DROUGHT TOLERANCE OF COMMERCIAL SUGARCANE VARIETIES IN SOUTH AFRICA

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Abstract

The results of several variety trials that suffered various degrees of water stress in a recent drought are reported. In one trial at Pongola on a deep Shorrocks loam, four degrees of stress were artificially imposed on three varieties, NCo 376, N52/219 and N11. NCo 376 showed the greatest sensitivity to water stress although it was not always outyielded under stress conditions. N11 was less sensitive to stress and outyielded NCo 376 in the driest conditions. N52/219 was neither high yielding nor tolerant of drought. These characteristics were also apparent in the rainfed trials conducted on shallow soils. However, the poor ability of N11 to recover from drought that went undetected at Pongola, was evident in the rainfed trials. Two varieties of similar growth habit, N7 and N12, emerged as the most tolerant of drought and they appeared to recover quickly once stress was relieved. N13 also tolerated drought well and with N12 it usually outyielded the other varieties under conditions of stress.

Introduction

The past two dry seasons have shown how much the sugarcane varieties which are currently grown commercially in South Africa vary in their susceptibility to drought. NCo 376 the major variety was unfortunately more susceptible than most other varieties, whereas N55/805 and NCo 310, which are grown on a smaller scale, appeared to be more resistant to the drought. These general observations are consistent with the results of the trial reported by Hellmann[1], in which six varieties were grown under three irrigation regimes. In this trial NCo 310 yielded 25% less cane when deprived of adequate water, while NCo 376, N55/805, NCo 334, NCo 382 and CB36/14 yielded between 31 and 34%less cane when treated in the same way. The effect of the variety x water regime interaction on cane yield reached statistical significance in the second ratoon only. In this crop the yields of NCo 376, NCo 334 and CB36/14 relative to the treatment mean, were highest in the more favourable irrigation regimes while the relative yields of NCo 310, N55/805 and NCo 382 were highest in the dry regimes. The varieties included in this trial were originally selected in the plant breeding programme under similar conditions at sites near Mount Edgecombe and Mtunzini. There are now varieties in the industry that were selected under a much wider range of conditions and a greater variation in drought tolerance can therefore be expected, although this characteristic is not considered specifically when selections are made.

The results reported in this paper were obtained from a trial at Pongola that succeeded the one mentioned previously, as well as some of the rainfed trials that included recently released varieties which endured the 1978 to 1980 drought.

Methods

Variety x irrigation trial at Pongola

This trial was planted in the spring of 1978 on a deep, well-drained Shorrocks loam with an estimated total available moisture (TAM) capacity of 200 mm. The three varieties (NCo 376, N52/219 and N11) and four irrigation treatments were randomized in four replications. Each of the 48 plots (12 x 9 m) could be irrigated independently from a perforated pipe supported just above the canopy on telescopic masts. The pressure in the pipe was adjusted so that the outside two rows (guard rows) of the six-row plots, only just received spray. The nearest row of a net plot adjacent to the one being irrigated was therefore three metres away from the spray. The flow meter connected to each perforated pipe permitted an application of exactly 50 mm of water to be made during each irrigation.

The irrigation treatments given below were not meant to represent any practical irrigation system but were chosen to emphasize differences that could have been inherent between the three varieties.

W1 Full irrigation (All crops): 50 mm on a 21 day minimum cycle.

W2 Mild stress:
- Plant crop: Full irrigation from March onwards.
- 1st ratoon: Full irrigation, summer only (including April).
- 2nd ratoon*: Allow ASM† to remain below 20 mm for 30 days before each irrigation.

W3 Moderate stress:
- Plant + 1R: Full irrigation winter only (April onwards).
- 2nd ratoon*: Allow ASM† to remain below 20 mm for 60 days before each irrigation.

W4 Severe stress (All crops): 50 mm only to prevent severe desiccation.

* The operators failed to follow this specification at times but this did not detract materially from the effect intended.

† ASM = available soil moisture as determined by a profit and loss account (Thompson and Boyce[3]).

Gypsum blocks were installed at four depths in all W2 plots in the second ratoon in order to have some check on the ASM determined by the profit and loss method. Cylindrical blocks were made and installed as suggested by Pereira[2]. A bouyocos moisture meter was used to obtain block resistance readings once a week.

The plant crop was cut when it was 12 months old and the first and second ratoons at 10 and 11 months of age respectively. The early harvest of the ratoon crops was necessary to avoid complete desiccation of stalks in the dry plots as well as severe lodging in the moist plots. The heights of the topmost dewlap of any 20 stalks in each plot were recorded each month. The number of stalks in one net row was recorded at the same time. All stalks in the net plot were counted and weighed at the time of harvest. Twelve of these were taken to the laboratory to determine the contents of dry matter, brix, pol and estimated recoverable sugar (referred to simply as "sugar" in this paper).

Rainfed variety trials

Details of the variety trials reviewed in this paper are given in Table 1. Stalk height and population counts as well as cane yield and quality were measured in the same way as the Pongola trial. The pre-emergence spraying of a mixture of metribuzin (Sencor) and diuron was most often the means of keeping the trials free of weeds. Fertilizers were applied according to soil and tissue analyses to obtain optimum yields under the conditions.

TABLE 1

Details of trials with released varieties that were harvested in rainfed areas during the 1978-1980 drought

No.	Trial Site	Soil	Crop	Start/ plant date	Harvest date	Age (months)
1	Ottawa	Windermere	P	6.12.77	14.06.79	18,3
			R1	14.06.79	2.06.81	23,6
2	Mtunzini	Shortlands	P	13.12.77	30.04.79	16.6
			R1	30.04.79	23.09.80	16,8
3	Paddock	Longlands	P	29.11.77	17.05.79	17,6
			R1	17.05.79	22.09.80	16,1
4	Ottawa	Windermere	P	16.10.78	10.06.80	19,8
			R1	10.06.80	17.09.81	15,2
5	Mtunzini	Shortlands	P	9.10.78	13.11.79	13,1
			R1	13.11.79	29.04.81	17,6
6	Paddock	Longlands	P	19.10.78	6.12.79	13,6
			R1	6.12.79	9.06.81	18,1
7	Dalton	Farningham	R1	8.08.79	7.08.81	24,0
8	Dalton	Farningham	R1	8.08.79	7.08.81	24,0
9	Dalton	Farningham	P	27.02.80	5.08.81	17,3

Results and Discussion

Variety x irrigation trial at Pongola

Some results of the two methods of determining soil moisture content are compared for the mildly stressed crops (W2) in Figure 1. The ASM derived by the profit and loss method was an underestimate of soil moisture content measured by the gypsum blocks, particularly during February. The ASM values are likely to be in error because a drought-stressed crop does not transpire at the potential rate as is assumed in the profit and loss method. However, the gypsum block readings are only an approximate measure of the actual moisture content of the soil. Note should be taken of the low water content of the soil at a depth of 2 000 mm. Previous data (Thompson and Boyce[3]) obtained from this site revealed that the crop can extract considerable amounts of water from this depth. Three seasons of relatively dry conditions under this treatment may have resulted in a relatively shallow effective rooting depth.

The soil in plots receiving treatments W3 and W4 was always drier than those of treatment W2.

Full irrigation (W1)

The stalk height measurements of the first two crops obtained from the frequently irrigated plots showed that growth was restricted to some extent either by low temperature or light conditions or by short-lived water deficits. Only in the second ratoon did the growth of NCo 376 proceed unhindered throughout summer (Figure 2). In this crop varieties N52/219 and N11 did not increase in height as much as NCo 376 did during the months of rapid growth. A cane yield of 156 t/ha from NCo 376 was the highest produced by any variety in the trial, although this variety produced about 20% more cane than the other varieties in the W1 treatment of the plant and first ratoon crops as well. The sugar yield of NCo 376 was 23% and 16% higher than the yield of N11 in the first two crops, but all the varieties produced similar sugar yields in the second ratoon (Table 2). Smut incidence in well irrigated NCo 376 had become serious in the second ratoon and this may have reduced its superiority in terms of sugar yield.

"Mild" stress (W2)

Mildly stressed plots in the plant crop received only 50 mm less water than fully irrigated plots, but stalk heights and yields of all varieties were nevertheless affected significantly by this difference. The effect seemed to arise due to low water availability in the W2 plots during February

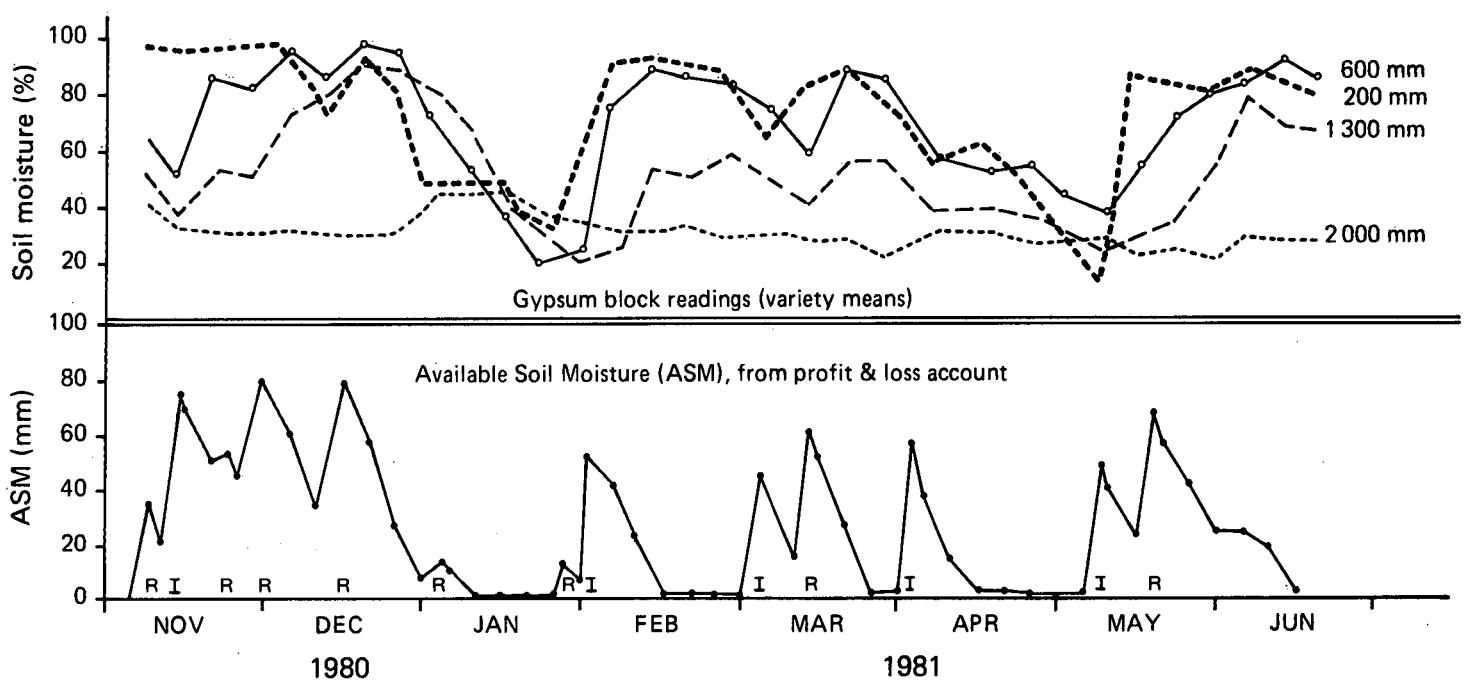

FIGURE 1 Soil moisture content in plots of sugarcane (2R) that were allowed to dry out for 30 days (W2) before irrigating. a) Gypsum block readings at four depths b) Available soil moisture according to a profit and loss account. I = irrigation R = rainfall.

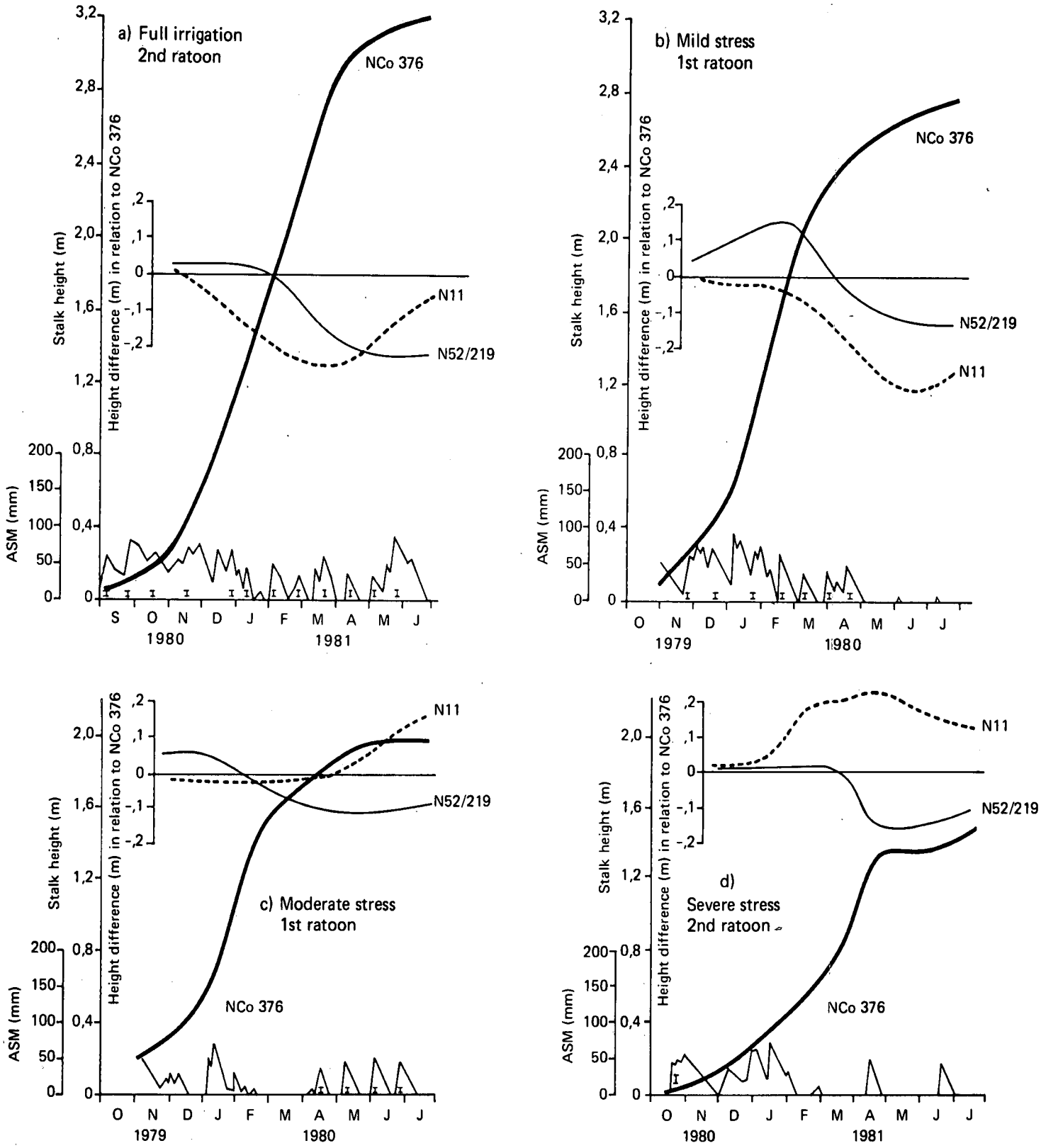

FIGURE 2 Stalk height of NCo 376 (bold line), heights of N52/219 and N11 relative to the height of NCo 376, together with the available soil moisture (ASM) estimated from a simple profit and loss account, for the duration of one of the three crops investigated. I = irrigation (50 mm).

when the evaporative demand was high. The average reductions in yield due to "mild" stress in the following two crops were 0,5 t and 2,7 t/ha of sugar respectively. The corresponding water deficits were 250 mm and 350 mm. The yield loss in the first ratoon was small because irrigation was withheld in the winter only. It appeared that the height growth and cane yields of N52/219 and N11 were affected more than those of NCo 376, by the lack of irrigation in winter. (See Figure 2 and Table 2). It is conceivable that NCo 376 used less water than the other varieties in the summer months, leaving sufficient water in the profile to meet the crop's requirements during winter.

The "mild" stress that was imposed on the second ratoon crop was more severe than that experienced in the first ratoon, since stress periods occurred in summer as well as in winter. In this case the yield of NCo 376 was reduced as much as that of the other varieties.

TABLE 2

Effect of water regime on the yield of cane and sugar of three varieties grown for three crops at Pongola

	Water regime	Cane yield (t/ha)				Sugar yield (t/ha)			
		NCo 376	N52/ 219	N11	Mean	NCo 376	N52/ 219	N11	Mean
					Plant crop				
W1	Full irrigation	129	102	104	111	15,6	13,1	12,7	13,8
W2	Mild stress	106	79	81	88	11,5	9,2	9,2	10,2
W3	Moderate stress	103	76	69	83	11,5	9,1	8,7	9,8
W4	Severe stress	78	65	63	69	9,4	9,2	9,3	9,3
					1st Ratoon				
	Full irrigation	142	124	114	127	15,7	14,7	13,5	14,6
	Mild stress	143	116	109	123	15,3	14,1	12,9	14,1
	Moderate stress	97	85	87	90	10,8	9,6	10,9	10,4
	Severe stress	74	69	80	74	5,1	6,2	9,3	6,8
					2nd Ratoon				
	Full irrigation	156	126	128	137	14,9	14,8	14,7	14,8
	Mild stress	115	103	99	106	11,9	12,5	11,8	12,1
	Moderate stress	89	82	90	87	8,8	8,6	11,1	9,5
	Severe stress	47	33	47	42	3,1	2,8	4,8	3,6

Moderate stress (W3)

In the plant crop, the low amount of available water in February and March resulted in a marked reduction in stalk elongation. The recovery from stress in April when these plots were irrigated was rapid, particularly in NCo 376. Water deficits occurred in autumn in the subsequent two crops. Growth was retarded similarly but the crops failed to recover immediately with the resumption of irrigation (Figure 2c). N11 did recover slowly and its yield compared more favourably with that of NCo 376 in this treatment than in the wetter regimes.

Statistical evidence of a variety x irrigation interaction that was lacking in the first two crops was present in the third crop in terms of tons cane per hectare. N52/219 and N11, which yielded significantly less cane than NCo 376 in the W1 and W2 treatments, yielded as well as NCo 376 in the W3 treatment. With its superior sucrose content, N11 produced 2,3 tons of sugar per hectare more than NCo 376 and N52/219 in the W3 regime, having been no better than these varieties in the more favourable regimes.

Severe stress (W4)

Sugarcane in the severely stressed plots received almost no supplementary irrigation. The amounts of water applied to the three successive crops were 70, 110 and 50 mm respectively. The low rainfall received by each crop (624, 550 and 690 mm respectively) served to heighten the stress conditions. The average annual rainfall over the past 15 years at Pongola is 644 mm. Although the first two crops yielded poorly, they produced at least as much as the commercial target of 9 t/ha per 100 mm water that was observed for sugarcane by Thompson and de Robillard[4]. The mean yield of the second ratoon was 40% lower than that of the first two crops and the water use efficiency of 5,6 t/ha per 100 mm water was well below target.

The varieties responded quite differently to the conditions of severe stress. In the plant crop, the prolonged stress reduced the sugar yields of all varieties to a similar level, NCo 376 having outyielded the other varieties by at least 2 t/ha in the wetter regimes. The sucrose content more than the cane yield of NCo 376 was responsible for this reduction in relative sugar yield.

In the first ratoon NCo 376 yielded less sugar per hectare than the other varieties due to reductions in cane yield, sucrose content and juice purity. N11 gave considerably higher yields of cane and sugar than did the other varieties of this severely stressed first ratoon crop.

Similar results were obtained in the second ratoon in which the interaction between variety and irrigation regime reached a level of statistical significance. N11 produced approximately 60% more sugar than NCo 376 and N52/219.

The stalk height data in all three crops confirmed the superiority of N11 under dry conditions (see Figure 2d).

Rainfed variety trials

The yields of varieties in released variety trials that have been conducted over the past fifteen years seldom differed by more than 15% unless a variety was clearly unsuited to the conditions of the trial or it was severely infected with a pest or a disease. The results of trials that were harvested during the recent drought are given in Table 3. Relative yields that were abnormal because of eldana or rust infestations have been indicated. Those considered to be abnormal becaue of the drought are **underlined.**

The results show that NCo 376 can yield very poorly under extremely dry conditions such as those experienced in the plant crop of trial 4. N52/219 is no better than NCo 376 in this respect but is usually inferior to NCo 376 in better growing conditions. N11 was clearly one of the more drought resistant varieties in the plant crops of trials 1 and 4 and in the first ratoon of trial 7, but it yielded poorly compared with other varieties under better conditions.

These results obtained under rainfed conditions thus confirm to some extent those of the variety x irrigation trial at Pongola. However, N11 gave the lowest yield in the

TABLE 3

Sugar yields, as a % of the yield of NCo 376, of varieties in trials harvested during the drought of 1978-80

Trial No. Site	Crop	NCo 376	N52/219	N55/805	J59/3	N7	N11	N12	N13	Mean cane yield /month t/ha	Drought description
1 Ottawa ..	P	100	100	89	**129**	104	**120**	—	—	4,4	Second season rainfall 40% of long term mean (LTM)
	1R	100	100	93	91	112	**67**	—	—	2,2	Most stalks died in first season, reasonable rains in the next
2 Mtunzini ..	P	100	95	70†	95	101	79*	—	—	6,3	Dry for final three months
	1R	100	92	82	109	111	98	—	—	4,5	Very dry February to April (35% of LTM) during 9 to 11 months of age
3 Paddock ..	P	100	80	47†	98	—	75	—	—	6,7	Fairly dry during final five autumn months
	1R	100	114	54†	105	—	106	—	—	5,6	Moderate summer rains, dry during final 4 winter months
4 Ottawa ..	P	100	103	—	**121**	—	**139**	**155**	**130**	2,2	Two very dry summers, totally droughted at harvest
	1R	100	88	—	86	—	90	101	99	4,1	Good recovery after drought in plant crop. Dry autumn
5 Mtunzini ..	P	100	90	87	—	—	107	113	116	4,0	February to April dry while crop was 5 to 7 months
	1R	100	60*	—	44*	—	44*	**121**	62*	4,1	February to August dry while crop was 4 to 10 months
6 Paddock ..	P	100	92	53†	—	—	94	98	102	6,9	Fairly dry February to June while crop was 5 to 9 months
	1R	100	97	85	—	—	83	119	110	6,7	Both summers experienced dry spells
7 Dalton.. ..	1R	100	97	**120**	103	—	**136**	—	—	2,4	Two dry summers, severe frost, 24 month crop
8 Dalton.. ..	1R	100	—	**120**	—	—	100	**158**	**142**	3,8	Two dry summers, fairly severe frost, 24 month crop
9 Dalton.. ..	P	100	85	—	—	—	96	—	75	4,4	Two dry summers, mild frost, 17 month crop

† Low value because of rust infection * Low value because of eldana infestation

severely stressed ratoon crop of trial 1. This result, as well as those of the first ratoon crops of trials 4 and 5, seem to arise because of the inherently poor ability of N11 to recover from very severe stress. The first ratoon crop of trial 1 was in effect a second ratoon crop because a large proportion of the first ratoon stalks had died during the drought. The elongation of the new N11 stalks was much slower than that of the stalks of the other varieties.

Another indication that N11 recovers poorly following drought was the high stool mortality that occurred in the second ratoon of trial 4. Over 1 000 stools per hectare of N11 died compared to 800 stools of J59/3 and less than 400 stools each of NCo 376, N52/219, N12 and N13.

The proportion of stalks that died in the first ratoon of trial 1, differed significantly between varieties (Table 4). N7, which suffered the least stalk loss was one of the best varieties in this trial. However, NCo 376 and N52/219 which also yielded comparatively well, lost a high proportion of stalks in the drought.

The results from both crops in trials 1 and 2 indicate that N7 is able to endure and recover from drought better than the other varieties grown in these trials. The relatively good performance of N7 at Mtunzini was also due to the significantly lower eldana infestation than in some other varieties. Drought resistance and resistance to eldana may be linked.

N55/805 often looked less droughted than the other varieties but its yields were generally low on account of rust, which was sometimes severe in the young crop.

Encouraging results were obtained from the two new varieties, N12 and N13. N12 was considerably more tolerant of drought than NCo 376 in the very dry conditions of the plant crop at Ottawa (trial 4) and also at Mtunzini and Dalton. A comparatively low eldana infestation in N12, as in N7, contributed to its superiority at Mtunzini.

TABLE 4

Composition of cane harvested from the first ratoon of trial 1 at Ottawa

		N7	NCo 376	N52/ 219	N55/ 805	J59/3	N11	LSD (5%)
% new shoots in crop		59	81	91	69	77	71	1,6
Sugar content %	old stalks	6,3	3,1	6,8	5,0	4,7	0,0	3,3
	new stalks	10,6	8,6	9,0	8,2	9,9	8,4	1,1

Figure 3 illustrates the relationship between the yield of sugar per month for each variety and the mean yield of cane per month for each trial. The mean cane yield serves as a measure of the environment and the slope of the line reflects the extent to which a variety response to favourableness of the environment. NCo 376 showed the greatest and N11 the least sensitivity to changes in growing conditions. The yields of N11 were greater than those of NCo 376 only under poor growing conditions. N12 and N13 displayed desirable characteristics by giving higher yields than NCo 376 over the range of conditions encountered, and by being less sensitive to poor growing conditions.

The reactions to stress that were observed in NCo 376 and N11 in the irrigation trial at Pongola were essentially

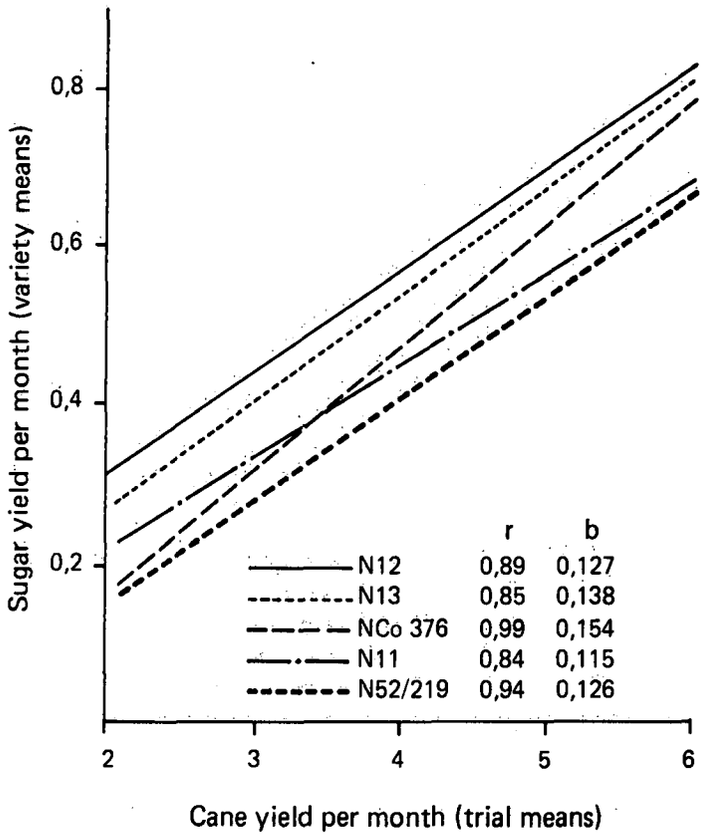

FIGURE 3 The relationships, established by linear regression, between sugar yield per month of five varieties and the mean cane yield per month for each trial which included these varieties. (r and b are the correlation and regression coefficients respectively.)

the same as those which occurred under rainfed conditions as illustrated in Figure 3. It may therefore be reasonable to expect that the characteristics of N12 and N13 illustrated in Figure 3 are likely to be experienced over a wide range of environmental conditions.

Conclusions

Varieties that are selected at rainfed sites in South Africa are likely to be well adapted to an environment in which short periods of water stress occur frequently. This type of adaptation does not necessarily equip the variety to endure prolonged periods of stress which occur less frequently.

Provided it is free of disease, NCo 376 is capable of outyielding most varieties under the best conditions in our industry as well as under some of the worst conditions. Its poor adaptation to severe water stress is therefore not surprising.

Two varieties of similar growth habit, N7 and N12 appear from the results, to be able to survive a drought reasonably well and also to recover quickly. N13 although quite different in growth habit also yielded fairly well compared with other varieties during drought.

More useful information could be obtained by subjecting released varieties to a controlled range of moisture conditions as was done at Pongola. However the type of stress that occurred in the deep soil at Pongola is not likely to provide a good test for varieties that will be grown in shallower soils that can dry out very rapidly. It would also be useful to study some of the physiological factors responsible for drought tolerance in varieties.

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