THE EFFECT OF CHEMICAL RIPENERS ON THE GROWTH, YIELD AND QUALITY OF SUGARCANE IN SOUTH AFRICA AND SWAZILAND

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Abstract

Data are presented from six field experiments with variety NCo 376 and one with variety N55/805. Ethrel and Polaris were the most promising of several ripeners tested and both chemicals had similar effects on growth, cane quality and sugar yield under a wide range of conditions. Ethrel in the three trials and Polaris in the six trials in which they were tested consistently improved the juice purity and the sucrose percent fresh and dry weight of NCo 376. The yield of estimated recoverable sugar was also increased on most sampling occasions but the size of the response varied with the maturity of the crop and the length of time that had elapsed between spraying and harvesting. In two trials the yield of sugar obtained from Polaris-treated sugarcane on later sampling dates was lower than in control plots, despite increases in yield on earlier sampling occasions. The response to the ripeners was greatest in young, immature NCo 376 sugarcane and there was a negative relationship between initial juice purity and yield response. Ethrel, and to a lesser extent Polaris, stimulated cane growth and reduced the quality of variety N55/805.

Introduction

The juice purity and the sucrose percentage of sugarcane are naturally low at the beginning and at the end of the milling season so that any means of improving the quality of the cane and increasing sugar yield at these times would be of tremendous value to the sugar industry. Many chemicals have been screened for their ability to ripen sugarcane (Nickell and Tanimoto,[5] Nickell, Takahashi and Terry,[8] Yates[12]) but field trials have often given conflicting results. Nickell and Maretzki[6] examined several compounds that had shown promise as ripeners but could find no common chemical properties or biological effects among them. There have been several reports of the exceptional promise shown by CP 41845, now named Polaris (Tianco and Escober,[10] Nickell and Takahashi,[7] Alexander and Montalvo-Zapata,[1] Nickell[4]) but Bieske[3] obtained only a small response to treatment with this chemical. Yates[12] found that promising results obtained with Ethrel under glasshouse conditions were reversed in the field, a result that he attributed to differences in varietal response to the chemical.

Because of the wide range of chemicals reported to ripen sugarcane and the conflicting results obtained in other sugarcane growing areas, a series of field trials was undertaken in South Africa and Swaziland. This paper contains the results of six experiments with variety NCo 376 and one with variety N55/805 carried out during 1971 and 1972. In the first experiment several chemicals were tested on very young, immature sugarcane which was chosen to ensure that any decline in growth with increasing age would not affect the response to the ripeners. Ethrel and Polaris, which were found to be the most promising chemicals, were then subjected to further tests under a wide range of conditions. Later work was concentrated on Polaris because it was known that this chemical was likely to be released for use on sugarcane in the foreseeable future.

TABLE I
Experimental details

Experiment	Site	Date treated	No. of replications	Type of crop	Age when sprayed (months)	Estimated initial cane yield (t/ha)	Initial juice purity (%)
1	Chaka's Kraal	29 Apr., 1971	4	Plant	9	80	61
2	Flanders Estate	30 Dec., 1971	5	Plant	14	110	86
3	Chaka's Kraal	5 Apr., 1972	4	1st ratoon	10	80	67
4	Ubombo Ranches	21 Mar., 1972	7	3rd ratoon	10	101	65
5	Seven Oaks	29 Mar., 1972	7	2nd ratoon	18	100	85
6	Ubombo Ranches	20 Sept., 1972	6	3rd ratoon	10	100	87
7	Ottawa Estate	26 Oct., 1972	4	1st ratoon	12	105	88

TABLE II
Details of the actual treatments applied in experiments 1, 2, 3 and 7

Treatment	Experiment 1	Experiment 2	Experiment 3	Experiment 7
1	Control	Control	Control	Control
2	Ethrel (1,2 kg a.i./ha)	Ethrel (1,2 kg a.i./ha)	Ethrel (1,2 kg a.i./ha)	Ethrel (0,5 kg a.i./ha)
3	Polaris (3,9 kg 85% a.i./ha)	Polaris (3,6 kg/ha)	Polaris (2,9 kg/ha)	Ethrel (1,0 kg a.i./ha)
4	Pesco 1815 (44 l/ha standard formulation)	Pesco 1815 (47 l/ha standard formulation)	Polaris (3,8 kg/ha)	Ethrel (1,8 kg a.i./ha)
5	DA5 (3,4 kg a.i./ha)		Polaris (5,6 kg/ha)	Polaris (3,2 kg/ha)
6	Hydrothol (3,7 kg a.i./ha)		Polaris (6,1 kg/ha)	Polaris (3,7 kg/ha)
7	CGA 11610 (3,9 kg a.i./ha)		Polaris residual*	Polaris (5,3 kg/ha)
8			Hydrothol residual*	Polaris (6,1 kg/ha)

*To determine any residual effect from Experiment 1.
No further application made to this crop.

Materials and methods

Details of the experiments are given in Table I and the actual amounts of the chemicals applied in Experiments 1, 2, 3 and 7 are given in Table II. In Experiments 4, 5 and 6 replicated plots were either untreated or sprayed with Polaris and the rates of application were 4,4 kg/ha in Experiments 4 and 6; and 5,7 kg/ha in Experiment 5. Half of the control and the treated plots in Experiment 6 were irrigated to permit maximum crop growth up to harvest and the remaining plots were dried off in the normal estate manner. Variety NCo 376 was used in Experiments 1 - 6 and variety N55/805 in Experiment 7.

Ethrel 68-250 (Amchem Products) is mainly 2-chloroethane phosphonic acid. Polaris (Monsanto) is N,N,-bis-(phosphono-methyl) glycine and contains 85% active ingredient. Pesco 1815 (Fisons) is a mixture of 15% 2-methyl-4-chlorophenoxyacetic acid and 4,8% 2, 3, 6-trichlorobenzoic acid. Hydrothol 191 (Pennwalt) is the Mono (N,N dimethyl alkylamine) salt of 3,6-endoxohexahydrophtholic acid. The compositions of DA5 (Dupont) and CGA 11610 (Ciba-Geigy) have not been disclosed.

Experiments 2, 6 and 7 were carried out at the end of the season and the other experiments at the beginning of the season. All experiments except number five were irrigated but it was not possible to irrigate Experiment 2 for the first six weeks after treatment, when only 40 mm of rain fell. Experiment 3 was dried off from nine weeks after treatment and the appropriate plots in Experiment 6 were dried off from eight weeks. With these exceptions there was adequate irrigation or rainfall to permit normal growth in all of the experiments. Polaris was applied by aeroplane in approximately 56 l of water per hectare in Experiments 4, 5 and 6, and plot sizes were either 0,25 or 0,30 ha. Plot size was 92-100m² in the remaining experiments and the chemicals were applied by means of a hand-operated knapsack sprayer in 300-500 l of water per hectare. All chemicals were applied with a wetting agent.

Random samples of 16 (Experiment 1) or 20 stalks were taken from each plot in all experiments, usually at two-weekly intervals, and analyzed either on the same day, or on the following day (Experiments 4-6). Counting the spindle leaf that was more than half unfurled as number one, the sixth leaf was identified on each stalk and the top of the stalk was broken off at the base of the sheath attached to this leaf (node 6). The tops were examined and then weighed and dried to constant weight whenever this was possible. The remaining leaves and trash were removed from the stalks, which were then divided for analysis into the top six internodes (6-11) and the remainder of the stalk. The samples were completely disintegrated with a modified wood planing machine and homogenized with water before filtering. The amount of soluble solids (brix) in the filtrate was determined with a refractometer and the sucrose concentration was estimated with a saccharimeter after the filtrate had been clarified with lead subacetate (Anon[2]). A sample of the disintegrated material was dried to constant weight.

At the end of Experiments 1, 4, 5 and 6 all the stalks remaining in each plot were harvested and the weight of cane determined. There was sufficient cane from each plot in Experiments 4, 5 and 6 for it to be crushed commercially at the mill and the brix and sucrose content of the first expressed juice was determined. The sucrose percentage of the cane was then estimated by means of the Java Ratio.

Results

Growth effects

Hydrothol, Ethrel and Polaris were the only chemicals to affect growth appreciably. Hydrothol scorched the leaves severely within one week of spraying and caused reductions in cane yield and quality. Ethrel and Polaris had less obvious effects on growth than Hydrothol and these effects varied with both the variety and the condition of the cane at the time of spraying. Polaris, particularly at the higher rates of application, produced white spots and bleached parts of some young leaves of NCo 376 but these symptoms were not severe and they did not always occur. The size and weight of either some or all young leaves and sheaths of shoots of both NCo 376 and N55/805 were often reduced by both Ethrel and Polaris. In general, the higher the rate of application of the chemicals, the greater the effect on the foliage (Table III). Neither chemical had any effect on the total number of green leaves per stalk.

Polaris but not Ethrel, caused the upper buds of the stalks of NCo 376 to swell and in some instances to begin to grow, and in Experiment 2 it was observed that side-shooting occurred only in the thicker stalks within a plot. Increasing the rate of Polaris application from 5,6 to 6,1 kg/ha increased the severity of these symptoms in Experiment 3 but in Experiment 5 Polaris at 5,7 kg/ha had no visual effect on the growth of either the foliage or the upper internodes. There was some flowering in Experiment 4 and Polaris reduced the number of flowers that emerged. Polaris applied to the plant crop in Experiment 1 caused a chlorosis and a purpling of some shoots of the first ratoon crop but this did not appear to affect either shoot population at three months of age or the yield of cane when the crop was harvested at 12 months.

Ethrel and Polaris both reduced the length of stalks of NCo 376, measured from the ground to either the uppermost visible collar or to the point of topping, but the chemicals did not reduce the length of all the upper internodes of the stalk. Polaris also reduced the length of stalks of N55/805 but Ethrel increased stalk length in this variety. A typical example of the effect of Ethrel and Polaris observed in most experiments with NCo 376 is illustrated in Table IV. The general

TABLE III

The effect of Ethrel and Polaris on the length of upper internodes and the dry weight of the five youngest leaves of topped stalks of N55/805 in Experiment 7.

Results expressed as a percentage of control

	Internode length						Leaf dry weight
Internodes	1 — 5		6 — 8		9 — 11		
Weeks	4	8	6	8	6	8	8
Treatment							
Control	100	100	100	100	100	100	100
Ethrel (0,5 kg a.i./ha)	166	107	125	126	87	94	68
Ethrel (1,0 kg a.i./ha)	176	109	128	134	89	104	61
Ethrel (1,8 kg a.i./ha)	206	118	143	136	106	118	42
Polaris (3,2 kg/ha)	112	109	96	99	98	104	82
Polaris (3,7 kg/ha)	108	122	93	98	90	93	71
Polaris (5,3 kg/ha)	132	118	93	103	92	86	43
Polaris (6,1 kg/ha)	134	130	95	103	95	90	46
Mean	142	114	109	112	95	99	64
L.S.D. (0,05)		18		12		10	10
(0,01)		25		16		14	14
C of V (%)		11		7		7	9

TABLE IV

The effect of Ethrel and Polaris on the length and dry weight of upper internodes of topped stalks of NCo 376 in Experiment 3, expressed as a percentage of control

	Length									Dry weight				
Internodes	1 — 5				6 — 8			9 — 11		1 — 5			6 — 8	9 — 11
Weeks	4	6	12	14	6	14	16	14	16	6	12	14	14	14
Treatment	*	****	***	**	****	**	****	**	****	****	***	**	**	**
Control	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Ethrel (1,2 kg a.i./ha)	110	120	121	103	87	90	85	90	87	106	132	117	68	85
Polaris (2,9 kg/ha)	61	116	98	91	99	102	104	96	100	103	97	95	73	88
Polaris (3,8 kg/ha)	99	127	119	72	98	91	101	88	100	105	132	69	68	87
Polaris (5,6 kg/ha)	112	137	147	148	86	99	90	89	88	118	204	186	82	99
Polaris (6,1 kg/ha)	105	112	166	100	81	89	92	90	94	130	253	98	65	93
Mean	98	116	121	102	93	95	96	92	96	110	153	111	76	92
L.S.D. (0,05)		24	21		9		9		8					
(0,01)		33	30		12		12		12					
C of V (%)		12	10		6		7		7					

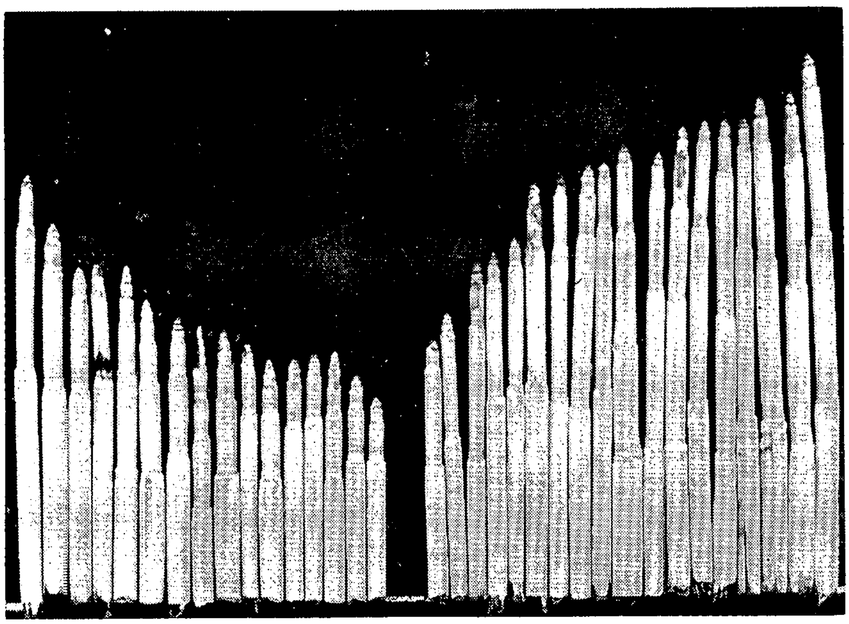
* Means of 8 stalks
** Means of 10 stalks
*** Means of 60 stalks
**** Means of 80 stalks

A B

FIGURE 1: The tops of two stalks of variety NCo 376 taken from the same plot 13 weeks after spraying with Polaris at the rate of 3,6 kg/ha. A. Severe stunting and side shooting of the upper buds. B. Only leaves that were small at the time of spraying were stunted and subsequent shoot growth was normal.

A B

FIGURE 3: Representative stalk samples taken 6 weeks after spraying with 5,6 kg/ha Polaris in Experiment 3, showing the reduction in the length of internodes below the point of topping. Node 9 has been marked in black on each stalk. A. Control. B. Polaris.



A B

FIGURE 2: Representative stalk samples taken 6 weeks after spraying, showing the effect of Polaris applied at a rate of 4,4 kg/ha in Experiment 4 on the length of internodes above the point of topping.
A. Control. B. Polaris.

effect of both Ethrel and Polaris above a rate of 2,9 kg/ha, was to increase the length and weight of internodes 1-5 until at least 12 weeks after spraying (Figure 2). In contrast to this both chemicals reduced, the weight and the length of the six internodes below the point of topping (Figure 3).

The effects of Polaris on internode length and weight in variety N55/805 were similar to those on NCo 376 (Table III). Ethrel, in addition to increasing the length and weight of internodes 1-5 of N55/805 also increased the length and the weight of internodes 6-11 at the 1,0 and the 1,8 kg a.i./ha rates of application. The higher the rate of application the greater the effect.

Cane quality

Of the chemicals tested in Experiment 1 only Ethrel and Polaris gave results that justified further experimentation. Cane quality and sugar yield were improved slightly by DA5 and Pesco 1815 and they were reduced by Hydrothol. CGA 11610 had no apparent effect on either the quality or the yield of the crop.

Ethrel and Polaris improved juice purity and the sucrose content of the stalks of NCo 376 from four weeks after spraying in all experiments except number 2, in which drought conditions delayed the response to the chemicals (Figures 4 & 5). The chemicals had a greater effect on the quality of the upper six internodes of the topped stalks than they did on the remaining part of the stalk and this is illustrated in Figure 5 using data from Experiment 3. The 5,6 kg/ha level of Polaris application had almost exactly the same effect on the quality of all parts of the stalk as Ethrel at 1,2 kg/ha and the Polaris data have not been plotted on the graphs.

The improvements in juice purity and sucrose percent fresh and dry weight as a result of spraying NCo 376 with either Ethrel or Polaris followed a similar pattern in all experiments and were maintained until at least 12 weeks after spraying (Figures 4 & 5). Polaris had less effect in Experiment 6 than in the other experiments and the beneficial effects of Polaris and drying off treatments were additive (Table V). In contrast to these beneficial effects of Ethrel and Polaris on the quality of NCo 376 both chemicals caused a reduction in the quality of N55/805 (Figure 6).

There were large positive responses to application rates which ranged from 3,6 to 4,4 kg/ha of Polaris in Experiments 1, 2 and 4 but there was little response to either 4,4 kg/ha in Experiment 6 or to less than 5,6 kg/ha in Experiment 3. Increasing the rate of Polaris application to 6,1 kg/ha in Experiment 3 further improved cane quality (Figure 7).

Cane and sugar yields

Ethrel and Polaris below a rate of 6,1 kg/ha had little effect in any experiment on the dry weight of cane produced by NCo 376 up to 10 weeks after

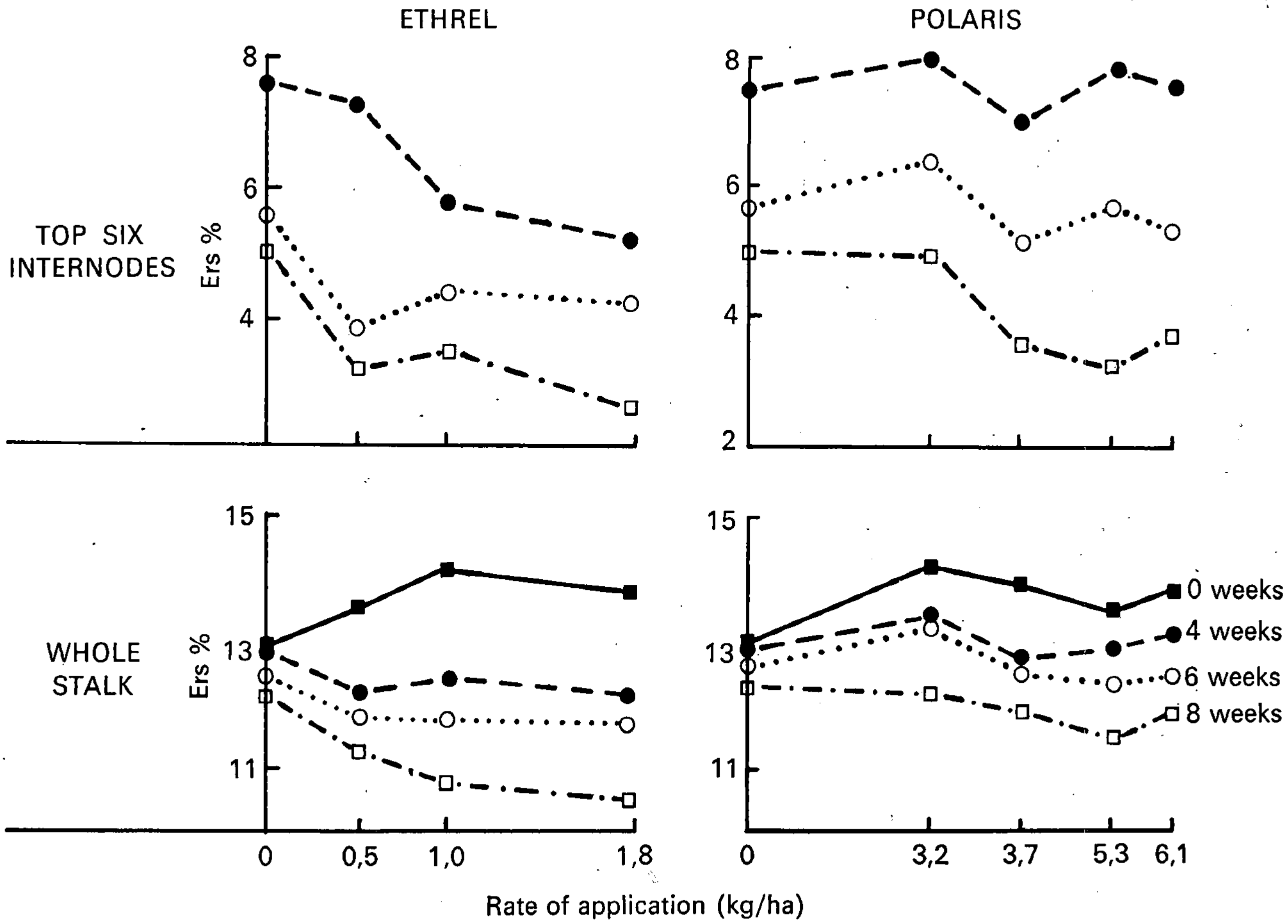


FIGURE 6: The effect of different rates of Ethrel and Polaris on the percentage estimated recoverable sugar in variety N55/805.

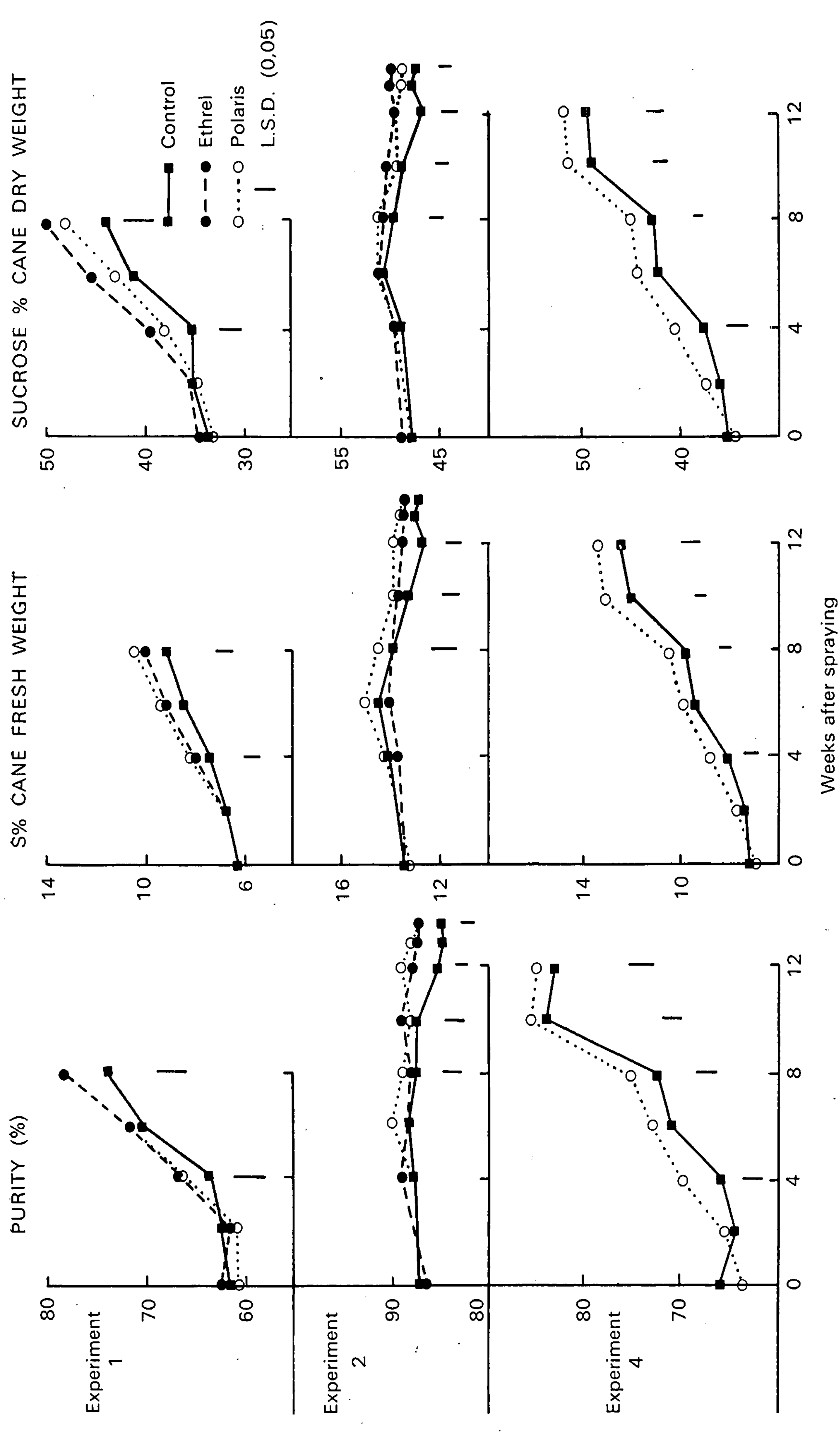


FIGURE 4: The effect of Ethrel and Polaris on the juice purity and the sucrose concentration in whole stalks of NCo 376 in Experiments 1, 2 and 4.

TABLE V

The effect of Polaris on sugarcane yield and quality
Harvest data from experiment 6

Treatment	Cane yield (t/ha)	Sucrose %	Purity %	Sugar yield (t/ha)
Irrigated control	110	13,4	84,2	12,4
Irrigated Polaris	107	13,8	84,6	12,4
Dry control	107	13,9	85,1	12,7
Dry Polaris	108	14,1	85,2	12,8
Mean	108	13,8	84,8	12,6
L.S.D. (0,05)	6,9	0,2		0,7
(0,01)	9,9	0,3		1,0
C of V (%)	5,0	1,6		4,2

spraying, but the moisture content of the cane and therefore cane fresh weight was generally reduced. Increasing the rate of Polaris applied from 5,6 to 6,1 kg/ha in Experiment 3 reduced cane dry weight, but sucrose percent cane dry weight increased (Figure 7) and there was no effect on sucrose yield. Delaying harvest until 13,5 weeks in Experiment 2 and until 12 weeks in Experiment 5 resulted in appreciably lower yields of cane from treated than from untreated plots. This more than offset the improvements in cane quality and resulted in both Ethrel and Polaris in Experiment 2 and Polaris in Experiment 5 reducing sugar yield (Table VI). The beneficial effect of Polaris on sugar yield is demonstrated in Table VII with harvest data from Experiment 4. Ethrel above 0,5 kg a.i./ha stimulated the growth of N55/805 in Experiment 7 (Table III) and increased the estimated yield of recoverable sugar in spite of reductions in the quality of the cane (Figure 6).

TABLE VI

The effect of Polaris on sugarcane yield and quality
Harvest data from experiment 5

Treatment	Cane yield (t/ha)	Sucrose %	Purity %	Sugar yield (t/ha)
Control	115	12,2	84,6	12,0
Polaris	104	12,8	86,1	11,4
% change	—9,6	+4,9	+1,8	—5,0
L.S.D. (0,05)	7,1	0,6	2,3	0,8
(0,01)	11,2	1,0	3,7	1,2
C of V (%)	4,4	3,3	1,8	4,4

TABLE VII

The effect of Polaris on sugarcane yield and quality
Harvest data from experiment 4

Treatment	Cane yield (t/ha)	Sucrose %	Purity %	Sugar yield (t/ha)	Reducing sugars % juice
Control	137	10,6	77,2	10,8	1,14
Polaris	135	11,7	82,0	12,4	0,91
% change	—1,5	+10,4	+ 6,2	+14,8	—20,2
L.S.D. (0,05)	12,9	0,5	3,3	0,8	
(0,01)		0,8	5,2	1,3	
C of V (%)	6,9	3,2	3,0	5,1	

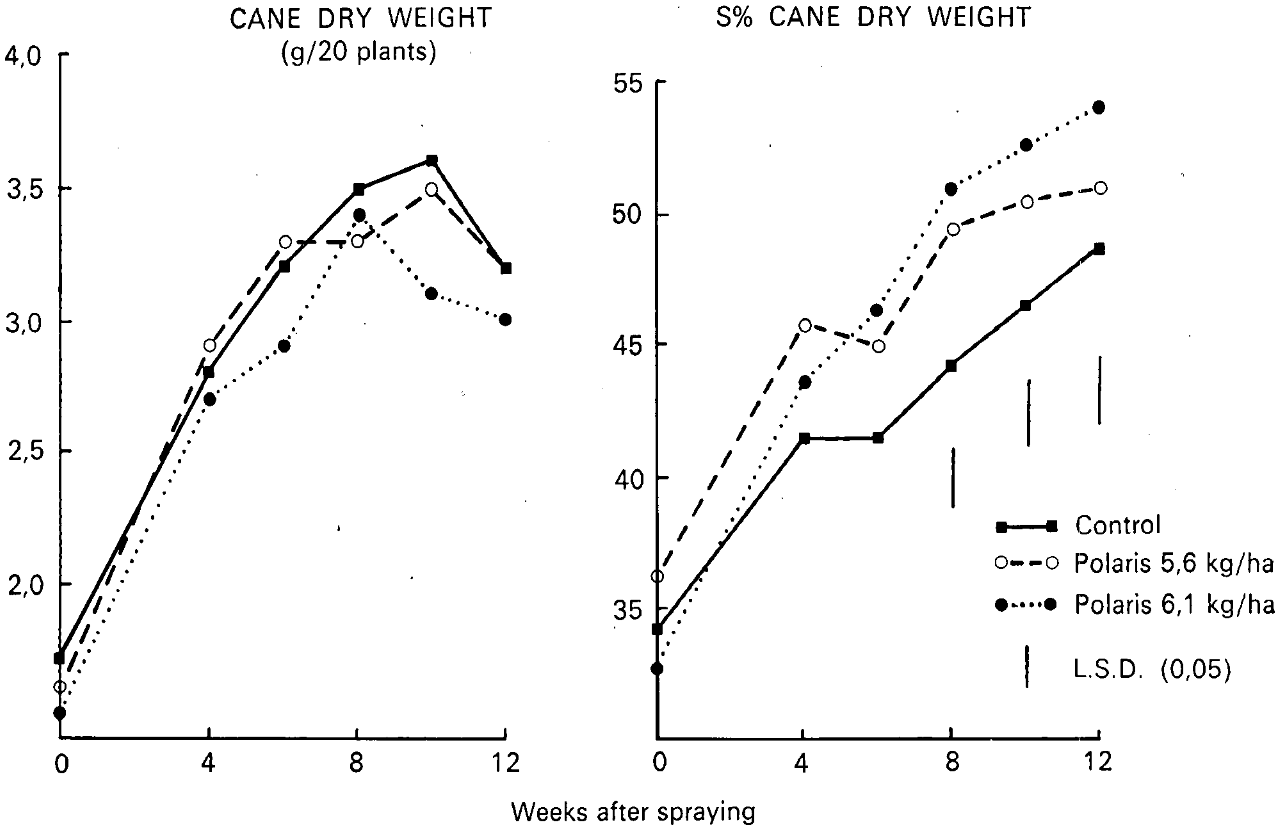


FIGURE 7: The effect of increasing the rate of Polaris application in Experiment 3 on cane dry weight and sucrose percent cane dry weight of NCo 376.

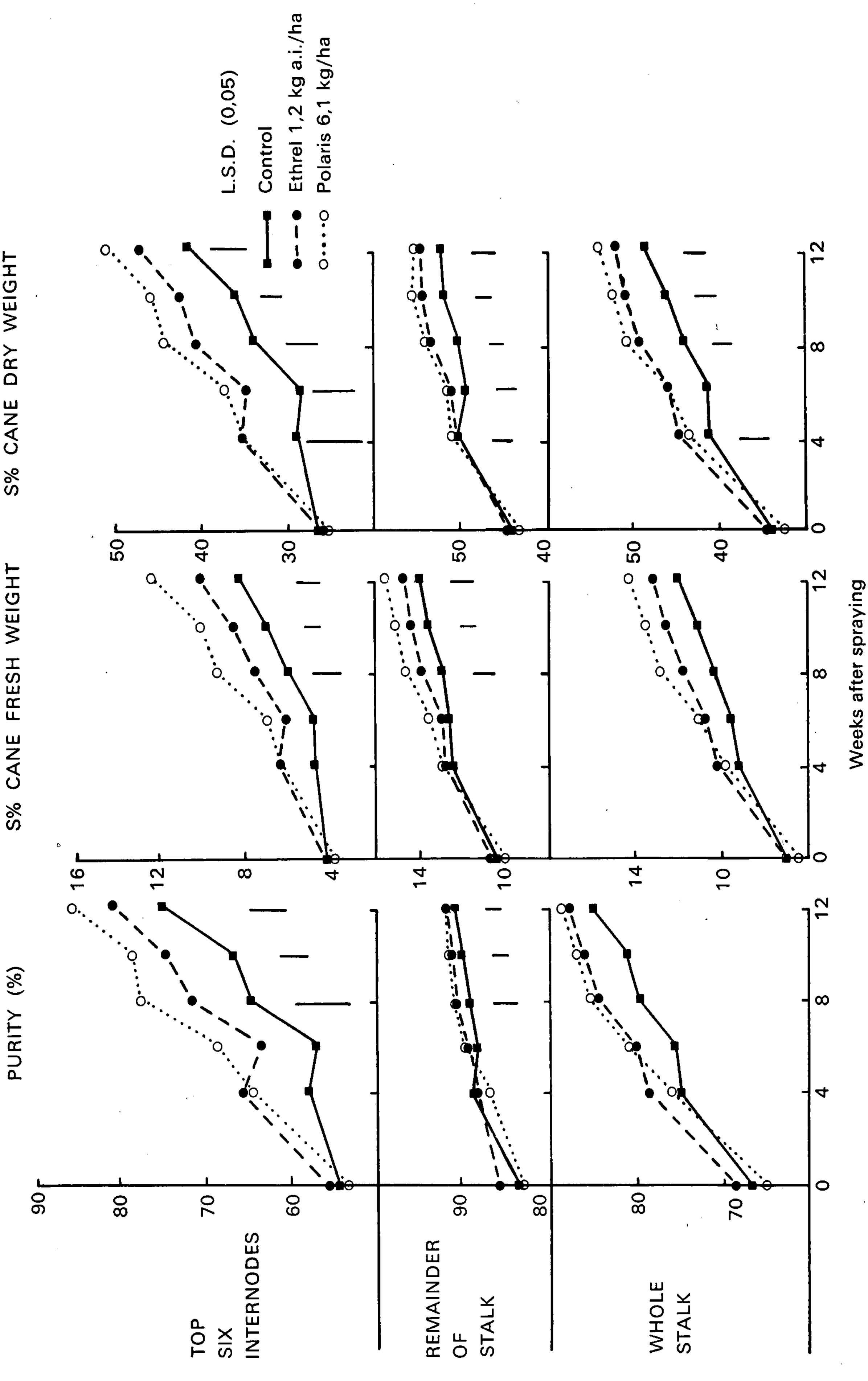


FIGURE 5: The effect of Ethrel and Polaris on the juice purity and the sucrose concentration in different parts of the stalk of variety NCo 376 in Experiment 3.

TABLE VIII
The percentage response in the weight of estimated recoverable sugar to spraying NCo 376 and N55/805 with Ethrel and Polaris

Chemical	Ethrel				Polaris						
Variety	NCo 376			N55/805	NCo 376						N55/805
Experiment	1	2	3	7	1	2	3	4	5	6	7
Weeks after spraying											
4	+23	− 8	+ 3	+12	+13	−14	+ 8	+11	+ 1	− 1	+ 5
6		−10	+16	− 2		+ 4	+ 8	+ 1	+ 7	+ 2	+12
8	+20**	+ 2	+15	+ 1	+32**	− 1	+11	+ 7	+ 5	+ 4	− 3
10		+ 5	+14			+ 2	+ 5	+27	+14	+ 2**	
12		+14	+ 6			+11	+ 6	+13**	− 3**		
13		+ 8				− 1					
13,5		− 4				−14					
Mean 6-12	+20,0*	+2,8	+12,8		+32,0*	+4,0	+7,5	+12,0	+5,8	+2,7	

* These values are probably high because the cane was very immature and had a low purity.
** Harvest data at these times showed the following changes:

Experiment 1 (Ethrel and Polaris)	+1,6 ters/ha (+22%)
Experiment 4	+1,6 ters/ha (+15%)
Experiment 5	−0,6 ters/ha (−5%)
Experiment 6	+0,1 ters/ha (+1%)

A summary of the effects of Ethrel and Polaris on yields of estimated recoverable sugar (ters*) is given in Table VIII. In the table, data for the 1,0 kg a.i./ha Ethrel and the 4,4 kg/ha Polaris rates of application have been used for Experiment 7. In Experiment 3 sugar yields for the 5,6 and 6,1 kg/ha rates of Polaris were similar and they have been averaged. Because the data in this table are derived from 20-stalk samples taken from each plot too much reliance should not be placed on any one figure. Nevertheless the consistency of the results and the good agreement between sample and harvest data in Experiments 1, 4, 5 and 6 indicate that the overall positive responses are probably real.

Ethrel and Polaris increased the yield of estimated recoverable sugar on most sampling occasions in all experiments but the size of the response varied with the initial maturity of the crop and with the length of time that elapsed between spraying and harvesting. It was found that the average yield response to both Ethrel and Polaris was better correlated with the initial purity of the juice of NCo 376 (Figure 8) than with either the age of the crop or the time of the year at which the crop was sprayed. The maximum response in variety NCo 376 occurred between 6 and 12 weeks after spraying in all experiments. From the data for the experiments that were eventually harvested it was observed that Experiments 1 and 4, which showed the biggest response to the ripeners, also had the fastest rate of increase in cane weight during the course of the experiment.

Discussion

The consistent improvements in the juice purity and the sucrose content of variety NCo 376 in all experiments following the application of either Ethrel or Polaris, confirmed that both these chemicals have the ability to ripen sugarcane. However, the considerable variation in the size and the pattern of the response of variety NCo 376 in terms of sugar yield, and the reduction in the quality of variety N55/805, indicate that further work is necessary to ascertain the conditions under which these chemicals can be used successfully. The results reported in this paper show that the response of NCo 376 was determined

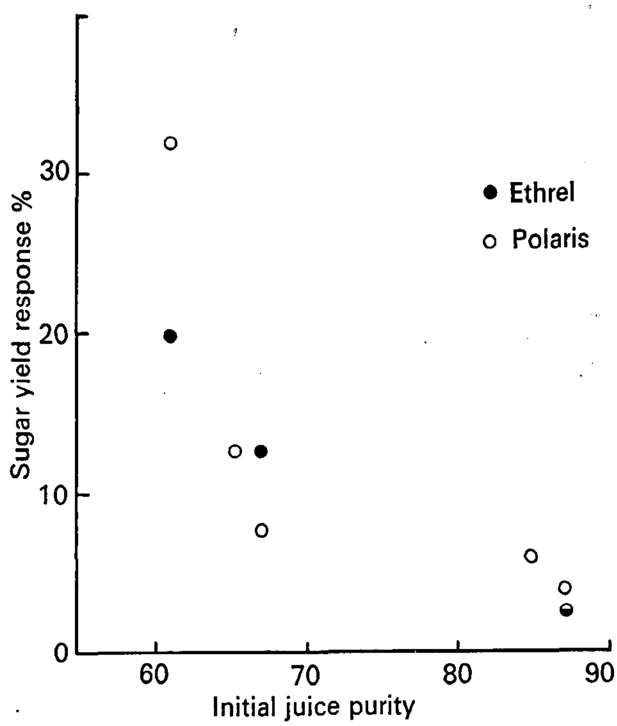


FIGURE 8: The relationship between the purity of juice from whole stalks of NCo 376 at the time of spraying and the average percentage response in sugar yield between 6 - 12 weeks after spraying.

*Ers % cane = S % Cane — 0,485 Non sucrose —0,056 Fibre % cane.

by the pattern of growth after spraying, which was apparently related to the maturity of the crop at the time of spraying, measured in terms of juice purity. The similarity in the response of sugarcane of differing maturities to Ethrel and Polaris suggests that the mode of action of the two chemicals within the plant may be similar. It was not possible to determine the optimum rates of either Ethrel or Polaris from the data available, but the results of Experiment 3 indicate that as much as 5 kg/ha of Polaris (85% a.i.) may be necessary to ripen immature sugarcane.

In relatively mature crops (Experiments 2, 5 and 7), Ethrel and Polaris has less effect on juice purity and sucrose percent fresh weight of cane than in other experiments on immature sugarcane having a low initial juice purity. The chemicals also retarded crop growth to a greater extent in these mature crops, resulting in a reduction in cane and sugar yield when harvest was delayed too long. These results confirmed those of Bieske,[3] who found that the cane and sugar yields of mature sugarcane crops were reduced by Polaris.

In contrast to these results, Ethrel and Polaris significantly improved the yield of sugar from immature crops which grew rapidly during the period between spraying and harvest, confirming the results of Tianco and Escober.[10] There was, therefore, a positive association of rapid growth and chemical ripening, which confirmed the results of Alexander and Montalvo-Zapata,[1] who examined the effect of Polaris on the growth of young plants in pots. Chemical ripening was thus most successful under conditions that did not favour natural ripening.

Immature cane, which is difficult to process at the mill, is usually a problem at the beginning and at the end of the season, and any improvement in the quality of this type of cane will be of tremendous value to the miller. From the grower's point of view, the highest rates of production per hectare per annum under good growing conditions are obtained from young, irrigated crops harvested between May and July (Rostron,[9] Todd[11]) but the quality of the cane is poor. Chemical ripening will improve the yield of sugar from this type of cane, will improve its acceptability to the miller, and by improving the sucrose percentage of the cane, will reduce the transport cost per ton of sucrose sent to the mill.

Conclusions

The practical implications of the results of these trials are important and far-reaching, and the following conclusions need to be confirmed by further experimental work. Variety NCo 376 can be ripened under a wide range of conditions by both Ethrel and Polaris, but the results with variety N55/805 indicate either that the chemicals may not ripen other varieties, or that quite different amounts of the chemicals may be needed to ripen other varieties. The best ripening response should be obtained in the Northern irrigated areas, from young crops that are harvested at the beginning of the season. Ethrel and Polaris improve both sucrose yield and the ease with which the sucrose can be recovered from the crop. Therefore, in an industry where farmers are paid only on the basis of the weight of sucrose delivered to the mill, the maximum benefit from chemical ripening will be obtained by the miller-cum-planter.

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