

ADVANCES IN AGRICULTURAL PLANT BREEDING IN THE SOUTH AFRICAN SUB-TROPICS

By W. L. FIELDING.

A Board of Trade and Industries report ¹⁴ states "Apart from green manure crops, cane forms substantially the only crop in the sugar area: that is, monoculture is practised."

Where such an agricultural system exists scientific research on the crop concerned may tend to become introspective and confined in its trends of thought. A great deal of experimental work has been done on various crops in the sub-tropical areas of South Africa during the last 20 years, and it may be stimulating to consider plant breeding advances made with other crops as well as sugarcane. Some aspects of the work of two experiment stations in this agricultural tract are discussed in this paper. These two research institutions, the Cotton Experiment Station at Barberton, in the Eastern Transvaal and the Sugar Experiment Station at Mount Edgecombe, in Natal, started work, curiously, in the same year, 1924.

The areas in which it is considered that cotton can be grown lie in a belt immediately to the east of the Drakensberg Mountains. This belt is about 50 to 60 miles in breadth, extending from the Zoutpansberg Mountains (Lat. 23° S) some 400 miles southward to the Tugela River (Lat. 29° S); 1,000 to 3,000 feet is the most suitable altitude. The Cotton Experiment Station at Barberton is situated about midway in this tract, (Lat. 25° 47' S. Long 31° 03' E) at an altitude of 2,500 feet. Developed substations existed for a number of years at Bremersdorp and Croydon in Swaziland and at Magut in northern Natal whilst co-operative experiments were carried out on numerous private farms, at Pongola and in the Zululand native reserves.

Sugarcane is grown along the coastal belt of Natal and Zululand, from Mtubatuba (Lat. 28° S) southwards to the Umzimkulu river (Lat. 32° S). Expansion of cane growing to the Pongola area is projected. The Sugar Experiment Station at Mount Edgecombe is situated towards the southern part of this tract (Lat. 29° 42' S. Long. 31° 3' E) whilst a permanent sub-station is established at Chaka's Kraal, 25 miles north of the main station. Co-operative sub-station experiments on private plantations and estates have provided information on suitability of cane varieties and husbandry methods to more localised environments.

The sugarcane and cotton belts of South Africa overlap, therefore, in northern Natal. The respective areas are depicted on the map which accompanies this paper.

The cotton areas have an average annual rainfall of 25 inches to 30 inches, but are subject to spasmodic and severe droughts whilst violent hail and wind storms frequently cause severe damage to crops. A large part of the tract is used mainly or exclusively for cattle ranching, whilst in winter sheep approach from the high veld in large numbers onto the Drakensberg foothills overlooking the area to the west. At Barberton in particular, snuff tobacco is grown (largely for consumption by native underground workers on the Rand Mines), whilst large quantities of sub-tropical fruits and vegetables contribute their share to a flourishing agriculture. Maize is grown extensively and groundnuts and a miscellany of beans to a minor extent.

The sugar areas have, on the whole, a higher average rainfall, around 40 inches per annum, than the cotton areas. The climate generally is one of less violent changes and the sugar crop does not suffer so frequently from damage by hail and high wind as do the crops in the cotton areas.

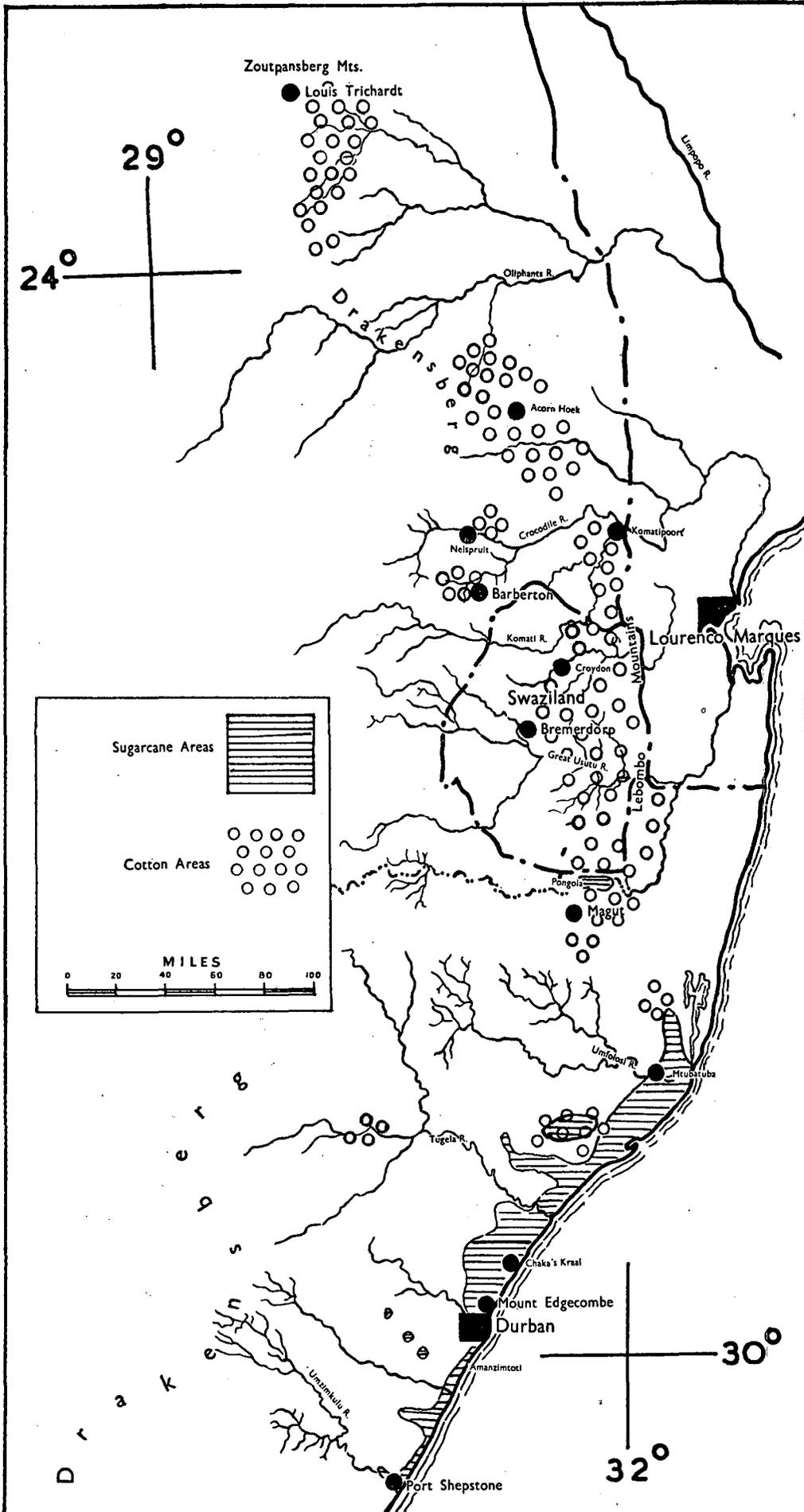
Research has played a great part in shaping developments. It would be impossible to discuss here the contributions made by workers in the several branches of science involved. This dissertation is confined therefore to certain aspects of plant introduction, hybridization and selection with cotton, maize and sugar.

Cotton Breeding.

Portuguese explorers found the inhabitants of South Africa in 1516 growing cotton and wearing cotton garments. In 1846 Dr. Adams of the American Mission grew cotton at Amanzimtoti, Natal. Cotton was later grown in the Cape Colony and thereafter received a *coup de grace* as a result of the discovery of the Kimberley diamond fields. Cotton growing was resuscitated in 1909 and in the early 1920's experienced a boom. From then on falling prices, unfavourable seasons, the growing of unsuitable varieties and over-capitalisation of many ventures resulted in a gradual fading out of the industry on any extensive scale.

It was at this stage that properly organised research in cotton problems began at Barberton. At that time attacks by the plant sucking insect, the *Jassid*, (*Empoasca sp.*) threatened to wipe out the industry. This pest is common to many cotton areas in Africa.

A large type collection of introduced material was grown at Barberton and in 1925 a single plant



in a plot of cotton grown from seed believed to have originated in Uganda was selected by F. R. Parnell, primarily because its leaves showed little sign of the red, curled leaf of the jassid susceptible plant.

This single plant was designated U4; it gave rise to a heterogenous family in which selection was practised up to 1939. It is possible that the plant was a natural hybrid.

Its early multiplication history was:—

- 1925—one plant,
- 1927—one acre, giving 475 lbs. seed,
- 1929—950 acres, giving 220 tons seed.

The variety grown locally, when the Experiment Station commenced work in 1924 was "Improved Bancroft." Its drawbacks were extreme susceptibility to jassid and poor yield.

From Parnell's early observations it was apparent that tolerance to jassid attack was associated with length and density of epidermal hairs on the stem and foliage of the cotton plant. That this is so has been proved in academic studies at Barberton, an account of which is due for publication in Bull. Ent. Res. These studies have resulted in the evolution of an efficient technique for practical use in breeding for jassid resistance.

The yield of the early U.4 bulk compared with Improved Bancroft was as below:—

	Yield of lint, lbs. per acre.		
	1928.	1929.	Mean.
Improved Bancroft ...	106	96	101
U.4	295	359	327

The early U.4 bulk was such a great improvement on all other available varieties that it soon became the standard variety and breeding stock, not only in South Africa, but in the Rhodesias and Nyasaland. It provided successful breeding material for parts of Tanganyika, Uganda, and the Belgian Congo, and its derivatives are widely grown in Portuguese territories in Africa.

Parnell (1925) describes how the breeding policy adopted aimed at conserving genetic variability. Although all plants selected were promising economic types they covered a wide range, and these were narrowed down gradually, after experience with them in different conditions. Few were discarded hastily. These are important axioms to remember in any plant breeding work and an excellent feature of the sugarcane breeding work at Mount Edgecombe is the trial of many new types on co-operative sub-stations in numerous environments before decisions are made regarding them.

"Special Bulks" were made from the first U.4 progeny, and from later promising single-plant selections; these provided both reservoirs of variability for subsequent re-selection and material repre-

sentative of the stages of the selection process which could be compared in later years.

Table I quotes data given by MacDonald, Fielding and Ruston, ^(10, 11), rearranged for ease of comparison by Hutchinson and Manning ⁽⁸⁾. The progress obtained by the selection policy adopted is obvious from the figures.

TABLE I.
Yields of U.4 Selections of Different Ages, Expressed as Percentages of the Yield of U.4/4/052/5143.

Strain.	Year of selection.	Yield as a percentage of 5143.		Date of putting into cultivation.
		1938-39 trials.	1939-40 trials.	
U.4 bulk	1925	—	68	1929-30
U.4/4	—	—	81	—
U.4/4/052	1930	94	85	1935-36
U.4/4/053/5143 ...	1935	100	100	1939-40
U.4/4/052/5143/6128 and 6130	1936	108	101	—
Four 1937 selections	1937	117	—	—

Significant difference, $P = 0.05$ 5.7

Note.

(1) Actual yield of 5143 was—

296 lbs. lint per acre in 1938-39,
562 lbs. lint per acre in 1939-40.

(2) No significant difference is given for the 1938-39 data as this is compiled from a wide range of trials carried out at Barberton, Bremersdorp, Croydon and Magut.

Despite the high yields of lint obtained in the 1939-40 trial, very significant differences are shown between the two strains of U.4 issued for general cultivation and U.4 bulk itself. The striking yield increases of the 1936 and 1937 re-selections from 5143 over their parent were not maintained at Barberton in the 1939-40 season, but in Swaziland they showed the same superiority as before. The weather conditions at Barberton were good in this season whilst in Swaziland they were poor.

It became obvious at this stage that after working through 12 generations from the parent bulk stage, selection in U.4 was being exercised largely in the direction of closer adaptation to local environment and particularly to seasonal circumstances.

Within the U.4 group, 5143, the variety last released for general cultivation was significantly out-yielded, for the three years 1943-45, by two newer strains from other U.4 families. One of these would possibly have replaced 5143 in general cultivation but by now extremely promising material was available from a U.4/5143 × Cambodia hybrid. Cambodia is a type widely grown in Indo-China. The best selection made in this material for Barberton conditions was designated A.2106. Data

obtained by MacDonald, Fielding, Ruston and King, (12) compare A.2106 with its U.4. parent:—

	Yield of lint, lbs. per cent.		Mean per cent.
	1944.	1945. increase.	
U.4/4/052/5143	414	317	100
U.4/4/052/5143 × Cambodia/A.2106	632	441	146
Significant difference P = 0.05	60	34	—

Having outyielded 5143 so very considerably in two seasons of widely differing conditions A.2106 was issued to selected farmers for multiplication in 1947. It is more jassid resistant and its lint in no way inferior to the best U.4 selections.

It is important that in both seasons 13 of the 19 selected hybrids in the trials significantly outyielded the best U.4 strain. This hybrid material could, therefore, be considered better, *en masse* than the U.4 parent material. It should be amenable to further local selection in other parts of Africa.

Yield is the only attribute considered in this paper; actually the attributes studied in cotton breeding and genetics are many and complex but the sum-total of them all can be expressed in terms of lint yield, except spinning quality. This complex attribute includes consideration of the length, strength and fineness of cotton lint. Price and suitability of lint to various markets depend on quality.

The Barberton breeding work is now mainly concentrated on a very extensive hybridisation programme. This includes production of inter-specific hybrids between U.4 (*Gossypium hirsutum*) derivatives and Sea Island (*G. barbadense*) cotton. *G. barbadense* types are practically glabrous and therefore highly susceptible to jassid; they are grown successfully in the West Indies and in Egypt and the parts of the Sudan where jassid attack is not a factor. U.4 and A.2106 lint is good 1½ inches staple; Sea Island is normally 2 inches staple. The hybrids are running about 1¼ inches to 1½ inches staple and the best of them are highly jassid resistant. It remains to be seen whether a stable bulk will result from this difficult inter-species cross, most of the material from which is now in F₈.

Maize Breeding.

Experimental work on numerous rotation crops for cotton was carried out at Barberton. Because of its value as a food crop for native labour and because research showed it to be useful as a trap crop for the American Bollworm (*Heliothis*) the most intensive work was concentrated on maize.

It was soon obvious that a potent factor influencing maize yields in the low veld was the streak virus,

transmitted by the maize jassid, *Cicadulina mbila* (Naude). It is curious that whilst the workers at Mount Edgecombe were searching for a streak resistant sugarcane the Barberton Station was devoting considerable time to the search for a streak resistant maize.

When working with a comprehensive collection of varieties in 1931 the writer observed that some exhibited a degree of tolerance or even immunity to streak. Table II gives the original data from definite counts made in a randomised block trial of selected varieties by Fielding and Rose (?).

TABLE II.

Percentage of plants infected with streak to different degrees.

Strain of maize.	Planted 24th December, 1931.			
	Light.	Medium.	Heavy.	Total.
Peruvian Yellow ...	4.5	3.5	0.5	8.5
Arkell's Hickory ...	8.5	14.3	12.0	34.8
Anveld... ..	9.8	16.8	19.3	45.9
White Flint	17.3	21.3	11.0	49.6
Potchefstroom Pearl	10.0	16.5	27.8	54.3
Wisconsin	16.3	25.0	18.8	60.6
Natal White Horse- tooth	7.5	21.3	35.0	63.8

N.B.—The season was one of only moderate infestation.

Yield, drought resistance and early maturation were aims in the breeding policy but above all the production of a streak resistant white grained maize was sought (Peruvian Yellow, is of course, a small, round red-yellow, only suitable for poultry food.)

This aim was achieved in the strain "P×H" (Peruvian Yellow×Arkell's Hickory) which is now meeting with commercial success in areas east of the Drakensberg escarpment where streak is prevalent.

The breeding process involved first the production of the most highly resistant types of Peruvian and Hickory, by making intra-varietal crosses of selected strains. The behaviour of these is illustrated by the data in Table III from early and late planted trials carried out by MacDonald, Ruston and King (13). Apart from showing greater resistance than their parents the yields of these crosses were disappointing and they tended to lodge. Their value was seen to be purely as breeding stock.

The P×H strain, produced as a result of crossing resistant strains of Peruvian and Hickory was very promising, however. It does not yield as well as the Hickory parent when streak is light but is the best type for planting when heavy streak infection is expected.

TABLE III.—Percentage of Plants Infected with Streak to Different Degrees, and Figures for Yield of Grain.

Strain.	Planted 16th November, 1942.				Lbs. per acre grain.	Planted 30th December, 1942.				Lbs. per acre grain.	
	Peak of Infection February 12th.	Light.	Medium.	Heavy.		Total.	Peak of Infection February 27th.	Light.	Medium.		Heavy.
Hickory	7.9	8.7	6.9	23.5	2,835	10.3	46.8	40.1	97.3	1,435	
Hickory, streak resistant ...	1.7	1.7	0.9	4.3	2,151	31.5	24.3	6.9	62.7	1,477	
Peruvian	2.1	0.8	0.8	3.7	2,056	18.0	12.7	3.2	33.9	1,621	
Peruvian, streak resistant...	Nil	Nil	Nil	Nil	1,350	3.6	1.5	Nil	5.1	967	
P×H, streak resistant ...	0.8	0.6	0.2	1.6	2,319	16.6	12.8	3.5	32.9	1,742	
Potchefstroom Pearl	8.0	8.7	10.2	26.9	2,246	7.2	37.0	55.6	99.8	671	
Significant difference, $P = 0.05$					264						179

In 1945 the early attack of streak was such that in an early planted trial at Barberton P×H was not significantly lower in yield than Hickory. In a late trial streak damage to Hickory was so great, 98 per cent. of the plants being attacked, that it yielded only 337 lbs. grain per acre, compared with 1,278 lbs. from the P×H resistant type.

The importance of streak resistance is the greater because a farmer planting cotton and tobacco as his main crops will leave his maize for planting on the later rains.

II.

Some Comparisons Between Sugarcane and Cotton Breeding.

It has been with very great interest that the writer has turned his attention from breeding problems connected with cotton, maize and other crops to consideration of sugarcane breeding.

Although the cotton plant is by habit a perennial shrub, it is grown commercially as an annual; ratooning is discouraged, and even prohibited in some countries, because it brings about a dangerous increase of insect pest populations. Cotton and maize breeding is thus based on the production of annuals from seed. Fielding^(5 6) has described the process involved in the control of natural cross pollination in cotton breeding. With sugarcane, once a seedling is established and the cane formed there is the advantage that the type can be fixed for an indefinite period by vegetative propagation, with only a remote chance of mutations occurring in some clones.

As sugarcane is successfully cultivated on the ratooning principle, the breeder does not know all the answers regarding his material till many years have passed. Nor is he likely to have sufficient material for testing the suitability of a promising seedling to different environments in the sugarcane belt, let alone for distribution to growers, for a considerable time. The sugarcane breeder is there-

fore faced at the outset with a long and hard row to hoe, compared with the cotton breeder where, as illustrated above, enough seed of U.4 was available in 4 years from the single plant stage to plant more than 20,000 acres. It is estimated that in the 1947-48 planting season about 2,000 tons of N:Co.310 must have been available for planting in the industry; thus in ten years from the seedling stage there is enough material to plant about 1,000 acres of this sugarcane. These are practical examples but broadly speaking one can say that material available for planting is multiplied between 400 and 500 times, annually for cotton and about 10 times for sugarcane.

The replacement of old by new strains is therefore a much more rapid procedure in a cotton growing industry than in a sugarcane industry.

Du Toit⁽³⁾, has given an exhaustive examination of the influence of new varieties on sugarcane yields. Certain of his data and also figures given by the Experiment Station⁽⁴⁾, have been used to produce the accompanying diagram.

After its introduction to Natal in 1883 Uba remained practically the only cane in commercial cultivation for over 50 years. The introduction of promising new varieties of sugarcane from sugar growing countries and their systematic study by the Sugar Experiment Station at Mount Edgecombe from 1924 onwards resulted in the eventual release of a number of them for commercial planting.

It is the effect of these on the yield of cane for the whole industry which is illustrated in the diagram. It is probable that the use of fertilizers and improvement in agricultural practice have improved yield. These benefits should, however, apply equally to Uba as to the non-Uba portions of the crop and the difference in yield illustrated by the shaded portion of the diagram must be due mainly to the introduction of better varieties.

The demise of Uba has been largely due to the susceptibility of this variety to the same leaf virus,

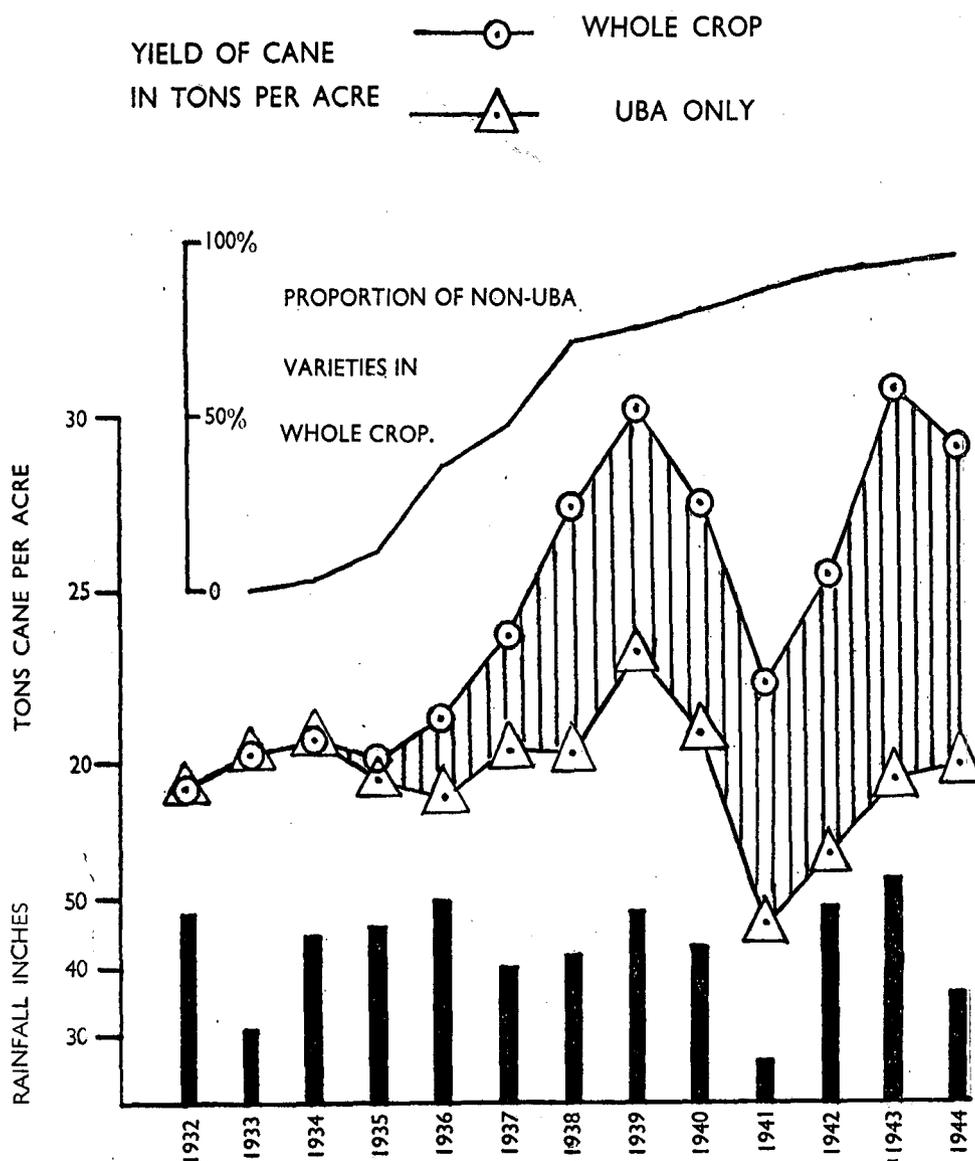
Streak, mentioned in connection with the maize breeding programme at Barberton.

It is worth pointing out that decrease in total amount of annual rainfall has been capable of temporarily obscuring the advantage gained with new varieties. Thus whilst the curve illustrating the proportion of new varieties continues on its upward trend, yield per acre drops badly in 1941.

As was pointed out by Dodds⁽¹⁾, "The introduction of varieties established in other countries is not an ideal method of procuring new varieties, however." It has been pointed out above, in connection with cotton breeding, that selection in any locality will eventually be exercised largely in the direction of closer adaptation to local environment. MacDonald, Fielding and Ruston ⁽¹¹⁾, reported on a trial carried out at Barberton of four strains selected from U.4 material in Southern Rhodesia and five strains selected at Barberton. The mean yield of seed-cotton per acre of the 4 Southern Rhodesia

strains was 741 lbs., and that of the 5 Barberton strains 1,034 lbs. These results were broadly reversed when the same material was compared in Southern Rhodesia. Hutchinson and Manning (1943) comment on the data "The intimate nature of the relation between genotype and environment involved in local adaptation is well brought out by the fact that each group of strains proved the more drought-resistant of the two on its home station."

Improvement of cane varieties has in recent years been concentrated on selection of seedlings grown from seed imported from cane breeding stations in other countries. It is thus possible to exercise immediate selection for local adaptation at Mount Edgecombe. When sufficient material of promising types is available selection for closer adaptation to varying soils and altitudes in the sugar belt is exercised by means of observation plots and replicated plot trials on numerous sub-stations. The importance of the latter work cannot be over emphasised. King ⁽⁹⁾,



has referred to this aspect of sugarcane breeding in Queensland. He states "A single varietal trial in a district is not a reliable criterion of the performance of any cane. The value of a new variety is found by having a large number of trials under a varying set of conditions and then summing up the results as follows: 'In twenty trials, the new variety exceeded the standard cane thirteen times, was equal to it four times, and was beaten by the standard three times.'"

The important aspect of measurement of improvement gained is well illustrated in the cotton data, particularly by Table I.

From the diagram it can be seen that improvement gained by introduction of sugarcane varieties was about 50 per cent. by 1943. This results from examination of tons cane per acre commercial yield data, and it is interesting to compare tons sucrose per acre data obtained from replicated trials in seven different localities over a period of years. The average significant increase Co.281 over Uba was 50.38 per cent. for 26 individual cases of plant cane and ratoons.

Dodds and du Toit ⁽²⁾, in an appendix dealing with sugarcane crop statistics, record a 7 per cent. improvement for Co.301 over Co.281, in tons cane per acre. That Co.301 may give higher yields than Co.281 is indicated by the fact that seedling yields quoted in Tables IV and V below show a greater increase over Co.281 than over Co.301. The latter cane is regarded as best suited to the lighter soils.

The point of great interest now is what improvement in yield over the older introductions can be expected from the newer seedling varieties selected at Mount Edgecombe. There is not a great deal of data available as yet, but that quoted in Tables IV and V illustrates that the possibility of real improvement in yield exists. All the cases quoted represent statistically significant increases over control variety.

TABLE IV.

Sucrose per Acre expressed as percentage of Co.281.

Seedling No.	Plant cane (Different localities).				Plant cane average.	First ratoon.
N:Co.291 ...	124	117	149	119	127	123
N:Co.310 ...	140	127	173	—	147	140
N:Co.330 ...	122	120	123	—	122	146
N:Co.339 ...	119	130	—	—	125	151
N:Co.349 ...	137	125	150	119	133	121
Average	131	136

TABLE V.

Sucrose per Acre expressed as percentage of Co.301.

Seedling No.	Plant cane (different localities).		Plant cane average.	First ratoon.
N:Co.293	130	—	130
N:Co.310	127	122	125
N:Co.349	121	118	120
Average	125
				120

Concluding Remarks.

1. From a perusal of the data quoted it is obvious that plant breeding methods as practised at Barberton and Mount Edgecombe have had a great influence in developing the agricultural potential of South Africa's sub-tropical areas, where sugar, cotton and maize are concerned.

2. The full production potential of these areas is more fully realised when the planting of forest trees, the growing of sub-tropical fruits, vegetables and tobacco and the very considerable ranching activities are all brought into the picture. The Sub-Tropical Research Station at Nelspruit, the Tobacco Research Station at Rustenberg, and the Wattle Research Institute, Cedara Agricultural College and the Faculty of Agriculture in Natal, are all assisting in developments in these spheres.

3. The method of local seedling selection gives greater scope for improvement in cane varieties than the importation of varieties which perform well in distant environments. This conclusion emphasises the importance of achieving a successful technique for the local production of hybrids. 4. Despite the strain imposed on Experiment Station staff the importance of sub-station experiments to study local adaptation of varieties cannot be over emphasised. This applies also to the study of manurial, spacing and other husbandry problems.

Acknowledgements.

I wish to acknowledge my indebtedness to Mr. D Cropper for searching the experimental files of the Agricultural Department for the data presented in connection with sugarcane breeding; also to those members of the Experiment Station Staff who were responsible for the experiments quoted, particularly Mr. C. D. Sherrard who carried out much of the field work and the statistical analysis of the seedling trials.

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Experiment Station,
South African Sugar Association,
Mount Edgecombe,
March, 1948.

The PRESIDENT commended the paper because it was a reminder of the work being done elsewhere in improving other crops as well as that done here in producing better sugar canes.

Dr. DODDS asked for more information concerning streak resistant maize varieties. He stated that some seed obtained from the Cotton Experiment Station and tried at Mount Edgecombe a few years ago, had given fairly good plants but had failed to flower and set seed.

Mr. FIELDING thought the seed must have been selections from the earlier bred varieties quoted in the tables. He had brought some P x H seed with him to Mount Edgecombe and this had behaved very well, giving a good yield with a very small percentage of streak infected plants.

Mr. DU TOIT pointed out that in the figures published by himself and Dr. Dodds and which showed a better yield from Co.301 than that given by Co.281, it should be remembered that Co.301 had a slight advantage in that it was composed of more plant cane and early ratoons than was Co.281. It did seem, however, that while Co.301 was clearly better than Co.281 south of the Tugela River, in

Zululand the position was rather different. This bore out the contention that certain varieties were more suited to particular areas. He asked what was meant by the phrase "varying sets of conditions" in the quotation from King regarding sugarcane trials in Queensland. Did it mean that the cane varieties should be tried out on varying soil types in the same district or under varying climatic conditions?

Dr. DODDS remarked that conditions in Queensland were very different from those in Natal. The industry in Queensland, although similar in size of production to that of South Africa, was split up into many areas distributed over two thousand miles of coastal belt. The reason for the summing up of several trials in one area, was to get a good general picture of the behaviour of varieties in a particular district.

Mr. VAN WYK said that some of Mr. Fielding's remarks appeared to have extensive application to experimentation with crops generally, and in particular to fertilizer experiments with maize. When carrying out a large experiment with maize, testing the soil fertility aspect rather than the genetics of the plant, it was possible to get results in a certain season which were not consistent with those in other seasons. To avoid inconsistencies of this sort, it was necessary to be very careful in selecting the seed used and in particular to choose acclimatised seed.

In one experiment quoted in the paper, it was noticed that in a dry season a plant that was acclimatised had an advantage over one just introduced. This was probably attributable to the fact that it did best under the climatic conditions which led to its selection. A tremendous argument goes on always between the school of thought that prefers breeding for productivity alone and that which prefers breeding for adaptability.

Mr. FIELDING stated that in the variety experiments at Barberton with both maize and cotton, the soil was always treated according to the findings of fertilizer experiments and manurial trials. Differences between varieties therefore, could not be ascribed to any soil deficiency which could be rectified. Fertilizer trials were carried out with standard commercial varieties which had been in the district for years and had presumably settled down and become acclimatised. Any deterioration of strains of cotton or maize occurred mainly through cross-fertilization due to other strains being grown nearby. Such cross-fertilization might amount to ten per cent. With sugarcane where the plant is fixed vegetatively this factor did not exist.