AN EMPIRICAL EVALUATION OF THE SUGARCANE VARIETY NCo310

PA DONOVAN

9 Gunda Crescent, Umhlanga Rocks, 4320

Abstract

An empirical estimate of the value, and of the benefit:cost ratio, of the sugarcane variety NCo310 is proposed. On the premise that a variety is one of a number of technologies contributing to the industry's productivity, its value can be obtained by sequentially estimating the contribution of research and development (R&D) to total productitivy, research to R&D, plant breeding to research and varieties to plant breeding. In this way NCo310's value was estimated as Rm 165,24, its cost as Rm 6,75, and hence its benefit:cost ratio as nearly 25:1. NCo310 was found to contribute positively to the industry's productivity for only the first 16 of the 39 years it was in use. Since the productivity of varieties is bound to vary with ecological and management conditions, estimates of variety value in different extension areas are likely to give different results to this industry-wide study and may be useful for promoting the earlier replacement of older, less productive, by newer, more productive varieties in particular areas.

Keywords: Sugarcane, varieties, evaluation, benefit:cost

Introduction

Nuss and Brett (1995) describe the origins of NCo310 and its importance to the South African and other sugar industries, but do not evaluate it in monetary terms. Because this is an important criterion, an attempt is made in this paper to make such an estimate empirically and to calculate its benefit:cost ratio.

The empirical evaluation is based on the hypothesis that a variety is an item of technology produced by the plant breeding component of an R&D institute's research programme which is but one of a number of factors determining the productivity of its parent industry.

Estimating the value of varieties

For the purposes of this paper the value of the sugar industry's production is calculated as the product of its annual production of sugar and its average annual export realisation. For the period 1949-50 to 1993-94 the annual value is given in Appendix 1 (column 1) adjusted for inflation (1994 = 100).

Table 1

Technology's percentage contribution to the industry's total productivity
(Donovan and Nieuwoudt, 1992)

1946-47 – 1955-56	13,35%
1956-57 – 1965-66	15,43%
1966-67 – 1975-76	33,63%
1976-77 – 1985-86	29,12%
1986-87 – 1988-89	29,12% (assumed)

Donovan and Nieuwoudt (1992) found that four factors contributed significantly to the industry's productivity, namely technology, rainfall, production costs and land (area under cane). Only technology is required for this paper and, using a Cobb-Douglas production function, they estimated its contribution to productivity, during the four decades to 1985, in percentage terms, as shown in Table 1.

In order to cover the whole period during which NCo310 represented at least 1% of the industry's cane production, namely from 1947-48 to 1989-90, it is assumed that technology's contribution remained at 29,12% for the three years 1986-87 – 1989-90.

The value of technology, calculated by applying these percentages to the industry's total product value, is given in Appendix 1 (column 2).

In apportioning technology among its various components Donovan and Darroch (1991) estimated research's share over three decades, as shown in Table 2.

Table 2

Research's share of technology over three decades, 1956-57 – 1985-86
(Donovan and Darroch, 1991)

1946-47 – 1955-56	80% (assumed)
1956-57 – 1965-66	65%
1966-67 – 1975-76	37%
1976-77 – 1985-86	17%
1986-87 – 1988-89	17% (assumed)

Prior to 1956-57, R&D at the Experiment Station consisted exclusively of research and specialist advisory services because the extension department, established in 1953, had not become functually effective until then. For the purposes of this paper, therefore, a reasonable estimate of research's share of technology for the decade 1946-47 – 1955-56 would have been 80%. For the last three years of NCo310's significant contribution to production it can also be assumed that research's share of technology remained at the previous decade's level of 17%.

Table 3

Plant Breeding's share of research value, 1946-47 – 1988-89

Decade	% increase in total during the decade	Variety productivity over the following decade	Plant Breeding's share of research value
1st 1946-47 – 1956-57	28,8	22,9	9,7 x 1,229 = 11,9%
2nd 1956-57 – 1965-66	5,9	3,3	9,4 x 1,033 = 9,7%
3rd 1966-67 – 1975-76	2,6	1,3	9,3 x 1,013 = 9,4%
4th 1976-77 – 1985-86	1,5	0	9,3[1] = 9,3%
5th 1986/87 – (1988/89)	0	0	9,3[2] = 9,3%

[1] Obtained in a previous study (Donovan, 1989)
[2] Assumed unchanged from previous decade

The value of research can now be calculated using the appropriate percentage (given in Table 2) of the value of technology, and is given in Appendix 1 (column 3).

The only estimate made of plant breeding's share of research value, namely 9,3%, was made by Donovan (1989) for the fourth decade 1976-77 – 1985-86. If plant breeding's share of research value for the other decades can be considered proportional to total variety productivity, its share, in percentage terms, for each of the other decades, can be calculated by increasing the fourth decade share, *viz.* 9,3%, by the percentage change in total variety productivity over the previous decade, as shown in Table 3.

The value of plant breeding in monetary terms can then be calculated as these percentages of the value of research, and is given in Appendix 1 (column 4).

The value of each variety is obtained by apportioning the value of plant breeding among the varieties producing cane in proportion to their productivity, that is, their productivity expressed as a percentage of total variety productivity (Appendix 1, column 10). Variety productivity (VP) is the product of a variety's yield index (VI) and its percentage contribution (V%) to the industrial crop, and total variety productivity is, therefore, the sum of the productivity of all varieties producing cane in each year. A variety's yield index is the factor by which it exceeds a reference or standard variety, which for the purposes of this paper is Uba, with a yield index of 1. The yield indices of varieties used in this paper were calculated from data provided by [1]Inman-Bamber (personal communication) and are given in Table 4.

Table 4

Yield indices of varieties contributing at least 1% to the industrial crop

UBA	1,00	NCo292	1,40	N12	2,08
*O&M	1,40	NCo376	1,99	N14	1,98
Co331	1,57	NCo382	1,61	N17	2,01
NCo310	1,88	N50/211	1,57	N16	2,12
NCo339	1,75	N55/805	1,87	N19	2,07
NCo293	2,00	N52/219	1,89		

* The variety index for Other and Mixed Varieties (O&M) is calculated as the weighted mean of the indices of all varieties in production and therefore changes as the varieties, or their percentage contribution to production, change. The changes in the index for O&M varieties is indicated in brackets in the O&M column of Appendix 2.

The calculated productivity (VI x V%) for each variety contributing to the industrial crop is given in Appendix 2 and is shown graphically in Figure 1.

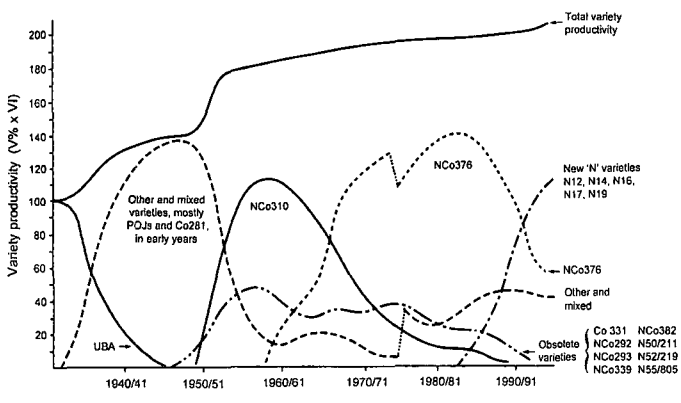

FIGURE 1: Productivity of released varieties

[1]NG Inman-Bamber, Principal Agronomist, SASA Experiment Station, Mount Edgecombe

NCo310's direct contribution to total variety productivity, in percentage terms, is given in column 5 of Appendix 1 and its value, calculated as the product of columns 4 and 5, is given in column 6.

The value of NCo310 to the industry should also take into account the loss in value if NCo310 had not been bred and released. This loss in value is calculated by replacing NCo310's productivity (VI x V%) with the productivity of the other varieties in use over the same period, in the proportions of their use. Furthermore, the evaluation should also include NCo310's contribution as a parent of the variety N55/805, the only first generation variety released so far, in which it was used as a parent. The estimates of these two additional components of the value of NCo310 are given in columns 7 and 8 respectively, of Appendix 1.

For comparative purposes, the direct value of NCo376 up to 1993-94 has been calculated in the same way and is given in column 9 of Appendix 1. Until it is no longer in use, it is not possible to estimate the loss in value if NCo376 had not been released, nor its parental value (as a parent of N12, N16, N17 and N19). However, it is of interest to note that, by 1992-93, NCo376's productivity was exceeded by the combined productivity of the 'New N' varieties (as shown in Figure 1) and so, for the last two years of this study, its continued use as a variety by the industry has resulted in a decline in total variety productivity.

The value of NCo310 to the South African sugar industry can now be estimated as Rm 165,24, being its direct value (Rm 151,21), plus the loss in value if it had not been bred and released (Rm 5,93), plus half the value of N55/805 (Rm 8,10), being its parental share of the value of the only released variety with NCo310 as a parent.

It is of interest to note from column 7 of Appendix 1 that, for the last 23 of the 39 years duing which NCo310 was in use, its continued production had a negative effect on total variety productivity, as indicated in column 7 of Appendix 1. It is likely that other varieties, particularly those with lower yield indices, would also have had negative effects on total variety productivity.

Estimating the cost of varieties

Until recently it usually took an average of 14 years from crossing to the release of varieties that were wholly bred at the Experiment Station; for example, 'N' varieties such as N12 and N14. However, in the case of the 'NCo' varieties, crossing was done in Coimbatore, India, at the request of the Experiment Station because, at that time, sugarcane seed could not be set in Natal. The imported true seed was then grown and the seedlings tested and selected in Natal by the Experiment Station.

In the case of NCo310, seed was received in May 1938 and, after seedling selection and testing, was released to the industry in November 1945. For the purposes of this paper, therefore, it is assumed that the cost of producing NCo310, and other 'NCo' varieties, was their share of the total cost of plant breeding at the Experiment Station for seven years and that no costs were involved in the crossing of their parental varieties at Coimbatore.

Plant breeding costs are assumed to be shared equally by all varieties in the 'breeding pipeline' in the same year *that they are eventually released.* This is in line with the general practice of sharing the R&D costs of 'dry holes' among 'wet holes'; that is, the costs of breeding varieties that are not eventually released being borne equally by those that are released.

The 'sharing factor' for each released variety, for each year it is in the breeding pipeline, is given in Table 5 which is derived from Appendix 3 (which sets out the breeding periods of released varieties to show their overlapping).

Table 5

Cost sharing factors for NCo310, NCo376 and the 'New N' varieties (see Appendix 3)

Variety	Breeding period	Overlapping varieties	Cost sharing factors	
NCo310	1938-39 - 1944-45	Co331	0,5 for each year	
NCo376	1948-49 - 1954-55	NCo293, NCo339, NCo292, N50/211, N55/805	1948-49 - 1950-51 1951-52 1952-53 - 1954-55	0,20 0,17 0,25
'New N' varieties	1965-66 - 1985-86	N52/219, N12 N14, N16, N17, N19	1965-66 - 1966-67 1967-68 1968-69 - 1969-70 1970-71 - 1971-72 1972-73 - 1974-75 1975-76 - 1986-87	0,50 0,67 0,75 0,20 0,83 1,00

Records of the total costs of the Experiment Station are available since its establishment in 1925 but, until comparatively recently, not separately for its individual departments. However, since salary and other staff costs consistently constitute about 70% of total costs, and since staff lists are available for the relevant period, it is considered acceptable to use the number of technologists in each department as a percentage of the total number, to estimate departmental from total Experiment Station costs.

Between 1938 and 1945, when NCo310 was being selected and tested, plant breeding staff numbers remained relatively constant although the staff of other departments was depleted by war service. During this period, therefore, plant breeding's percentage of total Experiment Station costs increased from a pre-war level of about 16% to 22%. By 1950-51 the pre-war level had been restored and then declined to about 10% by the mid-1950s as new departments and functions, particularly extension, were added to the Experiment Station's portfolio.

It is to the credit of the Experiment Station's policy and management decision-makers that this proportion of 10% for plant breeding was maintained through to the mid-1980s despite a four-fold increase in total Experiment Station staff.

The calculation of the cost of producing varieties NCo310 and NCo376 is given in Appendix 4. Estimates of the cost of producing the 'New N' varieties are also made in Appendix 4, based on the assumption that, on average, a new variety will have been released every second year from 1974-75 onwards. Table 6 summarises the variety cost calculations and estimates.

Table 6

Costs of production of varieties in Rm at 1994-95 prices (see Appendix 4)

Variety	Total	Per annum
NCo310	6,747	0,964
NCo376	2,408	0,344
N12	15,796	1,128
N14	13,269	0,948
N16	13,020	0,930
N17	12,629	0,902
N19	12,758	0,911

Benefit:cost estimates

Of the varieties considered in this paper, only for NCo310 is it possible to calculate a benefit:cost ratio because it no longer constitutes 1% of the industrial crop and therefore does not add value in monetary terms. With an estimated production cost of Rm 6,747 and an estimated value of Rm 165,24, its benefit:cost ratio is 24,48:1.

It is of academic interest to note that if the value of NCo310 had been calculated using the price of sucrose received by growers instead of the export realisation on sugar, that is, the equivalent of the 'shadow price', the benefit:cost ratio for NCo310 would have been appreciably lower at 17,68. The data for this calculation are given in Appendix 5.

By 1993-94, although in decline, NCo376 still comprised 30% of the industry's crop so its final benefit cannot yet be calculated. Its interim benefit:cost ratio is about 65:1 calculated from its estimated cost of production of Rm 2,408 and its interim value of Rm 156,92.

By the same year none of the 'New N' varieties individually consituted as much as 20%, although together they made up nearly 50%, of the industrial crop. Therefore interest in the value of the 'New N' varieties has, at this stage, to be limited to estimates made of their cost of production and speculation on their likely future benefits.

Discussions and conclusions

There is no doubt that NCo310 "...had a profound effect on the sugar industry in South Africa..." (Nuss and Brett, 1995). Unless a variety of similar quality and disease resistance had been released by the Experiment Station at that time, the industry might not have sustained the productivity necessary for survival.

The estimate made in this paper of NCo310's productive value, namely over Rm 165, and the fact that its benefit was nearly twenty-five times its cost, further emphasises its great contribution to the industry's productivity.

It is not easy to estimate the 'survival' value of a variety any more than it is easy to estimate the 'insurance' value of technologies and R&D services. Therefore, in any exercise of technology evaluation, such as this of a variety, the inestimable survival and insurance value of that technology must be an important, albeit unquantified, additional quantum.

It is interesting to note that NCo310 made a positive contribution for only 16 years, compared with NCo376's 34 years, yet its direct value to the industry was only 4% lower than NCo376's direct value. This emphasises the fact that the return on the research component of R&D as a whole was much higher during the period that NCo310 was the dominant variety than when NCo376 was dominant, as is indicated in Table 2.

This effect, together with the inevitable diminishing returns in variety productivity and the increasing cost of variety production indicated in Table 6, suggest that the new techniques such as biotechnology and inter-generic crosses are necessary if varieties with productivity levels high enough to be cost effective, are to be produced. Reduction in the costs of conventional plant breeding is likely to result in only small and short-term improvement in a variety's benefit:cost ratio.

An additional useful outcome of this research has been the quantification of negative productivity that results when a variety is maintained in production at the expense of more productive varieties. In the case of NCo310, it only increased productivity for the first 16 of its 39 years in use and there-

after should have been replaced because of its mostly negative effect on productivity. NCo376, on the other hand, remained positively productive for the first 37 years of its use, that is, until 1992 after which it should have been replaced.

Since the productivity of varieties (VI x V%) almost certainly varies with ecological and management conditions, it may be useful, as an extension tool, to evaluate variety productivity in the industry's different ecological or extension areas, and even under individual management conditions, in order to improve advice on variety replacement.

Variety replacement is a costly operation and quantitative information in monetary terms on the effects of variety changes on productivity, particularly if interpreted in terms of discounted cash flow, should facilitate decision-making by the grower.

Acknowledgements

The advice of Dr Peter Brett and Mr Karl Nuss on plant breeding aspects, and Prof Nieuwoudt on economic matters, is gratefully acknowledged as is the assistance given by Mr AA Hansen in locating and allowing access to early records of Experiment Station costs and staff establishments, and Ms S Bremner-Stokes for the data on sugar production and export realisation. Special thanks are due to Mr Murt Murdoch for his constructive criticisms and assistance with data processing.

REFERENCES

Donovan, PA (1989). Estimating returns on agricultural research and development in the South African sugar industry. PhD thesis, University of Natal.

Donovan, PA and Darroch, MAJ (1991). Estimating returns on agricultural extension. *Agricultural Systems* 37: 39-53.

Donovan, PA and Niewoudt, WL (1992). Estimating technology's contribution to productivity in the South African sugar industry. *Agricultural Systems* 39: 329-338.

Nuss, KJ and Brett, PGC (1995). The release of variety NCo310 in 1945 and its impact on the sugar industry. *Proc S Afr Sug Technol Ass* 69: 3-8.

APPENDIX 1

Column 1: Value of SA sugar industry's sugar production, Rm
Column 2: Value of technology generated at SASEX, RM
Column 3: Value of research component of technology, Rm
Column 4: Value of plant breeding component of research, Rm
Column 5: NCo310's % share of total variety productivity
Column 6: Value of NCo310, RM
Column 7: Loss in value without NCo310, Rm
Column 8: Value of N55/805, Rm
Column 9: Value of NCo376, Rm
Column 10: Total variety productivity
Column 11: Total variety productivity without NCo310

Year	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8	Column 9	Column 10	Column 11
1949/50	696	93	74	8.84	4	0.35	0.08			142	141
1050/51	933	125	100	11.86	18	2.14	0.43			156	151
1951/52	734	98	78	9.32	24	2.24	0.34			166	160
1952/53	901	120	96	11.46	41	4.70	0.53			175	167
1953/54	1129	151	121	14.35	44	6.31	0.66			176	168
1954/55	1178	157	126	14.98	52	7.79	0.85			178	168
1955/56	1283	171	137	16.31	59	9.62	1.03			179	168
1956/57	1203	186	121	11.7	60	7.02	0.71			180	169
1957/58	1347	208	135	13.11	62	8.13	0.81			181	169
1958/59	1489	230	149	14.49	61	8.84	0.85		0.20	181	170
1959/60	1255	194	126	12.21	61	7.45	0.51		0.53	183	175
1960/61	1156	178	116	11.25	60	6.75	0.39		0.64	184	177
1961/62	978	151	98	9.52	57	5.42	0.16		0.87	185	182
1962/63	983	152	99	9.56	55	5.26	0.15		0.93	185	183
1963/64	1861	287	187	18.11	51	9.24	0.15		2.08	187	185
1964/65	1470	227	147	14.3	47	6.72	0.07		1.79	187	186
1965/66	828	128	83	8.05	44	3.54	(0.04)		1.52	189	190
1966/67	1053	354	131	12.31	37	4.55	(0.08)		2.69	190	191
1967/68	1096	368	136	12.81	28	3.59	(0.06)		3.23	190	191
1968/69	943	317	117	11.03	22	2.43	(0.05)		3.10	191	192
1969/70	1631	549	203	19.08	21	4.01	(0.12)		5.81	193	194
1970/71	1436	483	179	16.79	18	3.02	(0.10)	0.07	5.08	193	194
1971/72	2729	918	340	31.92	16	5.11	(0.19)	0.86	10.05	194	195
1972/73	3079	1036	383	36.02	15	5.40	(0.20)	1.34	11.25	194	195
1973/74	3365	1132	419	39.35	12	4.72	(0.20)	1.86	12.86	195	196
1974/75	5661	1904	704	66.22	8	5.30	(0.22)	3.26	18.63	195	196
1975/76	5900	1984	734	69.01	8	5.52	(0.23)	4.14	19.99	195	196
1976/77	4258	1240	211	19.6	7	1.37	(0.06)	1.04	6.19	196	196
1977/78	3438	1001	170	15.83	6	0.95	(0.04)	0.84	5.13	196	196
1978/79	2450	713	121	11.28	5	0.56	(0.03)	0.52	3.76	197	197
1979/80	2614	761	129	12.04	4	0.48	(0.02)	0.51	4.16	197	197
1980/81	2767	806	137	12.74	7	0.89	(0.04)	0.44	4.35	197	197
1981/82	3810	1109	189	17.54	5	0.88	(0.04)	0.53	6.38	197	198
1982/83	1677	448	83	7.72	4	0.31	(0.02)	0.16	2.71	198	198
1983/84	771	225	38	3.55	4	0.14	(0.01)	0.06	1.21	198	198
1984/85	1815	528	90	8.35	2	0.17	(0.01)	0.11	2.89	198	198
1985/86	1524	444	75	7.01	2	0.14	(0.01)	0.07	2.15	198	199
1986/87	1814	528	90	8.35	1	0.08	(0.01)	0.08	2.53	199	199
1987/88	1582	461	78	7.28	1	0.07	(0.00)	0.06	2.09	199	199
1988/89	2462	717	122	11.34				0.07	3.01	200	200
1989/90	2988	870	148	13.76				0.07	3.33	202	202
1990/91	2476	721	123	11.4					2.53	201	201
1991/92	1793	522	89	8.25					1.65	200	200
1992/93	1384	403	69	6.37					1.00	202	202
1993/94	1017	296	50	4.68					0.69	202	202
Total	86956	23732	7351	711		151.21	5.93	16.2	156.92		

APPENDIX 2
VI = variety yield index (Uba = 1). In each variety column:
V% = variety's share of the industrial crop.
VIxV% = variety's productivity.
V% variety's percentage share of tale productivity.
O&M = other and mixed varieties.

Year	UBA (VI=1,00)			O&M (VI=1,40%)			Co331 (VI=1,57)			NCo310 (VI=1,88)			NCo339 (VI=1,75)			NCo293 (VI=2,00)			NCo292 (VI=1,40)			NCo376 (VI=1,99)		
	V%	VIxV%	VP%	V%	VIxV%	VP%	V%	VIxV%	VP%	V%	VIxV%	VP%	V%	VIxV%	VP%	V%	VIxV%	VP%	V%	VIxV%	VP%	V%	VIxV%	VP%
1946/47	1.9	2	1	98.1	137	99																		
1947/48	1.5	1	1	96.8	136	97	1.7	3	2															
1948/49				97.5	136	97	2.5	4	3															
1949/50				* 93.2	130	92	4.2	7	5	2.6	5	4												
1950/51				(1.50) 77.0	115	74	7.9	12	8	15.1	28	8												
1951/52				(1.60) 66.4	106	64	12.5	20	12	21.1	40	24												
1952/53				(1.70) 46.2	79	45	15.9	25	14	37.9	71	41												
1953/54				(1.75) 36.7	64	36	22.0	35	18	41.3	78	44												
1954/55				(1.78) 25.6	46	26	25.3	40	22	49.1	92	52												
1955/56				(1.79) 18.5	33	18	23.5	37	21	55.7	105	59	1.3	2	1	1.0	2	1						
1956/57				(1.80) 14.8	27	15	23.2	36	20	57.0	107	60	1.8	3	2	3.2	6	3						
1957/58				11.8	21	12	20.9	33	18	60.0	113	62	4.4	8	4	3.0	6	3	2.1	3	2	2.5	5	3
1958/59				(1.81) 9.3	17	9	18.8	30	16	59.4	112	61	3.9	7	4	4.0	8	4	2.5	3	2	8.0	16	9
1959/60				(1.83) 7.0	13	7	15.0	24	13	59.0	111	61	4	7	4	4.5	9	5	2.8	4	2	10.4	21	11
1960/61				(1.84) 5.2	10	5	12.8	20	11	59.1	111	60	4.7	8	4	5.0	10	5	2.4	3	2	17.0	34	18
1961/62				4.9	9	5	9.0	14	8	55.7	105	57	4.7	8	4	5.2	10	5	2.3	3	2	18.0	36	19
1962/63				(1.85) 6.9	13	7	8.9	14	8	53.7	101	55	3.7	6	3	4.6	9	5	2.1	3	2	21.4	43	23
1963/64				(1.86) 8.3	15	8	6.3	10	5	50.8	96	51	3.2	6	3	4.9	10	6	1.3	2	1	23.4	47	25
1964/65				(1.87) 12.0	22	12	4.4	7	4	46.9	88	47	2.6	5	3	3.7	7	4				35.7	71	38
1965/66				(1.89) 3.5	7	4	2.9	5	3	44.5	84	44				5.1	10	6				41.5	83	44
1966/67				(1.90) 2.0	4	2	2.1	3	2	38.0	71	37				6.8	14	7				48.0	96	51
1967/68				2.4	5	3	1.6	2	1	28.8	54	28				7.2	14	7				53.7	107	56
1968/69				(1.91) 2.7	5	3	1.6	2	1	22.4	42	22				8.3	17	9				58.6	117	61
1969/70				(1.92) 4.6	9	5				21.2	40	21				5.9	12	6				58.5	116	60
1970/71				(1.93) 4.3	8	4				18.5	35	18				8.2	16	8				61.0	121	63
1971/72				(1.94) 3.7	7	4				16.5	31	16				6.6	13	7				60.6	121	62
1972/73				3.7	7	4				15.2	29	15				7.2	14	7				63.7	128	66
1973/74				(1.95) 3.8	7	4				12.7	24	12				6.7	13	7				54.6	107	55
1974/75				18.5	36	19				8.4	16	8				6.0	12	6				56.6	112	57
1975/76				15.0	29	15				8.4	16	8				5.5	11	6				61.7	123	63
1976/77				13.1	26	14				7.0	13	7				5.2	10	5				63.5	126	65
1977/78				(1.96) 12.1	24	12				6.0	11	6				5.8	11	6				65.6	130	66
1978/79				12.0	24	12				5.6	10	5				6.2	12	6				68.0	135	68
1979/80				10.5	21	11				4.0	8	4				7.5	15	8				67.2	134	68
1980/81				(1.97) 11.6	23	11				6.8	13	7				6.4	13	7				71.8	143	73
1981/82				10.6	21	11				4.8	9	5				5.6	11	6				69.4	138	70
1982/83				13.3	26	13				4.4	8	4				7.2	14	7				67.5	134	68
1983/84				(1.98) 14.7	29	15				3.5	7	4				8.2	16	8				68.7	137	69
1984/85				15.6	31	16				1.6	3	2				7.6	15	8				60.9	121	61
1985/86				18.3	36	18				2.1	4	2				7.7	15	8				60.2	120	61
1986/87				(1.99) 16.3	32	16				1.3	2	1				6.7	13	7				57.2	114	57
1987/88				18.6	37	19				1.1	2	1				6.1	12	6				53.0	105	53
1988/89				(2.00) 19.2	38	19										6.2	12	6				48.9	97	48
1989/90				19.4	39	20										4.7	9	4				44.6	89	44
1990/91				19.9	40	20										3.3	7	3				40.1	80	40
1991/92				(2.01) 19.7	40	20										2.6	4	2				31.6	63	31
1992/93				18.8	38	19										2.1	4	2				30.0	60	30
1993/94				(2.02) 21.6	44	22																		

NCo382 (VI=1,61)			N50/211 (VI=1,57)			N55/805 (VI=1,87)			N52/219 (VI=1,89)			N12 (VI=2,08)			N14 (VI=1,98)			N17 (VI=2,01)			N16 (VI=2,12)			N19 (VI=2,07)		
V%	VIxV%	VP%	V%	VIxV%	VP%	V%	VIxV%	VP%	V%	VIxV%	VP%	V%	VIxV%	VP%	V%	VIxV%	VP%	V%	VIxV%	VP%	V%	VIxV%	VP%	V%	VIxV%	VP%
1.1	2	1																								
1.9	3	2																								
1.8	3	2	1.2	2	1																					
2.9	5	3	2.8	4	2																					
4.2	7	4	4.1	6	3																					
5.5	9	5	4.1	6	3																					
7.6	12	6	4.4	7	4																					
7.7	12	6	3.6	6	3																					
5.7	9	5	4.0	6	3																					
6.2	10	5	2.3	4	2	2.0	4	2																		
5.1	8	4	1.9	3	2	5.2	10	5																		
5.1	8	4	1.0	2	1	7.2	13	7																		
3.9	6	3				9.2	17	9																		
2.9	5	3				9.6	18	9																		
2.9	5	3				11.7	22	11																		
2.6	4	2				10.4	19	10																		
2.2	4	2				10.4	19	10																		
1.8	3	2				9.0	17	9																		
1.6	3	2				8.4	16	8																		
1.2	2	1				6.8	13	7																		
						6.0	11	6	1.2	2	1															
						4.1	8	4	1.6	3	2															
						3.4	6	3	1.5	3	2															
						2.7	5	3	1.1	2	1				1.2	2	1									
						2.1	4	2	1.1	2	1				2.7	5	3									
						1.9	4	2	1.0	2	1	1.4	3	2	6.4	13	7									
						1.6	3	2				2.8	6	3	9.8	19	9									
						1.2	2	1				4.6	10	5	10.8	21	11									
						1.1	2	1				7.8	16	8	11.6	23	11	1.0	2	1						
												9.0	19	9	14.1	28	14	1.5	3	2	1.3	3	1	1.1	2	1
												12.2	25	12	15.1	30	15	1.7	3	2	1.9	4	2	1.3	3	1
												16.4	34	17	14.3	28	14	2.0	4	2	2.3	5	2	2.1	4	2
												21.6	41	22	16.1	32	16	2.5	5	2	3.4	7	3	3.9	8	4
												18.5	38	19	17.4	34	17	3.1	6	3	4.0	8	4	5.4	11	5

APPENDIX 3
Breeding periods of released varieties.

Variety

Year	NCo310	Co331	NCo293	NCo339	NCo292	NCo376	N50/211	N55/805	N52/219	N12	N14	N16	N17	N19	(N?...N?)
1938/39	x	x													
1939/40	x	x													
1940/41	x	x													
1941/42	x	x													
1942/43	x	x													
1943/44	x	x													
1944/45	x	x													
1945/46			x	x			x								
1946/47			x	x			x								
1947/48			x	x	x	x	x								
1948/49			x	x	x	x	x								
1949/50			x	x	x	x	x								
1950/51			x	x	x	x	x								
1951/52			x	x	x	x	x	x							
1952/53					x	x	x	x							
1953/54					x	x	x	x							
1954/55					x	x	x	x							
1955/56							x	x							
1956/57							x	x							
1957/58							x	x							
1958/59							x	x							
1959/60								x							
1960/61								x							
1961/62								x	x						
1962/63								x	x						
1963/64								x	x						
1964/65								x	x						
1965/66									x	x					
1966/67									x	x					
1967/68									x	x	x				
1968/69									x	x	x	x			
1969/70									x	x	x	x			
1970/71									x	x	x	x	x		
1971/72									x	x	x	x	x		
1972/73									x	x	x	x	x	x	
1973/74									x	x	x	x	x	x	
1974/75									x	x	x	x	x	x	?
1975/76										x	x	x	x	x	?
1976/77										x	x	x	x	x	??
1977/78										x	x	x	x	x	??
1978/79										x	x	x	x	x	???
1979/80											x	x	x	x	???
1980/81											x	x	x	x	????
1981/82												x	x	x	????
1982/83													x	x	?????
1983/84													x	x	??????
1984/85														x	??????
1985/86														x	???????

APPENDIX 4
Calculation of variety production costs

Variety Year	Breeding staff %	Technical budget	Plant Breeding budget	Variety share of PB costs	Variety cost per annum	Total cost of varieties
NCo310						
1938/39	16	10.28	1.649		0.825	
1939/40	17	12.02	2.043		1.022	
1940/41	18	11.19	2.014		1.007	
1941/42	19	11.73	2.229	0.5	1.115	
1942/43	20	9.02	1.804		0.902	
1943/44	21	8.67	1.821		0.910	
1944/45	22	8.78	1.932		0.966	NCo310 = 6.747
NCo376						
1948/49	20	11.39	2.278	0.2	0.456	
1949/50	18	8.60	1.548	0.2	0.310	
1950/51	16	8.66	1.386	0.2	0.277	
1951/52	14	13.02	1.823	0.17	0.310	
1952/53	12	13.10	1.572	0.25	0.393	
1953/54	11	11.76	1.294	0.25	0.324	
1954/55	10	13.54	1.354	0.25	0.338	NCo376 = 2,408
New 'N' varieties						
1965/66			4.215	0.5	2.108	
1966/67			4.129	0.5	2.064	
1967/68			4.133	0.33	1.364	
1968/69			4.845	0.25	1.211	
1969/70			3.837	0.25	0.959	
1970/71			4.062	0.2	0.812	
1971/72			3.847	0.2	0.769	
1972/73			5.189	0.17	0.882	
1973/74	(Breeding staff %		5.174	0.17	0.880	
1974/75	remained fairly		6.621	0.14	0.927	
1975/76	constant for		5.690	0.17	0.967	
1976/77	the whole		7.776	0.14	1.089	
1977/78	period at		6.105	0.14	0.855	
1978/79	about 10%)		7.577	0.12	0.909	N12 = 15.796
1979/80			6.151	0.14	0.861	
1980/81			6.531	0.12	0.784	N14 = 13.269
1981/82			7.965	0.14	1.115	N16 = 13.020
1982/83			7.131	0.14	0.998	
1983/84			6.512	0.12	0.781	N17 = 12.629
1984/85			6.567	0.14	0.919	
1985/86			6.589	0.12	0.791	N19 = 12.758

APPENDIX 5

Column 1: Value of sucrose paid to growers, Rm
Column 2: Value of technology generated at SASEX, RM
Column 3: Value of research component of technology, Rm
Column 4: Value of plant breeding component of research, Rm
Column 5: NCo310's % share of total variety productivity
Column 6: Value of NCo310, RM
Column 7: Loss in value without NCo310, Rm
Column 8: Value of N55/805, Rm
Column 9: Value of NCo376, Rm
Column 10: Total variety productivity
Column 11: Total variety productivity without NCo310

Year	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8	Column 9	Column 10	Column 11
1949/50	438	58	47	5.56	4	0.22	0.05			142	141
1050/51	581	78	62	7.38	18	1.33	0.27			156	151
1951/52	447	60	48	5.69	24	1.36	0.21			166	160
1952/53	619	83	66	7.87	41	3.23	0.36			175	167
1953/54	705	94	75	8.96	44	3.94	0.41			176	168
1954/55	781	104	83	9.93	52	5.16	0.56			178	168
1955/56	877	117	9	11.15	59	6.58	0.70			179	168
1956/57	777	120	78	7.56	60	4.54	0.46			180	169
1957/58	847	131	85	8.24	62	5.11	0.51			181	169
1958/59	1022	158	102	9.94	61	6.06	0.58		0.14	181	170
1959/60	906	140	91	8.81	61	5.37	0.37		0.39	183	175
1960/61	877	135	88	8.53	60	5.12	0.29		0.48	184	177
1961/62	935	144	94	9.1	57	5.19	0.16		0.83	185	182
1962/63	1018	157	102	9.91	55	5.45	0.16		0.96	185	183
1963/64	1290	199	129	12.55	51	6.40	0.10		1.44	187	185
1964/65	1229	190	123	11.96	47	5.62	0.06		1.50	187	186
1965/66	803	124	81	7.81	44	3.44	(0.04)		1.47	189	190
1966/67	1456	489	181	17.02	37	6.30	(0.11)		3.72	190	191
1967/68	1558	524	194	18.23	28	5.10	(0.09)		4.60	190	191
1968/69	1354	455	169	15.84	22	3.49	(0.08)		4.45	191	192
1969/70	1581	532	197	18.49	21	3.88	(0.12)		5.63	193	194
1970/71	1260	424	157	14.74	18	2.65	(0.09)	0.15	4.46	193	194
1971/72	1498	504	186	17.52	16	2.80	(0.10)	0.47	5.52	194	195
1972/73	1496	503	186	17.5	15	2.63	(0.10)	0.65	5.47	194	195
1973/74	1545	520	192	18.08	12	2.17	(0.09)	0.85	5.91	195	196
1974/75	1839	619	229	21.51	8	1.72	(0.07)	1.06	6.02	195	196
1975/76	2261	760	281	26.45	8	2.12	(0.09)	1.59	7.66	195	196
1976/77	2156	628	107	9.93	7	0.69	(0.03)	0.53	3.13	196	196
1977/78	2010	585	100	9.26	6	0.56	(0.02)	0.49	3.00	196	196
1978/79	1970	574	98	9.07	5	0.45	(0.02)	0.41	3.02	197	197
1979/80	2003	583	99	9.22	4	0.37	(0.02)	0.39	3.19	197	197
1980/81	1902	554	94	8.76	7	0.61	(0.03)	0.30	2.99	197	197
1981/82	2092	609	104	9.63	5	0.48	(0.02)	0.29	3.50	197	198
1982/83	2008	585	99	9.24	4	0.37	(0.02)	0.19	3.25	198	198
1983/84	1686	491	83	7.76	4	0.31	(0.01)	0.13	2.65	198	198
1984/85	1989	579	98	9.16	2	0.18	(0.01)	0.12	3.17	198	198
1985/86	1719	500	85	7.91	2	0.16	(0.01)	0.08	2.43	198	199
1986/87	1763	513	87	8.12	1	0.08	(0.01)	0.08	2.46	199	199
1987/88	1581	460	78	7.28	1	0.07	(0.00)	0.06	2.09	199	199
1988/89	1671	487	83	7.69				0.05	2.04	200	200
1989/90	1687	491	83	7.77				0.04	1.88	202	202
1990/91	1574	458	78	7.24					1.61	201	201
1991/92	1551	452	77	7.14					1.43	200	200
1992/93	1467	427	73	6.75					1.06	202	202
1993/94	1224	356	61	5.63					0.84	202	202
Total	62053	16755	5007	484		111.32	4.07	7.95	104.37		