire and measuring 13 inches by 20-21 inches are filled with a rich, friable

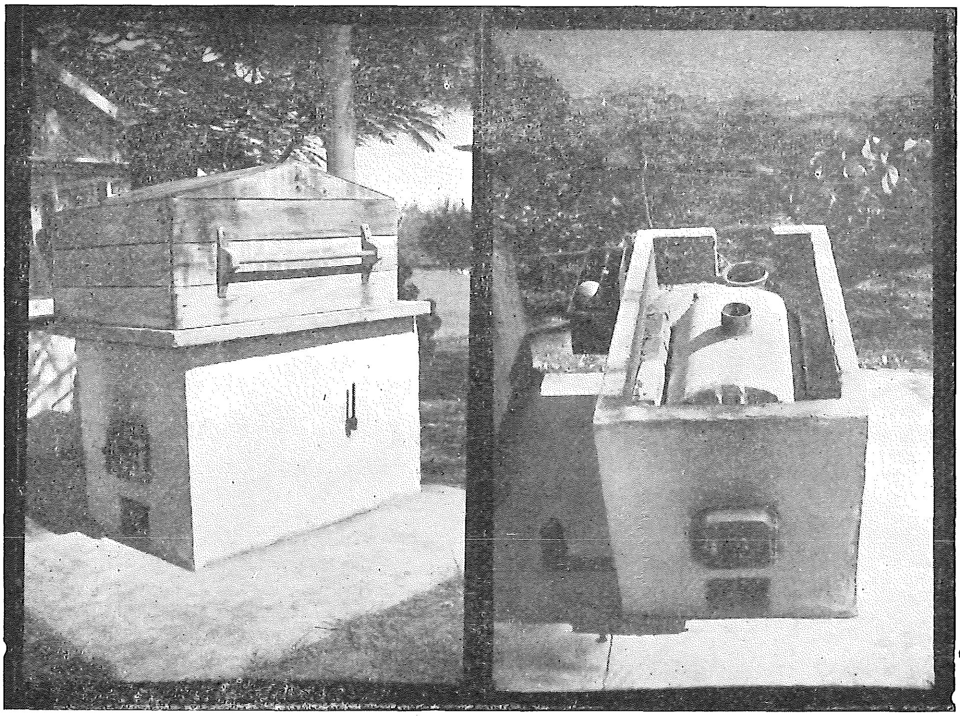

Figure 10.
Two views of the apparatus for steaming seedling flats at Mackay.

mixture of compost and soil or sand, moistened and then put over boiling water for at least four hours. An 80-gallon steel drum with a tightly fitting lid and grating in the bottom and taking four flats at a time has been used for the steam treatment, but a much more satisfactory arrangement is now being employed. This consists of a small boiler set in concrete (*see* Fig. 10) with a 4-inch steam outlet going up through a slab of concrete on which 24 flats can be stacked before sealing with a metal cover. The flats are steamed for nine hours. The steam treatment is not a complete sterilization—it does not always kill all the weed seeds—but it does kill the pathogenic soil fungi, such as *Pythium*, which are capable of causing serious losses in the seedling flats.

After treatment the flats are allowed to cool on benches in the glasshouse. These benches are of painted timber, are mounted on iron castors, and hold 10 flats. Their movability is of considerable help in the shifting of the flats to take full advantage of conditions in various parts of the house. When the soil in the flats is quite cool, the surface is smoothed and the fuzz planted. No attempt is made to separate the seeds from the husks and other flower parts, and the fuzz is spread over the surface of the flat and settled by patting with the hand under a fine spray of water. The flat is then covered with a sheet of glass or heavy waxed paper; unless direct sunlight threatens to heat the sown fuzz unduly, the covering is not moved until, 44 to 48 hours after sowing, the first tiny shoots are seen pushing up from the mat of fuzz. Management after germination is a matter for the individual operator: sometimes the glass cover may be left over the flat for two weeks or so; it may be put on to flats which were germinated under waxed paper; or, once germination is assured, all cover may be removed.

As a precaution against the introduction of fungi likely to cause losses, the flats are sprayed with a dilute solution of an organic mercurial, either at sowing or within the next few days. While the efficacy of this treatment has not been tested against pathogens in the glasshouse (for obvious reasons), it is noticeable that treated flats show much less growth of saprophytes, which frequently can grow over young seedlings if left unchecked. Occasionally green algae become apparent in the flats; control is usually obtained by spraying with dilute copper sulphate solution, combined with the removal of as much fuzz as possible from between the young seedlings.

The young seedlings in the good soil of the flats usually make satisfactory growth and do not require any fertilizer. However, some crosses frequently yield unthrifty seedlings, which usually respond to a balanced fertilizer. Losses due to unthriftiness occur within 10 days or so of germination and the survivors grow vigorously.

It is customary to plant approximately 4-10 gm. of fuzz per flat, and since this amount may contain 3,000 or even more viable seeds the resultant seedlings are frequently too crowded for proper growth. They are thinned out with forceps some two weeks after sowing, leaving 400 to 500 seedlings per flat. No attempt is made to transplant and save the thinnings.

The fact that seed may be stored successfully from one year to the next allows germination to be made whenever best suited to the needs of the individual Stations. At Meringa it is not possible to irrigate all the fields used for the propagation of original seedlings, and if the seedlings are to have the best chance they must be planted out when the ground is still moist from the wet season and when the showery early winter weather prevents undue drying of the soil. This means that for the early June planting out of seedlings the fuzz must have been sown in February or early March. Fields which can be irrigated can be planted during the dry late spring and early summer months, and seedlings for this planting come from fuzz sown in June or the first week of July. The summer sowing of fuzz at Meringa usually includes families which yield shorter types of canes suitable for a long growing season. The main bulk of the fuzz is sown in winter; but, in view of the fact that original seedlings at Meringa are not selected until the ratoon crop, the time of sowing has no direct bearing on the selection work.

At Mackay, all the fuzz is planted at the end of March or very early in April, and so the young seedling work is over before the commencement of harvesting, with its exacting demands on labour. Bundaberg Experiment Station, which experiences a severer winter than the more northerly centres, has to make all its sowings during the winter, otherwise the plants would be out of the glasshouse at a time when frosts might cause serious damage. The sowings at this Station are usually made in late June.

FROM GLASSHOUSE TO FIELD

The seedlings are usually taken from the glasshouse when they are 3-4 inches in height, but inclement weather or other circumstances not under control may cause delay, and seedlings up to eight inches in height have been successfully

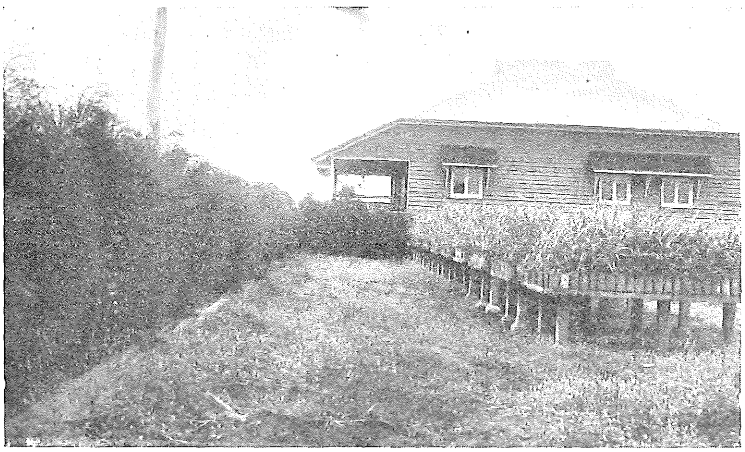

Figure 11.
Concrete seedling tables and windbreak on the Southern Experiment Station, Bundaberg.

transplanted. The larger seedlings, however, are usually cut back to compensate for the unavoidable root pruning they suffer when taken from the flats. Seedlings which are weedy, unthrifty, or much smaller than the average are not taken, but there is no attempt at selection in the flat stage.

The seedlings are transplanted individually into bottomless galvanized pots, four inches in diameter and approximately six inches in height. These are filled with friable soil, rich in well decomposed organic matter. A large proportion of this soil mixture is formed of composted organic matter prepared in covered pits. In a suitable compost all weed seeds have been killed, but on occasions these survive and cause a good deal of trouble in the seedling pots. The pots are placed on concrete tables (*see* Fig. 11), the tops of which are made of two slabs, each four feet square. The tables hold approximately 290 pots each and are so arranged that the pots can be transferred to the dray or truck with the minimum of handling.

At Mackay (*see* Fig. 12), where space for the tables is rather limited, adjacent tables have been connected by a further slab of concrete, so increasing the bench space without increasing the number of tables.

Seedlings on the benches may receive a liquid dressing of ammonium sulphate if there is any indication of nitrogen deficiency, but usually the soil is sufficiently rich for full growth in the pots. It has been found that wind will seriously check the seedlings, and some provision has to be made for their protection. At Meringa, a planting of flooded gum (*Eucalyptus grandis*) and *Callitris cupressiformis* provides a windbreak, though the *Callitris* is not thriving on this heavy clay and will have

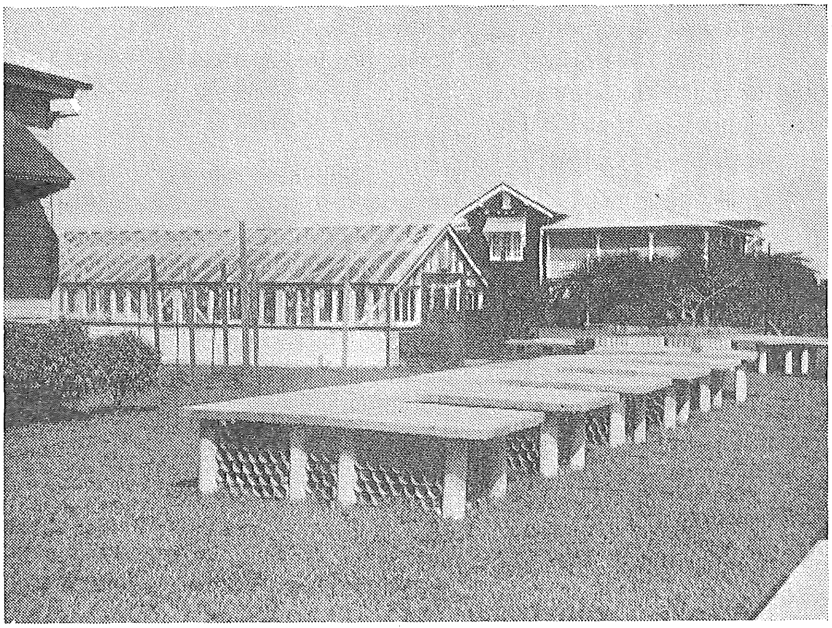

Figure 12.
Seedling benches and glasshouse at Central Experiment Station, Mackay.
Note the seedling pots stored beneath the concrete benches.

to be replaced by another species of similar growth habit. At Mackay, a break of *Callitris arenosa* has made a dense hedge and gives excellent protection to the seedlings. The Bundaberg planting of *Callitris cupressiformis* was not a success and within 10 years the break had become so gapped by the death of trees that temporary barricades of hessian have had to be erected around the break area.

Losses of seedlings on the benches are normally low, and can usually be made good from the seedlings remaining in the glasshouse after potting.

It is the aim to put the seedlings out in the field when they are 9-12 inches high (*i.e.*, 8-10 weeks after potting) though frequently they are larger than this. They have usually commenced to stool at this stage, and the transplanting does not check them unduly. The seedlings are taken to the field, which is handy to the benches, either by dray or motor truck, and the vehicle goes right on to the field. Holes are made in the opened, fertilized drill by means of chipping hoes or trenching tools, and before the soil dries the seedlings are dropped through the pots and firmed into place. Care is taken that all seedlings are planted at the same depth and that the irrigation water does not cause any variation in cover. The autumn or early winter planting at Meringa is not watered, but all other plantings are. At Meringa, furrow irrigation is practised, but a spray system is used at the other Stations.

The seedlings are planted out at Meringa in May or early June for the early batch, and from mid-October to mid-November for the late batch. Mackay field plantings are made at the end of July or very early in August, and those at Bundaberg during the first or second week of November. Every effort is made to plant the seedlings out into the field as quickly as possible so that the whole batch will be planted at much the same time. As far as possible, all members of the one family are planted on the one day.

Seedlings are not planted immediately adjoining a headland, drain or " finish out," and stools of a medium-vigorous standard cane are substituted in these positions. The spacing between rows of seedlings is 5 ft. at Meringa and 4 ft. 6 in. at Bundaberg and Mackay, while there is 2 ft. 9 in. between seedlings at Meringa and Bundaberg and 2 ft. 6 in. at Mackay.

Individual families of seedlings are planted in rows running the length of the field rather than in a greater number of shorter rows. The chief reason for this is that the long rows will run through the different variations of soil which might occur in the block, and in addition the plantings are made more easily with less chance of confusion amongst the families. The selection work among the original seedlings is based on a unit of 1/40th acre of seedlings, with adequate comparison with standard canes, so all seedling blocks are laid out with this in mind. The usual practice is to plant 12 seedlings in the drill, then one sett of a standard cane followed by 12 more seedlings, and then three setts of the cane end to end. The planting can be represented as follows; where O=a seedling and X= a sett of a standard cane :—

XXXOOOOOOOOOOOOXOOOOOOOOOOOOXXXOOOOOOOOOOOOX
XXXOOOOOOOOOOOOXOOOOOOOOOOOOXXXOOOOOOOOOOOOX
XXXOOOOOOOOOOOOXOOOOOOOOOOOOXXXOOOOOOOOOOOOX

Under this scheme there are rows of the standard cane running across the drills after every 12 seedlings; every seedling, therefore, is within six yards of a stool of the commercial cane.

The selection of a cane for standard amongst the seedlings has to be carefully made. The cane must not be so vigorous that it will lodge when mature, for a lodged cane will give erratic brix values, making adequate comparison with the seedlings impossible; on the other hand, the cane must grow quickly in the early stages, so that it will not be crowded out by the seedlings. The cane must also be a reliable ratooner (where selections are made in the ratoons), it must have at least average sugar content, and its behaviour towards the ubiquitous diseases such as top-rot and the various leaf spots should be well known. At Meringa, Badila is suitable as a standard for the early batch of seedlings, and either Q.13 or Korpi is used for the late; at Mackay, Q.28 is used, while at Bundaberg Q.49 appears to be suitable. P.O.J.2878 is the standard in the planting of seedlings at Lansdowne Road, Mackay, and Badila is included with the Babinda seedlings.

When the Babinda plot was first planted (in 1945), original seedlings, germinated and potted at Meringa, were transported in the pots to the farm. However, this involved a large amount of labour at a busy time; it meant also that the young seedlings had to be watered by hand, since the farm was not irrigated, that there was a serious risk of introducing strange weeds in the pots, and that a considerable amount of harvest trouble could be expected owing to the inequality of the resultant crop. It was decided, therefore, to take setts from original seedlings at Meringa for the Babinda planting; experience over two seasons has proved the soundness of this method. It should be emphasized that there is no selection of the original seedlings at Meringa; two setts are taken from every seedling, the only exceptions being those with some very obvious inherent defect, which would prevent their ever becoming commercial canes. At Babinda, the planting of these setts is treated as a routine farm operation, except that the pair of setts of each seedling is spaced 2 ft. 9 in. from its neighbour in the row, and setts of Badila are included as standards. The planting is made under favourable conditions, since there is more flexibility with regard to time of planting, no watering is necessary, the comparison between seedlings from setts and the standard stools is probably more reliable, and the comparatively uniform crop facilitates harvesting.

The numbers of seedlings planted at the various centres varies somewhat from year to year, but the figures for the 1947 season give an indication of the numbers handled. At Meringa, 2,500 seedlings were planted in the first batch, 6,700 in the later; there were 920 seedlings (*i.e.*, 1,840 setts) at Babinda; Mackay planted 7,000 on the Station and 1,900 at Lansdowne Road, and Bundaberg put out 5,900.

The growing seedlings are kept under close observation until selection, but all notes are on a family basis, not on that of the individual seedlings. Leaf freckling, ring spot and other minor diseases, and genetical aberrations are only noted if particularly severe; red stripe and the subsequent top rot are always present at Meringa, and counts of sticks killed by the disease are made during the later stages of growth; mosaic occasionally occurs at Bundaberg, and diseased stools are rogued. Insect pests are usually confined to the root-pruning white grubs, which are now easily controlled by benzene hexachloride.

THE SELECTION OF SEEDLINGS

Seedlings at Meringa are selected either for breeding or for commercial purposes, but all other plantings are selected for commercial canes only. Selection for breeding purposes follows the standard methods in use for the improvement of any crop, bearing in mind the heterozygous nature of sugar cane. Certain essential commercial characteristics, such as vigour, satisfactory habit, freedom from malformations, etc., should be present in a breeding cane, but the particular important features which make its use warranted should also generally be apparent, and the cane must, of course, be a comparatively free arrower. However, it is not intended to discuss in detail the selection of Queensland parental material, vital as it is to the success of the whole cane-breeding programme.

The selection of commercial canes commences with the selection of the combinations which are to provide the seedlings. This is an obvious truism, but one which quite often does not receive as much attention as its fundamental importance warrants. The extremely heterozygous genetical make-up of sugar cane results in the production of seedling families which are not uniform and which yield only a small percentage of selectable seedlings. Progeny-testing on an adequate scale is, then, very difficult, and special care must be exercised in deciding whether certain combinations are to be discontinued or not. Some families may be definitely discarded after only one year's trial (*e.g.*, Badila crosses at Bundaberg produce obviously unsuitable types, and Co.356 families do likewise in North Queensland). There are very many families, however, which are not so patently unsuited, and every cane breeder has had the experience of getting a most unimpressive lot of seedlings from a combination which in other seasons has yielded commercial canes. Very little significance can be attached to average figures for a family, and the emphasis should be on a critical examination of the necessarily few seedlings selected for further propagation; as long as a family is yielding commercial or near commercial canes, though as a very small percentage of the total seedlings examined, that cross must be repeated. Two crosses in particular may be cited as examples of combinations which justify considerable repetition on the basis of actual yields of seedlings, though they frequently show nothing of promise; the cross P.O.J.2364 × E.K.28, which in Java yielded P.O.J.2878, a cane of considerable importance in Queensland, has been very disappointing here, though several hundred seedlings have been examined; the cross Co.290 × Q.1098, which yielded Q.28 in 1935, has shown little promise since. The unwillingness to discard families where there is a chance of a successful cane will, of course, lead to some accumulation of crosses on the Stations, but it is considered more desirable to have fewer seedlings of many crosses than to have fewer crosses. Much more information is provided by, say, 200 seedlings for each of five years, than 1,000 seedlings of the same cross in one year, and probably there is more chance of selecting a good cane.

The importance of the established commercial canes as parents of new canes for a particular district is only proved by trial and error. In North Queensland, the noble Badila is still the most important cane, yet Badila seedlings which have reached commercial propagation are very rare, though thousands have been grown. Most of the other prominent nobles have also been disappointing, though occasionally they may be of importance in transmitting certain characteristics; Korpi, for instance, appears to transmit a high sugar content to its progeny. While a commercial cane should on *a priori* grounds yield seedlings of satisfactory performance, it is frequently a related cane that is just below commercial standard which proves the best parent.

The original seedlings are selected at Meringa during June, at Mackay during July, and at Bundaberg during August; the selection work is timed to give adequate sugar content for comparison, and yet not be too late for the spring planting of the selected canes. At Meringa, as far as possible selections are made among the ratoons of the original seedlings, though in addition outstanding seedlings, as revealed by a rapid inspection, are usually taken from the plant blocks. Selection from the ratoons is preferable to that from the plant, because very frequently selections in the plant crop do not impress at all in the ratoons. In addition, a large proportion of the seedlings being selected from the plant crops at Meringa eventually showed themselves to be very poor ratooners and their discard on that account left only small numbers of seedlings for commercial propagation. It is not claimed that because an original seedling stool gives a good ratoon stool the following year it is necessarily a sound ratooner, but the odds are in favour of it, whereas the ratooning powers of a plant selection would be absolutely unknown. At the present time, owing to shortage of suitable land, selections are made only on the plant crop of original seedlings at Mackay and Bundaberg.

As far as possible, the selection of the seedlings is carried out by a group of officers rather than an individual. The group works as a unit, and each selection is decided upon by discussion between the members *in the field*. Such factors as cover, habit, number, size and shape of sticks, refractometer brixes and the presence of any abnormalities or pathological features are considered in relation to the other seedlings and the nearest stools of the standard cane. Selections are made in blocks of approximately 1/40th acre, each of which consists of six rows containing 12 or 13 seedlings each and is bounded at the row ends by stools of the standard cane. This collection of 72 or 78 seedlings, which may represent six families, one to each row, or, at the other extreme, belong completely to one family, is selected as a discrete entity without reference to neighbouring rows or blocks. The importance of selecting block by block through a field and making comparisons only with the seedlings and the standard cane in each individual block is emphasized when there are soil or other variations in different parts of the field—it is very easy, for instance, to carry on a mental picture from the first 1/40th acre examined, even though growth may be markedly different in other parts of the field.

Normally not more than four canes are selected from each 1/40th acre plot, and none at all is selected when the seedlings fail to equal or better the standard. It is very difficult to get any statistical basis for making comparisons between original seedlings and the standard cane, which has of course been grown from setts, but what appears to be a reasonably sound basis for comparison between individual seedlings (*i.e.*, for the selection of the better seedlings) has been worked out. It is based on comparisons of differences in stooling and brix (practically the only factors lending themselves to ready examination and statistical analysis) as between individual original seedlings and their subsequent performance when, as selections, they are planted out in 40-sett plots for their first vegetative propagation.

The measure of stooling in the original seedling stool is the number of sticks of millable cane at the time of the selection, whether the selections are being made in the plant or the ratoon crops. The stooling in the (4×10)-sett plot is obtained by dividing the number of sticks in the plot by the number of stools, in the plant crop only. An attempt was made to measure the effect on stooling of the gaps caused through the failure of some of the setts to grow, but the correction figure obtained from a consideration of plots of standard canes showed that the small

Table 7

Regression Coefficients of Stooling in Original Seedlings and in 40-sett Plots.

n = number.

b = regression coefficient.

—	Plant Original Seedlings									Ratoon Original Seedlings					
	Meringa			Mackay			Bundaberg			Meringa			Bundaberg		
	n.	*b.*	Sig.	*n.*	*b.*	Sig.	*n.*	*b.*	Sig.	*n.*	*b.*	Sig.	*n.*	*b.*	Sig.
"A" Seedlings ..	83	.143	**	95	.214	**	45	.185	**						
"B" Seedlings ..	130	.142	**	59	.171	**	88	.134	**						
"C" Seedlings ..				8	.101										
"D" Seedlings ..				8	.192					62	.035		75	.080	*
"E" Seedlings ..	79	.211	**	34	.147	**				17	.071	*			
"F" Seedlings ..	14	.128	**	86	.204	**	69	.309	**	145	.110	**			
"G" Seedlings ..				84	.250	**									
Average		.154	**		.193	**		.223	**		.077	**			
Remarks	Homogeneous			Homogeneous			Not Homogeneous			Not Homogeneous			—		

* = significant at 5 per cent. level.

** = significant at 1 per cent. level.

percentage of failures occurring had little, if any, effect on the stooling of the survivors. It was not used in the calculations discussed below. Owing to the wide variation in stooling of the standard cane planted as a grid through the field of original seedlings, it was found useless to attempt to compare the stooling in the seedlings with that in the standard, and the seedling figures are therefore used as absolute values. Likewise, the figures for the 40-sett plantings are not referred to those of the standard.

The correlation coefficient is a value which can be used to measure the interdependence of two factors and would be suitable, for instance, in calculating the relationship existing between the average stooling in the original seedlings and that in the 40-sett plots. However, it has the serious weakness that, while it expresses the relationship in general terms, it fails to provide any means whereby the figure for stooling in an individual original seedling could provide a basis for calculating the expected stooling of the same cane in the 40-sett plot. On the other hand, the regression coefficient concept will allow this to be done. It involves the calculation of the frequency distribution of the individuals having one value in common; in this instance, the 40-sett stooling figures are examined for every cane having the same number of sticks in the original seedling. It was found in this work that a straight line provided the best fit for the successive frequency distributions. The regression coefficients were highly significant for the majority of the groups of seedlings for which data were available on the stoolings in the two crops. The coefficients obtained, plus a noting as to the significance of each, are set out in Table 7.

The essential factor being sought is the significance of differences between the stooling in original seedlings in order that the selectors may know with some degree of certainty the difference in stooling which has to be noted. A measure of this can be obtained from the regression coefficients, and the percentages of increases obtained in stooling in the 40-sett plots for varying differences between original seedlings are set out in Table 8. An increase in 50 per cent. of the cases is, of course, due to chance alone, and it may be arbitrarily assumed that a two-to-one chance of increase means that an improvement is being effected. These odds show as an increase in 66 per cent. of the samples.

Table 8

SIGNIFICANCE OF DIFFERENCES IN STOOLING BETWEEN ORIGINAL SEEDLINGS.

Differences Between Original Seedlings (Sticks)	Percentage of Seedlings Giving a Positive Difference in 40-sett Plots.				
	Plant Original Seedlings			Ratoon Original Seedlings	
	Meringa	Mackay	Bundaberg	Meringa	Bundaberg
0	50	50	50	50	50
1	56	56	56	53	52
2	62	61	62	56	54
3	67	66	68	58	55
4	73	71	73	61	57
5	77	76	78	64	59
6	82	80	82	66	61
7	85	84	86	69	62
8	88	87	89	71	64
9	91	90	92	74	66
10	93	92	94	76	67

It will be noted that the figures for the plant original seedlings are virtually the same for each of the three Stations; the figures for ratoons at Meringa are markedly at variance with those for the plant stools; the Bundaberg ratoon figures are for one year only and should be accepted with caution on that account. The conclusion is warranted that selectors in *plant* original seedlings, in weighing the agricultural characteristics of one seedling against another in the same 1/40th acre plot, should not take cognisance of a difference of less than three sticks. The average stooling of the selected original seedlings in the plant crop at Meringa was 8.15 sticks, at Mackay 8.8, and at Bundaberg 12.2, so that the difference of three sticks represents a difference of the order of 25 to 35 per cent. A stooling of 11.0 in the ratoon seedlings at Meringa needed differences of six sticks, and in addition the regression coefficients were not homogeneous; the conclusion is that little importance can be attached to any except extreme differences between stooling in the ratoon seedlings.

The brix figures of the original seedlings were obtained by averaging the hand refractometer readings from juice extracted by a steel tryer from a point one-third of the way up the stick; five, or half the total number of sticks in the stool, whichever was the greater, were sampled. Readings were taken at the same time on the standard cane which was planted as a grid over the seedling field. It was mentioned above that comparisons of stooling in the original seedlings and the standard cane would not be valid, but there does not appear to be any reason why brix figures should not be compared, especially since comparisons at selection time are made in the one 1/40th acre plot—*i.e.*, with the same stools of the standard. The figure for the seedling was subtracted from that for the nearest standard stools to give the figure for use in the subsequent analysis. The figures for the 40-sett plots were taken from readings made on every alternate stick in the central two rows; similar readings were made for the plots of the standard cane, and the differences between the two used. The relationships between the seedling-standard brix differences in the original seedlings and in the 40-sett plantings were subjected to the same analysis as were the stooling figures. Details of the regression coefficients obtained are set out in Table 9.

Table 9

REGRESSION COEFFICIENTS OF BRIX FIGURES IN ORIGINAL SEEDLINGS AND IN 40-SETT PLOTS.

n = number.

b = regression coefficient.

——	Plant Original Seedlings									Ratoon Original Seedlings		
	Meringa			Mackay			Bundaberg			Meringa		
	n.	*b.*	Sig.	*n.*	*b.*	Sig.	*n.*	*b.*	Sig.	*n.*	*b.*	Sig.
"B" Seedlings				53	.61	**						
"D" ,,										64	.48	**
"E" ,,	80	.21		31	.46	*						
"F" ,,	14	.21		45	.51	*	69	.14		146	.59	**
"G" ,,	73	.15		84	.57	**				80	.20	
Average		.16	*		.55	**					.45	**
Remarks	Homogeneous			Homogeneous						Homogeneous		

* significant at 5 per cent. level.

** significant at 1 per cent. level.

The significance of differences in brixes of original seedlings as reflected in differences in the figures for the 40-sett plots is set out in Table 10.

Table 10

SIGNIFICANCE OF DIFFERENCES IN BRIXES BETWEEN ORIGINAL SEEDLINGS.

Differences Between Original Seedlings : Units Brix	Percentage of Seedlings Giving a Positive Difference in 40-sett Plots			
	Plant Original Seedlings			Ratoon Original Seedlings
	Meringa	Mackay	Bundaberg	Meringa
0	50	50	50	50
1	53	62	52	57
2	56	72	54	63
3	59	82	56	69
4	61	88	58	75
5	64	93	60	80
6	67	96	62	84

The assumption that a positive difference in two cases out of three means that an improvement is being effected may be made for the brix figures as for the stooling, and from Table 10 it is apparent that little attention need be paid to brixes of original plant seedlings at Meringa; the figures for plant seedlings at Bundaberg indicate the same conclusion, though they were for only the one year. At Mackay, however, a difference of less than two units should not be considered when selecting the seedlings, and in ratoon seedlings at Meringa the difference should be at least three units. Brix averages for batches of seedlings vary from 18 to 23, so that the 2-3-unit differences required represent 10-15 per cent. It may be noted here again that selections at Mackay are made entirely on the plant original seedlings and at Meringa almost entirely on the ratoons.

The number of seedlings selected varies somewhat from year to year, but the figures for 1947 may be quoted as being fairly representative. In that year there were 170 selections from the original seedlings at Meringa, 25 at Babinda, 95 at Mackay, and 87 at Bundaberg. These numbers are, of course, obtained by the selection of the apparently best seedlings at each centre, which is the normal process of selection. It is a moot point, however, whether it is the most suitable method. A field of cane seedlings shows tremendous variation between individuals, and each seedling is so very sensitive to the immediately local environment that the development of a method of selection by discard should be given serious consideration. In this scheme, all seedlings except those with obvious defects debarring them from ever becoming commercial canes would be taken for further propagation and examination. It would involve an increase in the area of land under seedlings, but may be worth the extra work involved.

Each selected seedling is planted in a single 4-row × 10-stool plot; if 40 setts cannot be cut from any particular seedling, the balance of the plot is planted with setts of the standard commercial cane. Plots of a standard cane are dispersed through the field in such a way that every seedling plot contacts a standard plot. If necessary, the field is irrigated for a strike, but is not usually watered again unless continued dry weather threatens to kill the plants. Notes are made on the rapidity and completeness of germination, and on habit, early cover and vigour, in all cases in comparison with the plots of the standard cane.

It has been shown (Bell, 1938) that the variation between stools in a 40-sett plot is very large, and that there must be a difference in yield from these plots as high as 20 per cent. before any significance can be attached to it. It is extremely improbable that any new canes will outyield the present commercial canes in Queensland by 20 per cent. or more, so there is obviously no necessity for the determination of plot weights or volume of cane. On the other hand, refractometer brix shows comparatively small variation from stick to stick and can be used as an aid to selection. The selection, then, is chiefly visual, though every selector is provided with the brix figures (and the comparable figures for the nearest standard plot) and the early notes on germination, vigour, habit, etc. Several officers are co-opted for the selection work, but, in contradistinction to the selection by the team in the original seedlings, each selector works independently. The final decisions are made in discussion after each officer has formed his opinions. All the characteristics which go to make up a successful commercial cane are considered in these selections, but no attempt is made to allot points for each attribute separately. It is considered that such an allotment is not sound, for the total points would not give a true picture of the cane; for instance, a single item, such as very brittle sticks or excessive growth cracks, may prevent a variety ever being grown commercially despite the fact that its total of points is quite impressive. There is no objection, however, to the allocation of points to a variety *as a commercial cane*. In Queensland, it is the practice to assume a figure of 10 points for each plot of the standard cane. The plots of seedlings are compared with the nearest plot of the standard and allotted points according to the individual opinion of each selector.

The selection in the 40-sett plots is made in the plant crops at all Stations and takes place during the winter and early spring months. The crops have not then reached maturity, but the comparison with the standard cane, whose behaviour is known, provides a fairly accurate picture of what is to be expected within the next few months. Occasionally errors occur, as when the earliness of selection and cutting prevents the development of red rot in a susceptible cane, but the risks are worth the added advantage of the earlier planting.

The number of seedlings taken from the 40-sett plots depends to some extent on the quality of seedling offering, but usually at least 20 are selected; if there are many impressive seedlings, the total may be 30 to 40. The important point is that all the promising seedlings are taken. These go into what is rather loosely termed a "yield-observation trial." Each seedling is represented by a single plot, six to eight rows wide and varying in size from 1/20th to 1/40th acre, depending on the number of seedlings which have to be fitted into the trial. Plantings are made under normal commercial conditions, and notes are kept on the germination and general behaviour of the seedlings in comparison with the plots of the standard cane. During the following winter and spring, maturity tests are made and the crop harvested at the usual time. Weights and c.c.s.* figures are obtained at harvest; and, though they are for single plots only, some measure of significance can be attached to them when considered with those of the neighbouring plot of the standard cane. The trial is ratooned and kept under observation for a second season, and a further lot of maturity, c.c.s. and harvest results obtained before any selections are made.

The number of selections varies; on occasions, only a single cane may be worth further trial, sometimes 10 or 12. The number determines the form of the next trial; if four or fewer are taken they can be incorporated in a Latin square trial, but a larger number necessitates some form of randomised block trial. This trial is the final one on the Station and is carried through both plant and ratoon crops. In the meantime, if they were not already made during the previous trial, plantings of the promising seedlings are made on various farms in the district, and the canes are included in the various disease resistance trials. By the time a particular seedling has come through the Latin square or randomised block trial it has been grown in sizeable plots through four crops, its reactions to disease and the influence of different localities in the district are known, and an accurate estimation of its capabilities has been formed. Information is still lacking on its capacity to stand-over, but if a seedling appears to be a suitable type for two-year cropping arrangements can usually be made to standover one or two of the off-Station plots.

DISEASE RESISTANCE TRIALS

A description of the production and testing of new cane varieties in Queensland would not be complete without some reference to the important role played by the numerous diseases present in the State. A high degree of susceptibility to certain diseases can lead to the discarding of an otherwise very promising cane, or at least restrict its cultivation to those areas in which the diseases do not occur.

A seedling is grown on a Station under close observation for a period of six to seven years, and may also be on farms for two or more years before it is released for general distribution. During this period of selection and propagation it is exposed to natural infection from many diseases, and susceptibility to any of these would probably show. Diseases in this category include red stripe and top rot (due to *Xanthomonas rubrilineans*), ring spot (*Leptosphaeria sacchari*), eye spot (*Helminthosporium sacchari*), pokkah boeng (*Gibberella moniliforme*), leaf burn, cold chlorosis, root rots, rust and freckles. The exposure to chance infection may not be the best method of ensuring that the resistance of the variety is revealed, but it is virtually impossible to conduct organized trials with most of those diseases and only extreme susceptibility to any of them would eliminate a seedling.

The so-called " major " diseases of Queensland, which in the past have caused serious losses and only now are being controlled or eradicated, do not occur, except

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*
$$\text{c.c.s.} = \frac{3P}{2}\left(1 - \frac{5+F}{100}\right) - \frac{B}{2}\left(1 - \frac{3+F}{100}\right)$$

Where P = Pol in first expressed juice,
B = Brix in first expressed juice,
F = Fibre in cane.

inadvertently, on the Experiment Stations. Diseases in this group include mosaic and Fiji diseases (both of which are due to viruses), gumming (caused by *Xanthomonas vasculorum*), leaf scald (*Xanthomonas albilineans*), downy mildew (*Sclerospora sacchari*) and chlorotic streak, and special trials are run annually to test the reactions of the new seedlings to these diseases. Even when a variety is going into a district in which a particular disease does not occur, it is desirable to know the reactions of the cane in preparation for a possible outbreak or a possible use for the variety in a district which has the disease. Exceptions to this general rule are made when a whole region is free from a disease; for instance, it is not necessary to test new southern Queensland varieties for leaf scald nor northern canes for resistance to Fiji disease; they are put in trials only when there is a likelihood of them showing promise for the other region.

Mosaic disease is fairly widespread in every district except the mill areas north of Townsville, where it is somewhat rare, but in view of the possible development of a serious killing strain of the disease most new canes are tested for resistance. The trials are conducted in southern Queensland, where the trials for Fiji disease resistance are also carried out. Gumming disease now occurs in one mill area only, but all new varieties are still tested for resistance; susceptibility, of course, does not mean discard of a seedling for the gumming free areas. Leaf scald is still a problem in the northern mill areas, and promising varieties are often prevented from becoming commercial canes because of susceptibility to the disease. The leaf-scald resistance trial is conducted near Cairns, in North Queensland, and usually includes only northern seedlings. Downy mildew trials are conducted in both North Queensland and southern Queensland, and every new variety automatically goes into one or other of these trials. Chlorotic streak trials are also run in both northern and southern parts of the sugar belt; but, owing to the fact that large areas are not affected by this disease, seedlings do not usually reach these trials until distribution of the canes to the growers is well advanced.

In addition to the two groups of diseases mentioned above, there is yet another; it includes diseases for which satisfactory disease trials have not yet been developed in Queensland and which cannot be relied upon to cause infection during the period of propagation of a seedling. It includes red rot (*Physalospora tucumanensis*), rind disease (*Pleocyta sacchari*), and pineapple disease (*Ceratostomella paradoxa*). These are normally regarded as minor diseases, but in susceptible canes under certain conditions can cause serious losses. Their incidence is very much affected by conditions of growth, and sometimes a susceptibility will remain unsuspected during all the early stages of selection and multiplication of a new cane. Recently a new seedling, Q.52, reached the stage of planned distribution to farmers before it was discovered that its susceptibility to red rot precluded it from ever becoming a commercial cane, despite its other excellent qualities. Rind and pineapple diseases are in a similar category to red rot; the potential importance of both these diseases has been brought home in recent years by the occurrence of rind disease over a wide area in standover crops of Q.49 and failures of plantings of several varieties due to pineapple disease. The problem of determining resistance to these diseases is receiving some attention at the moment.

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