THE CONTRIBUTION OF VARIETY NCo376 TO SUGAR PRODUCTION IN SOUTH AFRICA FROM 1955 TO 2000 AND ITS VALUE AS A PARENT IN THE BREEDING PROGRAMME.

KJ NUSS

South African Sugar Association Experiment Station, Private Bag X02, Mount Edgecombe, 4300, South Africa

Abstract

When NCo376 was released in 1955, it had to compete with the popular NCo310. However, its superior sucrose yield (but lower sucrose content) and wider adaptation to different growing conditions in South Africa, ensured that it became the major variety by 1965. It maintained this status until one of its seedlings, N12, produced more cane than NCo376 in 1995. From 1970/71 until the 1985/86 milling seasons, NCo376 produced more than 70% of the cane delivered to the mills in South Africa. The total sugar produced by NCo376 until December 2000 amounted to about 38.9 million tons.

N12 was the first seedling of NCo376 to be released and its hardiness, drought tolerance and resistance to mosaic and smut were traits preferred by growers. Subsequent releases that are offspring of NCo376 include N16, N17, N18, N19, N20 and N23. In the season 2000/01, N12, N16, N17, N19 and N23 produced 60% of the sugar in South Africa. Some second-generation offspring of NCo376 and other NCos appear most promising and should become available to the industry in the next few years.

Introduction

Nuss and Brett (1995) described in detail the history of variety development at Mount Edgecombe. After the release of NCo310, NCo293 and other NCos, the Experiment Station continued with selecting and testing new seedling varieties. This led to the release of NCo376 in 1955. It was to become the leading variety in South Africa.

This paper is a review of the development of NCo376 as a commercial variety, its contribution to the total sugar yield over many years, its use in research at the Experiment Station and its contribution as a parent of commercial varieties.

Selection process for the release of NCo376

On 4 March 1944, the third batch of seed of three crosses arrived at Mount Edgecombe from Coimbatore, India (see Table 1). The crosses were sown shortly afterwards and then planted in pots on a terrace. A total of 3425 seedlings were planted of which 1150 were obtained from the cross Co421 x Co312. On 27 and 28 September 1944, 2386 seedlings were planted out in field G3 at the Experiment Station (Table 1). There was a serious drought in the area in 1945/46 and, after one year, only about half the seedlings were alive. Few diseases were recorded. As the field was gappy, selection was carried out when the cane was 15 months old, earlier than usual. A comment on the cross (Co421 x Co312) in single stools, stated that it was "a vigorous and healthy cross". As there were so few stools to select, the team went through the field twice. The stool that later was to become NCo376, was only selected during the second round of selection. The selections were planted in single lines on 14 January 1946. In August and September 1947, stalks from the single line trial were milled and the quality traits were compared with those of the controls Co281, Co301 and Co331. The fibre content of NCo376 was lower than that of the controls, as well as its sucrose content and juice purity (Table 2).

Based on these values and agronomic traits, two lines from cross 1 were given NCo numbers and 19 from each of crosses 2 and 3 (Table 1). These were planted in a replicated trial in No-

Table 2. Clones in single lines submitted for testing in 1947 and having sucrose >13.00% at an age of 20 months.

Selection no.	Variety name	Sucrose % cane	Purity %	Fibre % cane
96	NCo373	16.6	92.7	14.8
97	NCo374	14.6	89.7	14.2
102	NCo375	13.5	89.6	15.0
103	NCo376	14.2	87.9	11.7
104	NCo377	15.3	90.7	13.6
121	NCo382	14.0	86.2	15.4
124	NCo383	16.2	91.1	13.4
Control	Co281	16.0	92.4	14.4
Control	Co301	15.7	89.7	12.5

Table 1. Seedling numbers from third batch of crosses from Coimbatore, India.

Cross no.	Parentage	No. of seedlings planted in the field in		
		Pots on terrace	Single stools	Single lines
1	POJ2725 x Co281	600	353	19
2	POJ2725 x Co301	1675	1131	80
3	Co421 x Co312	1150	902	107
Total		3425	2386	206

vember 1948. NCos 370, 376 and 382 produced the highest yields in this trial (Table 3). The best clones were tested in other trials, including the one at Cornubia (Table 4) and at the Experiment Station (Table 5). In the latter trial the yield of NCo376 was particularly good in the first ratoon.

Table 3. Quality and yield traits of selected clones in the NCo seedling trial harvested from 8 to18 August 1950 (plant cane, 21 months old).

Variety	Tons can/ ha	Sucrose % cane	Tons sucrose/ ha	% Co301
Co301	162.6	16.5	26.7	100.0
NCo310	134.7	17.7	23.8	88.3
NCo370	185.8	16.4	30.4	113.1
NCo376	197.7	16.0	31.6	117.6
NCo382	195.8	16.0	31.3	116.5
NCo390	156.9	17.1	26.8	99.8

P = 0.05 = 4.00 tons sucrose; P = 0.01 = 5.31 tons sucrose

Table 4. Mean of quality and yield traits of plant and two ratoon crops of NCo seedlings in the Quarantine Variety Trial – Natal Estates, Cornubia section. (Planted in 1948 and harvested at an average age of 23.6 months).

Variety	Tons Cane	Sucrose % cane	Tons Sucrose	% Co301
Co301	174	15.6	27.1	100
NCo310	176	17.3	30.3	112
NCo370	218	16.7	36.3	134
NCo376	218	16.3	35.5	131
NCo382	228	15.4	35.2	130
NCo390	137.2	17.3	23.7	87

Table 5. Quality and yield traits of selected clones in the NCo seedling trial in first ratoon harvested 10 to 24 July 1952 (age 23 months).

Variety	Tons can/ ha	Sucrose % cane	Tons sucrose/ ha	% Co301
Co301	176.7	13.5	24.0	100.0
NCo310	156.6	16.1	25.1	104.7
NCo370	186.8	14.4	27.0	112.6
NCo376	236.7	14.9	36.1	150.8
NCo382	210.4	14.0	29.5	123.3
NCo390	150.4	13.8	20.8	87.0

P = 0.05 = 1.80 tons sucrose; P = 0.01 = 2.39 tons sucrose

The notice for the release of NCo376 was published in the SA Sugar Journal in September 1955 (page 665). Apart from the botanical description, it was recorded that the yield of NCo376 was good in all trials, on all soil types tested and in different regions in the industry, from the hot and wet coastal areas to the cool midlands areas. It was regarded as resistant to smut and red rot, less susceptible to mosaic than other varieties but susceptible to the 'minor disease - brown spot'. (It is still frequently found with brown spot.) The sucrose yield of NCo376 was more than that of NCo310 but its sucrose content was 'slightly lower'.

NCo376 has a relatively high stalk population of about 112 000 stalks per ha, is shortish when compared with most other varieties and the diameter of its stalks appears thin because it has a bobbin-shaped internode. Although bundles of NCo376 appear small when compared with those of other varieties, the weights are as good or better. The leaves have a characteristic yellow leaf blotch.

Post release testing

The first post-release reports of NCo376 confirmed the information presented at the time of release. In the four agro-climatic regions described by Brett (1960), NCo376 was rated as either first or second in all regions. In another report (Brassey, 1961) NCo376 was used as the new standard to measure the performance of other varieties under test. NCo376 was also reported as performing well as a commercial variety soon after its release. Robertson (1959) regarded it as the best variety for poorer soils. It ratooned well, and while its canopy was not as good as that of NCo310, it was more erect and lodged less than other varieties. On a large estate, under commercial conditions, the best results were obtained from NCo376 although it had been harvested for the first time in the 1957/58 season. However, the incidence of some mosaic in NCo376 was disturbing (Steward, 1960).

In describing the new selection programme for the Experiment Station in 1960, the former Director, Mr J Wilson, wrote of the new varieties being released that "not all will be as good or better than NCo310 at its best and it will be even more difficult to better NCo376 which might be called the 'miracle' cane in the next decade if NCo310 qualifies to be called the 'wonder' cane"(Wilson, 1960).

NCo376 the major commercial variety

In 1965, NCo376 became the major variety in South Africa when it produced more sugar[1] than NCo310 with 36% of the cane crushed in South African mills (Figure 1). It produced more than half the sugar crop for 23 years, from 1969 to 1991, and it was the major variety for 30 years until 1995 when its production was superseded by one of its offspring, N12. The cumulative sugar production of NCo376 reached one million tons in 1964, ten million tons in 1974, 20 million in 1981 and 30 million tons in 1988 (Figure 1). At the end of the 2000/01 season it had produced more than 38 million tons.

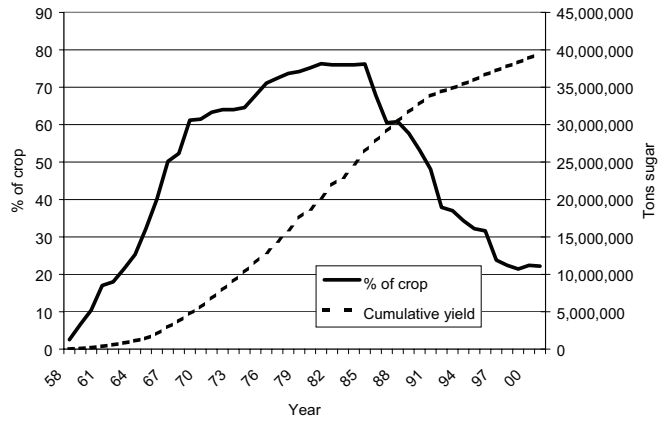

Figure 1. Percentage of crop produced by NCo376 in South Africa, 1955 to 2000 and cumulative sucrose yield of NCo376.

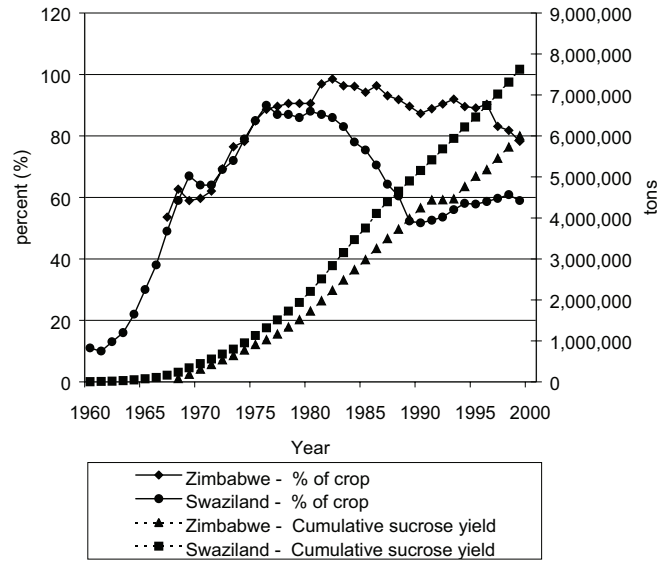

Figure 2. Percentage of crop and cumulative sucrose yield produced by NCo376 Swaziland, (1960 to 2000) and in Zimbabwe, (1965 to 2000).

NCo376 was also widely grown in countries north of South Africa such as Swaziland, Mozambique, Zimbabwe, Malawi and Zambia. It is still widely grown in Swaziland and Zimbabwe (Figure 2) and the total sugar produced from NCo376 in these two counties exceeds 13 million tons. It was not grown widely in continents other than Africa, in stark contrast to the popularity of NCo310. NCo376 was exported only to about 20 countries and estates within five years of release, compared with the 50 of NCo310.

The following features made NCo376 such a good variety:

- Adapted to wide climatic conditions from cool high altitudes, high and low rainfall conditions, irrigated sub-tropics and in tropical areas.
- Grew on a wide range of soils (sandy, loam, heavy clays, alluviums).
- Germinated well under most planting conditions, even when these were less than optimal.
- Was suitable for harvesting in variable cutting cycles, from long (two years) in the Midlands or as at the time of release, annual harvests on the coast and in irrigated areas.
- Resistant to most major diseases, in particular rust, gumming, leaf scald, pokkah boeng (and smut at the time of its release); tolerant to moderate and heavy levels of smut infections.
- Reasonably straight stalks, thus good truck weights of harvested cane.
- Ratooned well, up to 36 ratoons under irrigated conditions in Swaziland ([2] Butler, 2001, personal communication); 24 ratoons in rainfed conditions at Upper Tongaat in a field planted in 1960 and harvested at an average age of 20 months ([3] Hulbert, 2001, personal communication); and in a long-term variety trial to determine the feasibility of growing sugarcane also on sandy soil at Makatini, it performed well until the trial was terminated after the eleventh ratoon (Hellmann and Moberly, 1983).
- Although it was sensitive to droughts, it recovered well even in advanced tenth to fifteenth ratoons ([3]Hulbert, 2001, personal communication) (Inman-Bamber, 1982). Similarly, in the drought of 1983, when 75% of the crop was NCo376, the sugar crop was reduced by 40%. However, after good rains in the summer of 1983/84, the sugar production in 1984 was almost a record of 2.4 million tons.

Major reasons for its decline as a commercial variety include it succumbing to smut, first in the northern irrigated areas of South Africa when smut resistant N14 was released, and later in the high altitude rainfed areas, the better sugar yield of N12. With annual harvesting, the sucrose content of NCo376 early in the season is particularly low and newer N varieties such as N19 are superior in this trait.

The performance of NCo376 under irrigated and rainfed conditions was so good that very few imported varieties yielded as well as NCo376 (Bond, 1977; Cackett, 1979; James, 1975; Koenig, 1967; Nuss, 1999). A few varieties such as CP66/1043 and J59/3 were released in South Africa but their qualities did not match those of NCo376. Only with the release of N12 and N16 for rainfed conditions and with their resistance to mosaic, and N14 and N19 for irrigated areas and their resistance to smut, did the area under NCo376 decline.

The estimated cost of producing NCo376 was Rm 2.4 while the benefit to the SA sugar industry until the 1995/96 season was estimated to be Rm 156.9. Thus the benefit:cost ratio was 65:1 (Donovan, 1996). This value far exceeds the benefit:cost ratio of 24.5:1 for NCo310 and that of N12 of 8.6:1 (Donovan, 1998). While NCo310 made a positive economic contribution to the SA sugar industry for 16 years, the contribution of NCo376 lasted 34 years (Donovan, 1996). These calculations, however, do not include the insurance value of varieties such as NCo376 that ratoons well and is resistant to most serious diseases (the same can be said of NCo310 and N12).

NCo376, a scientific 'model'

NCo376 has been used as a control in most plant breeding trials since the early 1960s when it was compared with other

NCo varieties (Brassey, 1961). For almost 40 years NCo376 was used as a control in plant breeding trials from single stools in stage 1 to the late testing in secondary variety trials. From 1970 to 2000, it was planted annually in more than 1500 plots in these trials. An example of these annual numbers over four decades is given in Table 6. NCo376 was used because it is a reliable control, its yield is stable, it does not compete excessively with clones under test in one-row and two-row plots and it has high yields of sucrose. An advantage of using it over such a long period is that all varieties in the plant breeding database can be compared with NCo376. The relative performance of clones under test can be compared in relation to NCo376 even if they were not planted in the same trials.

From the early 1960s, NCo376 was used in numerous experiments to test theories and to improve the technical advice to South African cane growers. The usefulness of harvesting green cane was demonstrated with NCo376, 310 and 382 (Thompson, 1966). The guidelines on spacing for irrigated cane were developed at Pongola on NCo376 and other varieties (Boyce, 1970). The scientific procedure for scheduling irrigation of sugarcane in South Africa was also developed at Pongola using variety NCo376 (Thompson and Boyce, 1968). These methods were used widely until the crop modelling approach to describe the growth and water use in sugarcane was developed first for NCo376 in the late 1980s (Inman-Bamber, 1991).

In disease screening trials, NCo376 served as a control from as early as the 1960s. It was known to be susceptible to mosaic at the time of release (Thomson, 1963). This was confirmed later when it was shown to germinate well when infected stalks were planted but it was intolerant and reduced the cane and sucrose yield appreciably (Bailey and Fox, 1987). In South Africa it was regarded as resistant to smut in the 1970s, but in Zimbabwe it became infested with smut and procedures to rogue the whips were developed in order to prolong the life of the variety (James, 1968; 1969). When smut whips were rogued regularly, the sucrose yields of NCo376 actually increased (Pearse, 1989). NCo376 appears to be the only variety where such roguing methods have been successfully used to prolong the commercial life of a variety susceptible to smut. In screening varieties for eldana resistance, NCo376 is susceptible to the pest. Research has confirmed field observations that stress due to lack of water breaks down whatever resistance there was in NCo376 (Anon, 1984; Nuss and Atkinson 1983).

Research on the effects of different herbicides on varieties indicated that NCo376 was less affected by these chemicals than other varieties under test (Turner, 1982). The use of chemical ripeners was thoroughly evaluated on NCo376 as it responds to most commercial ripeners (Rostron, 1973, 1975; Leibbrandt, 1989). In South Africa, it is the variety that responds most to the combination treatment of ethrel followed by fusilade and results in yield increases of 3 to 5 tons ERC ([4]Donaldson, 2001, personal communication). In a drought tolerance trial at Pongola, NCo376 was one of the most sensitive varieties but it recovered well after receiving water again (Inman-Bamber, 1982). This confirms the observations of commercial yields of NCo376 ([3]Hulbert, 2001, personal communication). The Crop Nutrition and Soils department of the SASA Experiment Station has a comprehensive set of leaf threshold values for macro- and micronutrients in different soils. These were developed over several decades using NCo376 as the test and control variety. With newer varieties, these values need to be adjusted ([5]Meyer, personal communication).

NCo376 as a parent variety

The first crosses were made with NCo376 in 1953 when it was crossed with Co331. No seedlings were obtained. In 1955, 12 crosses were made and one promising variety was selected, N58/77, that was too susceptible to mosaic to consider for further use. The crosses that eventually produced the commercial varieties were only made in 1962, 1963 and 1965 and varieties N12, N20 and N16 were selected from these crosses. The number of crosses made with NCo376 and the seedling numbers in the successive selection stages are given in Table 7. The overall selection rates were about the average over this period of time. NCo376 was not an exciting parent nor were the selection rates of crosses very good, but it produced offspring which in the past milling season accounted for about 60% of the sugar produced in South Africa. These, together with NCo376, accounted for more than 80% of sugar production in the 2000/01 season. The varieties that contributed to the crop were N12, N16, N17, N19 and, to a lesser extent, N23. N18 and N20 are not grown on a large scale. N12 is grown widely in the Midlands and it is resistant to mosaic and ratoons well. N16 is gaining popularity in the Midlands as it can be harvested at an earlier age than N12; N17 is a useful late season variety and is mainly grown on the coast; N19 is a major variety in the irrigated north as well as in Zululand; and N23 is a minor variety in irrigated areas. Indi-

Table 6. Numbers of clones from the plant breeding programme in relation to the number of plots of NCo376 in trials planted from 1970 to 2000.

Year of planting	No of clones / plots of NCo376	Selection stages			
		Single lines	Observation plots	Primary variety trial	Secondary variety trial
1970	No. of clones	9508	1096	209	36
	Plots of NCo376	461	152	28	49
1980	No. of clones	11066	1111	230	50
	Plots of NCo376	497	165	50	49
1990	No. of clones	11683	1200	208	43
	Plots of NCo376	609	127	42	47
2000	No. of clones	20210	2012	295	72
	Plots of NCo376	1710	200	62	71

Table 7. Number of crosses made with NCo376 and resultant seedlings in various selection stages.

No. of crosses	1800	Selection rate to next stage %
No. of seedlings in stage 1	421 719	7.0
No. of seedlings in stage 2	29381	9.3
No. of seedlings in stage 3	2740	18.0
No. of seedlings in stage 4	494	20.8
No. of seedlings in stage 5	103	
No. of commercial varieties	7	

cations are that these offspring of NCo376 will be the major varieties for the next few years.

Crosses between first generation offspring of NCo376 and those of other NCo varieties produced second-generation offspring that seem to be giving higher yields of sucrose than the currently released varieties. N32 (seedling of N12) is very promising in the irrigated areas. 88H0019 and 88W1323, seedlings of N16 and N18 respectively, have in trials been yielding 17% or more sucrose than NCo376 (Table 8). However, they are too susceptible to eldana for them to be released as commercial varieties. A number of other promising varieties are still being evaluated.

Conclusion

In the process of selection, the sucrose yield of NCo376 was invariably greater than that of the 'wonder cane' NCo310. NCo376 was a high tons cane – low sucrose content variety. At the time of the release of NCo376 in 1955, NCo310 produced about 50% of the sugar crop in SA and was very popular. Within 10 years of its release, NCo376 became the major variety and continued to be so for 30 years. The total amount of sugar produced by NCo376 exceeds 38 million tons, which is equivalent to 15 years of South Africa's production of 2.5 million tons. The economic benefit to the industry was positive for 34 years. This shows that the sugar industry has benefitted enormously from having NCo376 as a variety. The value of a variety such as NCo376 far exceeds the monetary value that can be calculated.

Valuable attributes of NCo376 include wide adaptation to soil and climate, good ratooning, speedy and lasting recovery from drought conditions even in later ratoons and resistance or tolerance to major diseases, even 45 years after release. The decline in the commercial exploitation of NCo376 is due to newer varieties that are resistant to smut (N14 in irrigated areas), and mosaic, and have better adaptation to cooler conditions in the midlands (N12). NCo376 still yields well on the coast where diseases and eldana are not a problem.

NCo376 is a parent of several important varieties. As in the past season, NCo376 and its offspring will, for the next five to eight years, produce the greater proportion of the sugar crop in South Africa.

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Table 8. Yield of two second-generation offspring clones of NCo376 compared with those of NCo376.

Variety	Parents		Yield (tc/ha)	ERC % cane	Tons ERC
	Female	Male			
88W1323	77F637 (N55/805 x F152)	N16 (NCo376 x Co331)	85	13.5	11.5 (+17%)
NCo376	Co421	Co312	87	11.3	9.8
88H0019*	76H333 (NCo293 x [NCo310 x G255])	N18 (NCo376 x ?)	99	12.3	12.2 (+22%)
NCo376	Co421	Co312	77	13.0	10.0

* Results from Midlands trials only

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1 Reference to sugar production of NCo376 in this paper is slightly exaggerated because its sucrose content is lower than that of most other varieties. The proportion of tons cane delivered is not equivalent to the tons sugar made from each variety.

2 DW Butler, Extension Agronomist, SSAES, Swaziland

3 E Hulbert, Regional Extension Officer, SASA Experiment Station, Mt Edgecombe, SA.

4 RA Donaldson, Senior Agronomist, SASA Experiment Station, Mt Edgecombe, SA.

5 JH Meyer, Head Crop Nutrition and Soils, SASA Experiment Station, Mt Edgecombe, SA.