RECENT DEVELOPMENTS IN SUGARCANE BREEDING AND THE PRESENT VARIETY POSITION IN NATAL.

By P. G. C. BRETT

Introduction

The sugarcane breeder lives in a Looking-glass world where the advice of the Red Queen to Alice still holds good—"Now *here*, you see, it takes all the running *you* can do, to keep in the same place. If you want to get somewhere else, you must run at least twice as fast as that!" Varieties do not stay as they are: they deteriorate. Simply to maintain yields, a continuous supply of new varieties is needed. To improve yields, the sugarcane breeder has to "run at least twice as fast": he must not only produce seedlings of superior vigour, but he must also outpace the sugarcane pathogens which are continually improving their adaptation to the varieties in cultivation. It appears that in recent years the virus responsible for mosaic disease may have produced a new strain capable of attacking many varieties that in the past were commercially immune, and made the task of the sugarcane breeder correspondingly more difficult. The fact that smut disease, after apparently lying dormant for many years, is now not uncommon may also be the result of a new strain having been produced.

A big advance towards improved yields in Natal was made when Uba, a natural variety, was replaced by some of the artificially-hybridized Coimbatore varieties, in particular Co.281. The next advance was started with the replacement of the Co. varieties by the N:Co. varieties which had been raised and selected in Natal from seed sent from India. With each step forward in the improvement of yield, further advance naturally becomes more difficult, but now that sugarcane breeding can be undertaken in Natal we have at least a valuable insurance against deterioration in the present commercial varieties. Also, advances may prove possible in other directions besides yielding ability *per se*—for example, the production of varieties which flower rarely or not at all.

Intensive and extensive selection

The degree to which further increases in yield are immediately possible has its bearing upon whether an intensive or extensive system of selection should be adopted. Seedling selection in the early stages must necessarily involve many errors—the tree has to be judged not by the fruit thereof, but by only a single fruit taken at random. In Hawaii, stress is laid upon the raising of enormous numbers of seedlings, which for practical reasons, have to be greatly reduced in numbers without very thorough testing, and the chance of discarding a potentially valuable seedling is thereby increased. It is argued that the gain outweighs the loss because the more outstanding a seedling is, the less is the chance of its being overlooked (Warner 1953). This argument would have particular force if rare seedlings, far surpassing present commercial varieties in yield, could be expected. But the available evidence suggests that though steady advances may occur through generation to generation of sugarcane breeding, spectacular advances within a single generation are extremely improbable. Certainly in countries where sugarcane breeding has been in progress for some time, the production of a new variety has never resulted in yields being anywhere near doubled.

The smaller the margin by which the best seedlings surpass the standard of commercial varieties, and the greater the proportion of seedlings which almost, but not quite, reach this standard, the greater is the need for accuracy in the selection process.

Since the start of sugarcane breeding in Natal, there has been a rapid increase in the number of seedlings raised annually, but, because the standard of selection has been set higher, the number of first selections has not increased correspondingly with the number raised. It appears, however, that the law of diminishing returns may result in rather a minor advance for the extra work involved if the number of seedlings is greatly increased and the proportion selected correspondingly diminished.

The first evidence that this might be so was obtained in the following way. It so happened in 1949 that 1,665 seedlings of the cross Co.421 × Co.331 were planted in one area (A), and 800 of the same cross in another, more fertile, area (B). Because of their better growth, the seedlings in (B) appeared more attractive at the time of selection, and the selection rate was nearly twice as high as that for the seedlings in (A). The actual numbers selected were 265 from (A) and 236 from B. The selected seedlings were planted in the same field. The general standard of those from (A), despite the fact that they had been selected from a considerably larger number, was not obviously superior to that of those from (B), and at the time of the second selection, 28 of the (A) group and 31 of the (B) group were taken for testing in a replicated plot trial. This trial has now been harvested. Statistical analysis shows no evidence of any difference in the means of the seedlings of the two groups. For further testing, four

seedlings from each of the two areas have been selected. It would appear therefore that no difference in the standard of selected seedlings resulted when the selection rate was changed.

An experiment was planted in 1955 to try to gauge what effect a lowering in the present standard of selection would have. Three different selections were made upon single stools of the crosses Co.421 x Co.331 and N:Co.310 x Co.331, both of which crosses were regarded as promising. In both crosses, the first selection was carried out in the usual way and continued until 47 seedlings were obtained. A lower criterion of selection was then used for seedlings in scattered portions of the area already selected, and selection continued until a further 47 seedlings were obtained. The third selection was made in the same way, but the criterion of selection was still further lowered. Seedlings discarded in the first selection for reasons other than lack of vigour were not considered in the later selections.

The seedlings of the different selections were planted as single lines in blocks of three, the selections being randomized within the blocks. The seedlings of the two crosses, though planted in the same field were kept separate. The single lines were weighed at the time of harvesting (and determinations made for sucrose per cent juice). The results are shown in Table I.

TABLE I

Comparison of three selections from Single Stools

Cross	1st SELECTION		2nd SELECTION		3rd SELECTION		Mean wt. in lbs. of the three selections
	Mean wt. in lbs.	Approximate selection rate	Mean wt. in lbs.	Approximate cumulative selection rate	Mean wt. in lbs.	Approximate cumulative selection rate	
Co.421 x Co.331	109.1	1 in 30	107.9	1 in 11	98.2	1 in 6	105.1
N:Co.310 x Co.331	161.9	1 in 17	174.0	1 in 8	151.4	1 in 3	162.4

It will be seen that there is little difference between the three selections in the mean weight of cane per line. (If a common Java Ratio is applied and the three selections compared on the basis of mean weight of sucrose per line, the differences are even less marked.)

The mean weight of cane for the control lines of three standard varieties was 103.1 lbs. for the part of the field where the Co.421 x Co.331 cross was planted, and 189.0 lbs. for the part where the N:Co.310 x Co.331 cross was planted. One of the three standard varieties was N:Co.339 which, as is often the case, did not germinate well. However, even if allowance is made for the poor germination of N:Co.339, it appears that a large proportion of the seedlings of these two crosses could not have fallen very far short of commercial standards.

There is some additional evidence that in a good cross a fairly high proportion of seedlings may approach the yielding-ability of commercial varieties. As has been mentioned above, when sugarcane breeding was first started in Natal, only small numbers of seedlings were raised and a relatively high proportion of these were selected for further testing. In the first replicated plot trial of Natal seedlings, five came from the cross N:Co.310 x Co.331. These five had been selected from only ten original seedlings, and—as the selection is unlikely to have been perfect—they were probably not in fact the best five. Nevertheless their mean yield in the replicated plot trial was 43.92 tons cane per acre, as against 49.96 tons cane per acre for N:Co.310.

General conclusions regarding the selection of single stools.

It appears that, in the best crosses, only rare seedlings surpass the present commercial varieties in yield—and then only by a small margin—but that a fairly large number may approach the yielding-ability of the commercial varieties. These two classes cannot be efficiently separated at the single stool stage; hence raising the standard of selection may have only a slight effect upon improving the mean yield of the seedlings selected.

It has been observed that when the same standard is used in selecting from the single stools of a large number of crosses, the initial rate of selection generally provides an indication of the later rates of selection. It appears that in an inferior cross a few seedlings may by chance produce good stools and be selected. As the accuracy of selection is likely to be greater in the next stage, the chances of these seedlings again being selected will, if anything, decrease.

It therefore appears that though single stools can provide a fairly reliable estimate of the value of a particular cross, they do not provide, within a cross, an efficient means for separating a few good seedlings from a large number of mediocre ones.

The later stages of selection

Experience has shown that the performance of seedlings in single lines does not provide a very good estimate of what their performance in replicated plot trials will prove to be. It appears, how-

ever, that small, single plots, if a large number of controls are included, can provide a fairly accurate basis for selection.

To obtain an estimate of the value of single plots in selection, three separate experiments were carried out with 1/100 acre plots of four released varieties. These trials were harvested in 1956. The order of the varieties (in terms of weight of sucrose) was as follows—(1) N:Co.310, (2) N:Co.293, (3) N:Co.292 and (4) Uba. The same order was given by nine of the thirteen individual blocks of four, as is shown below:

Field 5A				Field 2			Field 5B					
1	1	1	1	1	1	1	3	1	1	1	1	1
2	2	2	2	2	2	2	1	3	3	3	2	2
3	3	3	3	3	3	3	2	2	4	4	3	3
4	4	4	4	4	4	4	4	4	2	2	4	4

The greater variability in the experiment in field 5B was probably caused by the washing out of many setts in this trial, as a result of heavy rains after planting. The gaps were later filled in, but an uneven stand resulted. Given reasonably uniform conditions, single plots should provide a fairly accurate basis for selection.

In conclusion, it may be said that the forty-thousand seedlings now being raised annually should be amply sufficient for selecting all the seedlings that can be handled in the later stages of selection. Greater benefit is more likely to accrue from extending the number of seedlings that can be handled in these later stages of selection—particularly in small plots—rather than by a still further increase in the number of seedlings raised.

The Present Seedling and Variety Position

The total number of seedlings at present under trial is about 100,000; these are of course in various stages of selection. Some details of the present seedling position are given in Table 2.

TABLE 2

Seedlings at present under trial

Year in which raised	Stage of selection and number of seedlings
1946 ...	Secondary variety trials 1
1948 ...	Secondary variety trials 3
1949 ...	Secondary variety trials 10; observation plots 15
1950 ...	Primary variety trials 45
1951 ...	Primary variety trials 28
1952 ...	Single lines 548
1953 ...	Single lines 1,197; bunch stools 472
1954 ...	Single lines 1,330; 3′ lines 161; bunch stools 112
1955 ...	Single stools 29,714; in bunches, ± 30,000
1956 ...	Single stools 41,901; in bunches, ± 2,000

Of the seedlings raised in 1948 and at present in secondary variety trials, two are showing some promise. These are N.50/123 and N.50/211. N.50/123, obtained from a cross of N:Co.310 with Co.331 appears morphologically indistinguishable from N:Co.310. In trials it has yielded a greater weight of cane than N:Co.310 but has shown a lower sucrose content. N.50/211 is a seedling of the cross P.O.J. 2725 x Co.285; it has lightly-adhering trash.

Two varieties are intended for distribution in 1957. These are N:Co.334, from the cross Co.421 x Co.312, and N:Co.382, from the cross P.O.J.2725 x Co.301. N:Co.334 has given reasonably good yields in trials on the coastal sands, and as it is fairly resistant to smut disease and does not flower as profusely as the other N:Co. varieties, it may prove a useful variety in these areas. It is, however, very intolerant of ratoon stunting disease, and infection with this disease can accordingly reduce yields very considerably.

N:Co.382, like N:Co.334, may prove of particular use on the recent sands of the coastal region. It, too, is fairly resistant to smut disease. Its tolerance of ratoon stunting disease is not yet known, but it appears more resistant to mosaic than N:Co.334. One of its weaknesses is its liability to lodging.

The main change in the varieties at present in commercial cultivation will almost certainly be in the direction of a steady replacement of the older Co. varieties by the newer N:Co.'s. This change was begun with the replacement of Co.281 by N:Co. 310. Now Co.301 is rapidly declining in importance, and the first signs that Co.331—the last Co. variety to be distributed—is losing ground, have appeared. N:Co.376, which is adapted to a wide range of soil and climatic conditions, will probably come to occupy a large part of the area formerly under Co.301 and Co.331. Unless N:Co.310 should deteriorate, it is not likely to be superseded by N:Co.376 in the best areas, but it may be displaced in some of the not-quite-so-fertile areas. The cultivation of N:Co. 376 on a larger scale has shown that it does not have quite as much resistance to mosaic as it appeared to have when still under trial.

N:Co.293 is likely to increase in popularity in areas where flowering is not profuse and smut disease is not prevalent. It is not only an easily-trashed variety but tends to form cane early. However, its tendency to ratoon poorly when conditions for ratooning are not favourable may limit its final spread.

It is difficult to estimate how popular a variety N:Co.339 will eventually become, for its good points in some directions are counter-balanced by weak points in others. For example, it ratoons well but germinates poorly; it is unusually tolerant of mosaic disease but also unusually susceptible; it is capable of giving good yields on the coastal sands but under certain conditions may flower early and profusely. It is also capable of giving good yields in the higher-

altitude areas, but—particularly in these areas—it may become seriously infected with red rot disease if attacked by borer.

N:Co.292 has neither the marked failings nor the exceptionally good points of N:Co.339. It is probably assured for some time to come of a place among the commercial varieties of Natal, but is not likely to attain major importance.

Summary

It appears that, in the best crosses, only rare seedlings surpass the present commercial varieties in yield—and then only by a small margin—but that a fairly large number approach the yielding-ability of the commercial varieties. These two classes cannot be efficiently separated at the single stool stage; hence raising the standard of selection may have only a slight effect upon improving the mean yield of the seedlings selected.

Given fairly uniform conditions, small single plots of seedlings with numerous controls should provide a fairly accurate basis for selection.

The forty-thousand seedlings now being raised annually should be amply sufficient for selecting all the seedlings that can be handled in the later stages of selection. Greater benefit is more likely to accrue from extending the number of seedlings that can be handled in these later stages of selection —particularly in small plots—rather than by a still further increase in the annual production of seedlings.

The main change in the varieties at present in commercial cultivation will almost certainly be in the direction of a steady replacement of the older Co. varieties by the newer N:Co.'s. It is expected that N:Co.376 will come to occupy a large part of the area formerly under Co.301 and Co.331.

REFERENCE

Warner, J. N. (1953). The evolution of a philosophy on sugarcane breeding in Hawaii. Hawaiian Planters' Record 54: 139-162.

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Dr. McMartin (in the Chair) said that this subject was a matter of great importance because from the varieties now being developed would come the future commercial varieties to be used in Natal.

Dr. Dodds stated that the varieties released for cultivation in Natal in recent years, had all been of the Co.421 × Co.312 cross. Neither of these parents had succeeded individually in field trials in Natal; but they were for many years the two predominating commercial varieties in the huge sugar industry of India, and, rather surprisingly, in view of their failure in this country, their mutual progeny had given us some excellent varieties for our conditions.

He noted that Dr. Brett was now using Co.331 to fertilize Co.421, and would like to know whether this variety also was of special promise in this capacity.

Dr. Brett replied that he had first tried the cross, Co.421 × Co.331, because Co.331 was very similar to Co.312 in derivation.

Dr. Van der Pol, commenting on the statement in the paper that these new varities did not persist, wanted to know if Dr. Brett could shed further light on the subject as to why this should be so. Was it due to hunger or was it due to ratoon stunting disease ?

Dr. Brett replied that he did not know exactly what caused varieties to deteriorate, but the fact remained that they did. Ratoon stunting disease was one of the factors involved and there might be other virus diseases about which we did not know.

Dr. McMartin pointed out that the question of deterioration in vegetatively reproduced crops goes back for a very long while, and one theory put forward many years ago was that the deterioration of fruit stock was due simply to propagation by cuttings. Progeny obtained by propagating cuttings from an old tree had not the vigour of those which had been derived from the same tree in its prime. The other theory to account for degeneration was virus diseases, particularly those which had no external appearance.

Mr. Barnes said that this question cropped up in every case where there was a discussion on cane varieties. Stevenson in Barbados years ago concluded that certain organisms attacking the roots of the cane developed to the point where only a new hybrid could resist for quite a long time the attack of those organisms, but they eventually developed and in time could damage the new variety. It should be remembered that sugarcane was growing in a living medium, and not in a static medium and there was a possibility that the organisms of the soil changed almost as rapidly as the hybrid they attacked, but there was a lag between the two rates of change so that new varieties proved successful for a certain number of years, but then had to be replaced.

Dr. Brett could not see why the introduction of cuttings from elsewhere should lead to a better type of yield. He could only suggest that the seed material itself which had been imported was more healthy.

Dr. Dodds said that the possible explanation suggested could hardly apply to natural varieties. Uba, for instance, was produced for many years without deterioration until it was attacked by streak disease. In Australia there was the example of a natural variety, Badilla. There the new seedlings come and go, but Badilla apparently goes on forever, though it is at last slowly declining in cultivation. It

might be that the products of natural selection were much more successful than we could ever duplicate by our present methods. It was conceivable that each successful natural cane variety represents a natural selection from a much larger number of seedlings spread over a much longer period of competition with other cane varieties and other plants under more severe natural trial conditions than man can at present emulate.

Dr. Brett pointed out that Badilla was more tolerant of ratoon stunting disease. This in itself was probably part of the explanation. If other—and at present unknown—virus diseases were responsible for deterioration, it would have to be assumed that Badilla was tolerant of these as well.

Dr. McMartin enquired of Dr. Brett if he preferred to make a cross which gave a large number of seedlings, some of which could almost be released for commercial propagation, and hope that this particular cross would one day produce a commercial cane, or would he keep on making crosses which gave a large number of inferior seedlings but which occasionally gave a good variety.

Dr. Brett considered that the value of a cross did not lie only in the mean quality of the seedlings but also in the variation within the seedlings from that cross. Although in general the mean could provide a satisfactory basis of comparison, it might sometimes happen that a cross with a very high mean might be less valuable than another cross with a lower mean but greater variability.