THE RELEASE OF VARIETY NCo310 IN 1945 AND ITS IMPACT ON THE SUGAR INDUSTRY

[1]KJ NUSS AND [2]PGC BRETT

[1]*South African Sugar Association Experiment Station, Mount Edgecombe.*
[2]*PO Box 573, Umhlanga Rocks.*

Abstract

The release of NCo310 in 1945 had a profound effect on the sugar industry in South Africa. At the time of its release it yielded up to 40% more sucrose than varieties Co281 and Co290. Within five years of release it was exported to 43 countries and estates, and became a major variety in Australia, Argentina, Louisiana, Taiwan and in the rest of Africa. It yielded more sucrose than its contemporary varieties under a wide range of environmental conditions and ratooned better. The effect of diseases such as smut and mosaic on the sucrose yield of NCo310 was aparently less than that of other varieties, which made cane growers reluctant to replace it with newer varieties. It was used successfully as a parent in Taiwan, Australia and other countries but not in South Africa. The outstanding qualities of NCo310 and its sib NCo376 ensured that, even under adverse conditions, many sugar industries could produce profitable yields.

Early history

The wellbeing of the South African sugar industry has been closely associated with the availability of varieties that combined high yielding ability with resistance to diseases and pests. When the industry started in the previous century noble, (*Saccharum officinarum*) varieties were imported by all who had access to suppliers of new varieties in foreign countries. As noble varieties flowered rarely in Natal and no fertile seed was found, the industry relied on imported varieties. In this way many noble varieties arrived here from Mauritius, India, Australia, Indonesia and Barbados. However, the noble varieties, of which Green Natal was one, proved susceptible to mosaic disease and, for a time, the *Saccharum barberi* variety known as 'China cane' was used to replace them. In 1880, China cane in turn proved susceptible to a fungal disease - in this case smut - and, for a while the industry had to revert to the noble varieties. Such varieties were not suited to local conditions; they suffered from drought and had to be replanted frequently. Between 1883 and 1885 the *S. sinense* variety Uba was imported, and found to be resistant to mosaic. Uba was a hardy variety which was resistant to drought and ratooned well, but had a low sucrose, high fibre content. In 1923 the Government pathologist, with the intention of achieving the eradication of mosaic disease, proposed that all other varieties be ploughed out and only Uba be grown. This recommendation was accepted by the industry. However, the spread of mosaic to perennial indigenous grasses effectively destroyed any hope of the complete eradication of this disease from the industry. (Had this proved possible, mosaic-susceptible varieties could then have been grown.) About this time, Uba was found to be infected with streak disease. This encouraged the industry to establish the Experiment Station, with one of its main functions being to "introduce, test and establish new sugar cane varieties" (Anon., 1952). A quarantine glasshouse was also completed in 1925 and all subsequent varieties were imported through this facility.

The first variety introduced through the new importation procedures in 1933 was the Indian variety Co281, which was subsequently released for commercial cultivation. The varieties POJ2714, 2725, 2727 and 2878 (POJ stood for 'Proefstasie Oost Java') and another Indian variety, Co290, were also released. Co281 became very widely grown, but Co290 was, for the most part, confined to the coastal hinterland. The contribution of these varieties to the increase in sugar yield is given in Table 1 (Anon., 1948), which shows the increase in sugar yield associated with the decline in area under Uba. The sugar yield (harvested at an average age of 24 months) increased from 4,94 to 7,41 tons sugar in the seasons 1932 to 1944, as the area planted to Uba decreased from 99% to 3% of the industry.

Table 1

Improvement in sugar production/ha planted associated with decline in area planted to Uba (adapted from Anon. 1948).

Seasons	% area under Uba	Tons sugar/ha planted
1932-34	98,8	4,94
1935-37	68,2	5,93
1936-38	24,1	7,66
1941-43	9,5	7,17*
1944-47	3,0	7,41*

* low rainfall years

Introduction of seed

For a long time it was accepted that, due to pollen sterility, sugarcane was unable to set seed in Natal, and the Experiment Station therefore embarked on importing such seed (Anon., 1952). The first batch, received from Canal Point in March 1930, was sown at the quarantine glasshouse in Durban. Forty-seven seedlings were later transferred to the Experiment Station and planted in the field.

A second batch, a cross of POJ2878 and Uba Marot, was received from Mauritius in 1932. In 1936, at the request of the Experiment Station, three crosses - POJ2725 × Co214, POJ2725 × Co281 and POJ2725 × Co301 - were sent from Coimbatore, India. Although some promising seedlings were obtained, none were found to be good enough for release. The second batch of seed from Coimbatore came from the cross Co421 × Co312 and was made for the Experiment Station by the famous Indian sugarcane breeder, TS Venkatraman. This cross, as well as a second batch of the same cross (received in 1944), gave rise to the now famous NCo varieties (N for Natal where the seedlings were selected and Co for Coimbatore, the breeding station). Altogether 17 batches of seed were introduced from overseas: 10 from Mauritius, three from India, two from Queensland, one from Hawaii and one from Florida, USA. A total of 23 881 seedlings was planted in the field from the introduced seed.

A winning cross

The cross Co421 × Co312, presumably made in the 1937-38 crossing season in Coimbatore, arrived at the Experiment Station on 20 May 1938 and was sown in the glasshouse on 25 May 1938. (Sugarcane seed had to be dried after the cross was made and the seed then sown as soon as possible because its shelf life is only a few months. At that time no means of keeping it viable for a longer period were known.) Germination was excellent and more than 3 000 seedlings were transplanted into cardboard pots and also into tins, at a rate of 12 to 15 per tin (unpublished Experiment Station records and data).

From 27 October to 23 November 1938, a total of 3 268 seedlings were transplanted into four fields at the Experiment Station. At the first disease inspection in August 1939, 14 stools were found to be infected with mosaic, three with streak and one with both, giving an infection rate of only 0,7%. These seedlings were more vigorous than those from other batches of seed and appeared to be well adapted to local conditions. At the age of 12 months the single stools were selected on vigour, and 414 were planted as single lines of 20 feet (6 m) between 28 November and 1 December 1939. When inspected in April 1940, five lines (1,2%) were found to be infected with mosaic. Between 28 August and 6 October 1941, samples from all lines were analysed for sucrose % cane, fibre % cane and purity. Values obtained from some of the varieties which were later released are given in Table 2. The sucrose values and visual appearance of the seedlings were superior to those of the control variety Co281.

Table 2

Sucrose, fibre and purity values of single lines later released as NCo varieties

Line no.	NCo no.	Date of sample	Sucrose % cane	Purity % cane	Fibre % cane
164	349	11/9/41	15,49	93,6	14,17
201	282	15/9/41	15,60	93,4	15,12
218	334	16/9/41	17,53	94,2	12,31
271	291	23/9/41	16,32	92,9	15,81
279	282	24/9/41	16,18	92,7	15,84
287	293	24/9/51	16,65	95,8	13,41
298	339	25/9/41	17,01	95,3	12,82
385	310	2/10/41	16,77	93,5	12,67

Selections from single lines were given NCo numbers, 20 of the 46 selections being planted in a variety trial in field L3 on 2 October 1941 and 26 (including NCo310) in field E on 10 and 11 October 1941. After the plant cane crop of the latter field had been harvested, the experiment was abandoned because the ratoons had been flooded. The quality and yield results of some of the varieties in this trial are given in Table 3. These were the first results from this promising cross which showed the superiority of some of its selections over Co281 (the major variety at the time) and Co301, in both cane and sucrose yields.

Fourteen NCo selections were planted in another trial on 24 October 1943 and because the results of the plant cane crop in 1945 confirmed previous results showing NCo310's superiority, preparations were made for its release in 1945. (The results from first and second ratoon harvests later indicated that it also ratooned well.) It took NCo310 only a little over seven years to advance from seed to released variety. This rapid advancement was made possible because the yields of Co281 - the main variety at that time and the one with which NCo310 was usually compared - had declined alarmingly. Even without statistical analysis, trials clearly showed the superiority of NCo310 over Co281. Further, the failure of Co281 made the release of a replacement variety a matter of great urgency. (The reason why Co281 declined so drastically in yield was not known. However, it is now thought to have resulted from a very high rate of infection with ratoon stunting disease.)

Table 3

Sucrose content and cane and sucrose yields of some NCo varieties planted on 10 October 1941 and harvested on 3 December 1943

Variety	Cane yield (tons/ha)	Sucrose % cane	Sucrose yield (tons/ha)	% of Co281
NCo310	191	16,8	32,1	140**
NCo349	217	14,4	31,2	137**
NCo352	198	15,0	29,8	130**
NCo291	203	14,0	28,3	124**
Co301	190	14,5	27,5	120*
NCo292	177	14,8	26,2	115
Co281	147	15,6	22,9	100

*, ** significant at 5% and 1% level, respectively

Release of NCo310 in 1945

The first notice of the release of NCo310 appeared in the November 1945 issue of the South African Sugar Journal (Vol. 29: 505-507). A brief statement mentioned that NCo310 was adapted to a wide range of conditions, although it had been found to yield most satisfactorily in the heavier soils. Some points from the full description on its release (Anon., 1946) were that:

- the growth of the seedlings of the cross was very vigorous
- an outstanding feature was the low incidence of disease in this cross
- the selection rate was high and many were selected for further testing
- germination of NCo310 was good, giving a high population of stalks which, however, appeared short in the first season
- it formed a good canopy and good stools
- at harvest it remained fairly erect
- it had a tendency to flower
- its roots survived flooding (whereas those of Co281 did not)
- it was resistant to diseases such as streak and mosaic, moderately resistant to red rot, and neither leaf spots nor root diseases were recorded
- its sucrose yield in the first yield trial was significantly greater than that of Co281 (Table 4), with both cane yield and sucrose content being higher

- its sucrose content in a number of trials was uniformly good, it matured earlier than other varieties, and it was promising on heavy soils.

More than 400 applications were received from the cane growing community to purchase the limited amount of seedcane the Experiment Station had available. Some enterprising farmers planted their allocations as spaced, single budded setts and thereby greatly increased the areas they could plant to this variety.

Another highlight of 1945 was "what may prove to be a landmark in the history of sugarcane in Africa in the production of fertile seeds and seedlings from flowers grown in this country and self-fertilized" (Anon., 1945a). More than 1 000 seedlings were obtained after placing cane flowers in warm conditions during crossing (Brett, 1947). These procedures, with subsequent refinements, have now been adopted in many countries to ensure good seed set. On the negative side was the recurrence of mosaic disease in Co281 for the first time since its disappearance at the time Uba was grown universally (Anon., 1945b), and the re-appearance of smut in Co301 after the disease had disappeared in the previous century (McMartin, 1945). The 1945 rainfall figure of 21,8 mm was the lowest recorded for November since 1887 (Anon., 1945b).

NCo310 was propagated rapidly in many areas of Natal except for the weak sands, where Co301 was yielding well, and in the higher areas where other varieties performed better. Some phenomenal tonnages were recorded and a report was received of a plant crop of NCo310 producing 269 tons/ha at 22 months of age (Beater, 1988). The expansion of areas planted to Co301 continued from 1945 until 1952 (Figure 1), when this variety became severely infected by smut disease. The area under Co281 decreased from 71% in 1945-46 to 1% in 1955-56.

The advantages of growing NCo310 included its high sucrose content throughout the milling season, its good ratooning ability and its resistance to or tolerance of diseases such as smut and mosaic. Both diseases were frequently seen in fields of NCo310, which nevertheless continued to give good yields.

The good results published periodically in the SA Sugar Journal and favourable comments from growers did not satisfy the sceptics of NCo310, who complained of low sucrose values and low cane yields. The Experiment Station then published the results of numerous comparisons of NCo310

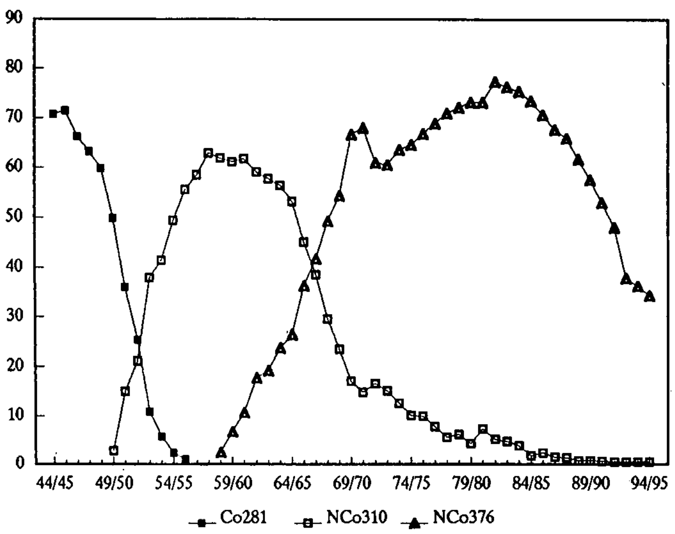

FIGURE 1 Variety percent of total crush (1944/45-1994/95).

Table 4

Yield and sucrose contents of variety NCo310 compared with other released varieties in 1950. (Adapted from Anon. 1950)

a. Cane yield

Variety	Co281	Co301	Co331	POJ2725	POJ2878
No of comparisons with NCo310	14	18*	3	3	1
Cane yield as % of NCo310	77,9	100,4	103,5	66,1	83,7

b. Sucrose contents

Variety	Co281	Co301	Co331	POJ2725
No of independent comparisons	33	46	16	6
Sucrose % cane	14,8	15,2	14,0	12,5
Sucrose % cane of NCo310	15,8	16,6	16,2	13,4

c. Sucrose yield

Variety	Co281	Co301	Co331	POJ2725	POJ2878
No of comparisons	14	18*	3	3	1
Sucrose yield as % of NCo310	73,8	91,3	88,9	63,0	89,1

* Several comparisons were planted on sandy soils where Co301 performed extremely well and NCo310 poorly.

with other varieties. A summary of these is given in Table 4.

From these results it became obvious that NCo310 performed well in many situations. The expansion of NCo310 in the industry can be seen from Figure 1 which shows how much it formed of the total crop in successive years. Ten years after its release NCo310 produced more than half the sugar in South Africa. Surprising it never surpassed 60% of the sugar production (Perk, 1967). The main reason for this was its replacement by NCo376, which usually gave better yields and was adapted to a wider range of soil and climatic conditions. By the end of the 1968-69 season, NCo376, which had been released in 1955, was producing 50% of the sugar. It was particularly popular on the Natal South and North Coast areas, whereas NCo310 remained popular in Zululand (Perk 1967). The combined sugar production of NCo310 and NCo376 exceeded 60% from 1957-58 until 1988-89, a period of 32 years. In a number of trials in the 1970s, Co281 was out-yielded by NCo310, which in turn was out-yielded by NCo376 (Table 5).

In addition to producing good crops up to many ratoons, the NCo varieties gave stable yields unless affected by severe drought, and proved more resistant to or tolerant of diseases than other varieties. From the first batch of the cross Co421 × Co312, varieties NCo291, 292, 293, 310, 334 and 339 were released. NCo293 was found to be a good variety for the higher areas. Although NCo339 produced sucrose yields as good or better than NCo310, it proved highly susceptible to mosaic and was therefore withdrawn from the approved list in the 1970s. From the second batch of the cross, only NCo376 was released.

Table 5

Sucrose contents and sucrose yield in three crops of Co281, NCo310 and NCo376 at three rainfed sites (L, C, H) planted in 1978 and one under irrigation (F) planted in 1972

Site	Co281		NCo310		NCo376	
	Sucrose % cane	Yield % NCo310	Sucrose % cane	Yield % NCo310	Sucrose % cane	Yield % NCo310
L	12,8	71	14,0	100	13,2	111
C	12,3	87	13,7	100	12,7	115
H	12,3	58	13,5	100	13,1	116
F	11,8	68	13,1	100	11,3	103

Milling quality

The milling quality of NCo310 appeared good from the fibre, purity and sucrose values obtained but, in several published articles, a high starch content in "Natal canes" was reported. Whereas little or no starch had been found in Louisiana (Alexander, 1954), the starch content in NCo310 was greater than in either Co301 or Co331. The solution to this problem was only solved years later when the enzymatic hydrolysis of starch was introduced to sugar processing (Smith, 1970).

NCo310 in other countries

Between 1945 and 1955, NCo310 was exported to 43 countries and estates, and included all major cane growing countries (Table 6). No detailed records of its distribution in Africa are available but, from casual mill and other reports, it appears that NCo310 was grown in all sugar milling countries in Africa. It was the major variety in Egypt until it succumbed to mosaic. It remained the major variety in Morocco, Sudan, Somaliland, Kenya, Zambia, Malawi, Mozambique, Zimbabwe and Swaziland until the late 1960s, when it was replaced by NCo376 and other varieties. NCo310 contributed to the expansion of sugar industries in Africa because it regularly produced good yields. Relative to NCo376, it was an early maturing variety. In Southern African countries it became heavily infected with smut and yet, in Malawi, despite such infection continued to produce up to 100 tons cane/ha up to the twentieth ratoon. NCo310 was particularly susceptible to smut, and roguing the whips did not effectively reduce the incidence of this disease. In the case of NCo376, this technique was used successfully in Zimbabwe and Swaziland (James, 1974; Pearse, 1989).

Table 6

List of countries and estates which imported NCo310 from 1945 to 1955

Year	Country (Estate)
1945	USA, Tucuman (Argentina)
1946	Zimbabwe, Sena (Mozambique), Nyasaland (Malawi) Brisbane (Australia)
1947	Havana (Cuba), Formosa (Taiwan), Amani (Tanzania), Philippines, Coimbatore (India), Brazil
1948	Queensland, Coimbatore, Gopalpur (India), Turkey, Somaliland, Madagascar
1949	Turkey, Paris, Uruguay, Belgian Congo
1950	Madagascar, Pakistan, Guadeloupe, Cuba, Israel, Angola, Kenya
1951	England, Marandellas (Zimbabwe), Livingstone (Zambia), Brazil, Angola
1952	Khartoum (Sudan), Nyasaland (Malawi), Tanzania, Kenya, Ethiopia, Swaziland
1953	Brazzaville, Mexico
1954	Mexico, Gold Coast (W. Africa), Spain, Argentina
1955	Tripoli (Tunisia), Belgian Congo, Zimbabwe

The rate of expansion of NCo310 in Taiwan must rank as one of the most rapid in any country (Huang, 1955). Imported from South Africa in 1947, the variety was tested extensively in Taiwan. It showed such promise, producing 20 to 59% more sugar than the control varieties, that all available land was used to propagate it. Progress was closely monitored by the plant breeder, Dr Li, who, with the support of the General Manager of the Taiwan Sugar Corporation, decided on maximum expansion. From July to September 1952, 39 869 ha were planted with NCo310 (Li, 1958) and the area under this variety in increased from 0,01% in 1951-52 to 42,75% in 1953-54 and 91,3% in 1956-57 (Figure 2). The advantages of NCo310 over other varieties included a higher sucrose yield of up to 50%, better juice quality, higher yields in ratoons, adaptation to poorer soils and resistance to wind damage. Its thinner stalks also enabled less seedcane to be used. (As 50% of the crop is plant cane, a large area is needed for seedcane.) By October 1955, NCo310 had earned the sugar industry in Taiwan an additional Taiwan $29 million (Huang, 1955). Although in 1967 it was replaced as the major variety by F146, itself a seedling of NCo310 (Shih and Juang, 1974), NCo310 had provided Taiwan with the foundation for a renewed sugar industry after World War II.

In 1954, NCo310 was released in Australia after extensive tests had shown that, despite early arrowing, it produced higher sucrose yields than Q47 and Q50 in different types of soil. It was an all-purpose variety although not an early maturing one, and an increase in the propagation of NCo310 in the Bundaberg and Gin Gin areas was decided upon (Anon., 1954). NCo, as it was known in Queensland, became a major variety in Australia from 1966 to 1986. The benefits that NCo310 provided included higher sucrose yields in Central (where it occupied 68% of the area in 1980) and Southern Queensland, its adaptation to a wide range of soil

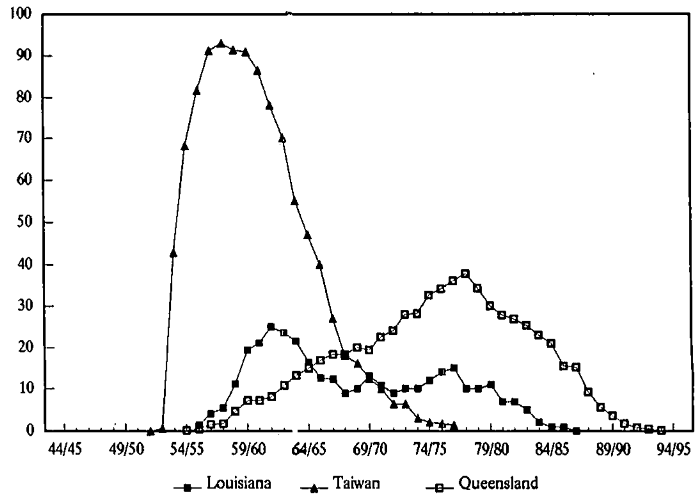

FIGURE 2 NCo310 percent of total cane production in Louisiana, Queensland and Taiwan.

and climatic conditions, its good ratooning ability and, its tolerance of mechanical harvesting even when lodged. NCo310 was later found to be extremely susceptible to Fiji disease, as well being a favoured host for its vector. Despite a valiant effort by the Australian industry to control Fiji disease by means of clean seedcane, NCo310 had to be phased out rapidly, and by 1993 accounted for only 0,3% of Australian sugar production.

In Louisiana, NCo310 was released for commercial cultivation in 1954 (Anon., 1955) and occupied up to 25% of the area (Matherne, 1969) (Figure 2). Later it was grown mainly in the south-west of the state and occupied up to 40% of the area. The advantages of NCo310 in Louisiana were that it was tolerant to damage by freezing, had good mechanical harvesting characteristics, developed a strong root system that enabled it to ratoon satisfactorily under adverse conditions, and it produced acceptable yields even when infected by mosaic disease. This, however, served to make it a reservoir of infection. It was a major variety in Louisiana for five years.

In Texas, the sugar industry in the Rio Grande Valley began planting NCo310 in 1962 and at one stage it occupied 65% of the area (Rozeff, 1986). It remains an important variety in Texas and is harvested late in the season. During the 1993-94 season, it produced 116 tc/ha in plant cane and 55 tc/ha in an 8th ratoon (*N Rozeff, personal communication, 1995). The advantages of NCo310 in Texas include high cane tonnages, high populations, borer resistance, good mechanical harvesting traits, strong ratoons despite adverse conditions and cold tolerance (Rozeff, 1986).

NCo310 was grown in several other countries such as Argentina, Mexico, Iran, Iraq and Spain. In Japan it was the major variety from 1960 until 1991-92, and at one time occupied up to 80% of the area planted to cane (Anon., 1991).

Part of the success of NCo310 may be ascribed to its breeding, which combines the POJ2878 line through Co421 (POJ 2878 × Co285) with the Co213 line through Co312 (Co213 × Co244), a combination which proved very successful in the breeding programmes of several other countries.

Reasons for the decline of NCo310

In South Africa, the area planted to NCo310 declined from the 1961-62 season onwards, initially because of its replacement by NCo376, which was more productive in many rainfed areas (Perk, 1967) and later because of its susceptibility to smut. In other countries the smut problem in NCo310 became more severe; here too it was replaced by NCo376. In Taiwan it was replaced by its seedling F146, by which it was out-yielded (Shih and Juang, 1974). In Australia, the incidence of Fiji disease took on serious proportions and, as NCo310 was the main source of inoculum for the disease, it was eventually replaced by disease resistant varieties which also proved higher yielding. In Louisiana, the major reason for its decline was its susceptibility to a new strain of mosaic known as 'strain H'.

NCo310 as parent variety

NCo310 was one of the parents used when breeders at the Experiment Station first started making crosses with flowers kept in heated glasshouses. In 1945, NCo310 was crossed with Co301 and, from the resulting 12 single lines, N10 (the tenth locally bred single line) seemed a promising variety but was not released because its yield in later trials proved inferior to those of NCo376. The same cross, made in 1953, resulted in the production of variety N55/805, which was released in 1965. Similar to Co301, N55/805 yielded well on sandy soils and formed 10,5% of the crop in 1977 (and in one mill area 19,8%). However, the area planted to N55/805 decreased rapidly because of severe rust and smut infection (Lamusse, 1978). In all, NCo310 was crossed with 340 varieties, from which 44 654 seedlings were obtained but only N55/805 was selected for release. On the other hand, a seedling from the cross NCo310 × Co331, which had been sent to Japan, was released there as NiN2; it was used by the Experiment Station as a parent after being imported from Japan and one of its offspring, 82E0123, is very promising. 82E0123 is at present being propagated for eventual release in the rainfed areas of the South African industry.

In Taiwan, NCo310 was an extremely useful parent. It was used in numerous crosses to produce millions of seedlings, from which nine varieties were selected for release (Shih and Juang, 1974). Of those released, F146 and F160 became major varieties, and a further 13 second generation offspring proved more productive than NCo310. In Australia, NCo310 was used widely as a parent, and 13 'Q' varieties are offspring. One of them, Q124, is the current major variety ([1]Hogarth, personal communication). In several other countries including Mauritius, Reunion and Cuba, NCo310 produced varieties that were released or used as parents.

Recently, NCo310 has been identified as one of the varieties giving better positive responses to transformation experiments, and it is possible that NCo310 could become the first variety to receive the genes that impart resistance to the herbicides Basta and Herbiace ([2]Irvine, personal communication). Another project aims at introducing into NCo310 a gene that will make it resistant to mosaic disease and another gene that will make it resistant to eldana borer ([3]Botha, personal communiction).

Conclusions

NCo310 heralded a new generation of sugarcane hybrids that:

- yielded well in a variety of environments, almost irrespective of the management practices imposed
- produced greater stalk populations and thus an earlier canopy
- had superior ratooning ability
- were resistant to or tolerant of many diseases and pests
- produced economic sucrose yields despite of being infected with mosaic (as in Louisiana), smut (Malawi and South Africa) or Fiji disease (Queensland)
- were widely adaptable to growing conditions.

"If it is fair to say that POJ2878 caused sugarcane's green revolution, it is fair to say that NCo310 was the second of the world class sugarcane varieties."([2]Irvine, personal communication). The high standards in yield and disease resistance/tolerance set by NCo310 made it difficult for many cane breeders to achieve better.

NCo310 helped make sugarcane farming in South Africa a profitable enterprise with its significantly greater sucrose yields from the same inputs and laid the foundation for a modern industry. The contribution of NCo310 to sugar industries in other African countries, and in Taiwan, Australia, Louisiana and Japan must rank as one of the most important made to sustained economic cane production.

* Rio Grande Valley Sugar Co, Texas, US.

[1] BSES, Queensland, Australia
[2] JE Irvine, Texas A&M University, Texas, USA
[3] FC Botha, Head Biotechnology Dept, SASEX, Mt Edgecombe

REFERENCES

Alexander, JB (1954). Some notes on starch in the sugar industry. *Proc S Afr Sug Technol Ass* 28: 100-104.

Anon. (1945a). Experiment Station Notes. New cane varieties. *S Afr Sug J* 29: 297.

Anon. (1945b). Experiment Station Notes. Release of NCo310. *S Afr Sug J* 29: 505-507.

Anon. (1946). A new released cane. Some notes on N:Co. 310. *S Afr Sug J* 30. 91.

Anon. (1948). South African Sugar Industry Crop Data 1932-47. *S Afr Sug J* 32: 510.

Anon. (1950). Yield and sugar content of variety NCo310. *S Afr Sug J* 34: 31-35.

Anon. (1952). Functions of the Experiment Station. *A Rep S Afr Sug Ass Exp Stn* 1952-53. p ii.

Anon. (1952). Introduction of Seed. A Rep S Afr Sug Ass Exp Stn 1952-53. p 21.

Anon. (1954). NCo310 released in Australia. Quality of Natal cane assessed. *S Afr Sug J* 39: 317.

Anon. (1955). NCo310 released in Louisiana. *S Afr Sug J* 39: 111.

Anon. (1991) Report on sugarcane research in Japan 1986-89. Sugar Crop Development (Tokyo, Japan): p 2.

Beater, BE (1988). Founding of the South African Sugar Association Experiment Station and the development of research over the first 50 years, 1925-1974. Published by SASEX 1988. 118 pp.

Brett, PGC (1947). An investigation into sugarcane breeding in South Africa. *Proc S Afr Sug Technol Ass* 22: 104-108.

Huang, JC (1955). Singing the praises of NCo310. *S Afr Sug J* 39: 715-719.

James, GL (1974). Roguing and its effect on yield and smut of sugarcane. *Sug Cane Pathol Newsl* 9: 20-22.

Lamusse JP (1978). Fifty third annual review of the milling season in Southern Africa. *Proc S Afr Sug Technol Ass* 53: 1-19.

Li, HW (1958). NCo310 and the sugar industry of Taiwan. Taiwan Sug 1: 13-19.

Matherne, (1969). A history of major sugarcane varieties. *Proc int Soc Sug Cane Technol* 13: 1061-1069.

McMartin, A (1945). Sugarcane Smut: Reappearance in Natal. *S Afr Sug J* 29: 55-57.

Pearse, T (1989). Influence of roguing on the incidence of smut in Swaziland. *Proc S Afr Sug Technol Ass* 63: 117- 121.

Perk, C (1967). Forty second annual summary of chemical laboratory reports. *Proc S Afr Sug Technol Ass* 41: 11-32.

Rozeff, N (1986). Saying goodbye to an old friend. Sugar J 49(2): 24.

Shih, SC and Juang, PY (1974). The role of NCo310 in sugarcane breeding in Taiwan. *Proc int Soc Sug Cane Technol* 15: 82-88.

Smith, IA (1970). Factors affecting enzymatic starch hydrolysis in sugar solutions. *Proc S Afr Sug Technol Ass* 44: 88-93.