THE EFFECTS OF POST-TREATMENT MOISTURE STRESS AND VARYING AMOUNTS OF APPLIED NITROGEN ON THE RIPENING RESPONSES OF SUGARCANE TO GLYPHOSATE AND ETHREL

By R.A. Donaldson

South African Sugar Association Experiment Station, Mount Edgecombe 4300 South Africa

Abstract

The effects of long or short drying-off periods and varying amounts of applied nitrogen fertilizer on the ripening response to glyphosate and Ethrel were tested on variety NCo376. The response to glyphosate was markedly reduced when post-treatment moisture stress occurred but the response to Ethrel was not affected as severely. Results confirm previous findings that responses to glyphosate were not affected by the amount of applied nitrogen but responses to Ethrel were slightly greater with larger amounts of applied nitrogen. No damaging residual effects on the following ratoon crops were evident when soil moisture stress developed after glyphosate had been applied.

Introduction

The potential for the use of ripeners is greatest on irrigated cane grown in the northern semi-arid parts of the South African sugar industry. Increases in sucrose yields have averaged 18 % (3,2 ts ha^{-1}) in irrigated cane at Pongola (Clowes and Inman-Bamber;[1] Donaldson and Inman-Bamber)[2] and in the Philippines, a 26 % increase in grams sucrose per stalk was recorded with the use of chemical ripeners (Tianco and Gonzales).[5] The effect that agricultural practices may have on the potential yield increase from ripeners is important and these have been discussed by Clowes and Inman-Bamber.[1] It has been established that the physiological state of the cane at the time of spraying affects the response to the ripener. Clowes and Inman-Bamber[1] showed that the occurrence of moisture stress affected the ripening response to glyphosate while Rostron[4] showed that responses to Ethrel were not affected by stress unless the symptoms were clearly apparent.

In the Eastern Transvaal, irrigation is usually suspended for about six to eight weeks before harvesting in the winter months and for about four to five weeks in the summer months. Because the average evapotranspiration rate (Et) during the summer months is 6 to 7 mm d^{-1} it is likely that the readily available soil moisture would probably be depleted within about 14 days of suspending irrigation in soils with less than 100 mm available moisture, unless there is rain. The effect that drying-off of irrigated cane has on the responses to glyphosate and Ethrel are reported in this paper and the interaction between the levels of applied nitrogen (N) and the responses to glyphosate and Ethrel are also discussed.

Materials and methods

The experiments were sited at the Shakaskraal farm of the South African Sugar Association Experiment Station on the north coast of Natal. A split-plot randomized block design with four replications was used. Whole plots which comprised six cane rows 1,378 m apart and 12,2 m long were treated with varying amounts of N. The plots were then split lengthwise for the ripener treatments and at the time of harvest the cane from the net plots comprising four rows 5 m long was weighted and sampled.

The variety used in the experiments was NCo376 which was grown on a Longlands form soil with a rooting depth varying from 450 to 900 mm. The mean available moisture capacity (AMC = field capacity to wilting point) in a saturated soil profile was calculated to be 75 mm. Rainfall was supplemented with irrigation by means of overhead sprinklers delivering 25 mm when the available soil moisture (ASM) was below 50 mm according to a soil moisture profit and loss account. Because of technical problems, irrigation was inadequate and soil moisture was depleted on several occasions in Experiments 1, 2 and 4. However, at the time of ripener application the condition of the cane was suitable for chemical ripening.

The various treatments were applied to the 5th, 6th, 7th and 9th ratoon crops (Experiments 1 to 4 respectively) and the 8th ratoon crop was cut back to change the cropping cycle so that the effects of Ethrel could be tested on cane harvested in autumn. Details of the experiments are shown in Table 1.

Nitrogen and potassium were applied as split dressings in the form of urea (46 %) and potassium chloride (KCℓ,50 %) respectively. Superphosphate was applied where necessary in Experiments 1, 2 and 4 and third leaf samples were taken from all plots at regular intervals to monitor the N levels. Irrigation by overhead sprinklers was suspended for a period before harvesting. Half the number of plots (W_1 plots) were then irrigated by means of perforated pipes placed in the interrows so that a predetermined amount of water could be applied to these plots to maintain the soil moisture at the required level until the time of harvesting. In these W_1 plots irrigation was suspended about ten days before harvesting. The remaining plots (W_2) were not irrigated during this period in order to simulate an extended drying-off period of 30 to 60 days. The estimated ASM in each of the two treatments from the time of spraying to the time of harvesting the crop is shown in Figure 1 for each of the four experiments.

Ripeners were applied as split plot treatments. Glyphosate was applied to the same plots in Experiments 1, 2 and 3, and in Experiment 4 the plots which received Ethrel treatment were re-randomised. The ripeners were applied by a hand-operated knapsack sprayer with an overhead boom fitted with two TK 1,0 floodjet nozzles. The spray mixture was pressurised to 200 kPa by CO_2 and was delivered at a rate of 70 l ha^{-1}. The rates at which the ripeners were applied are shown in Table 1.

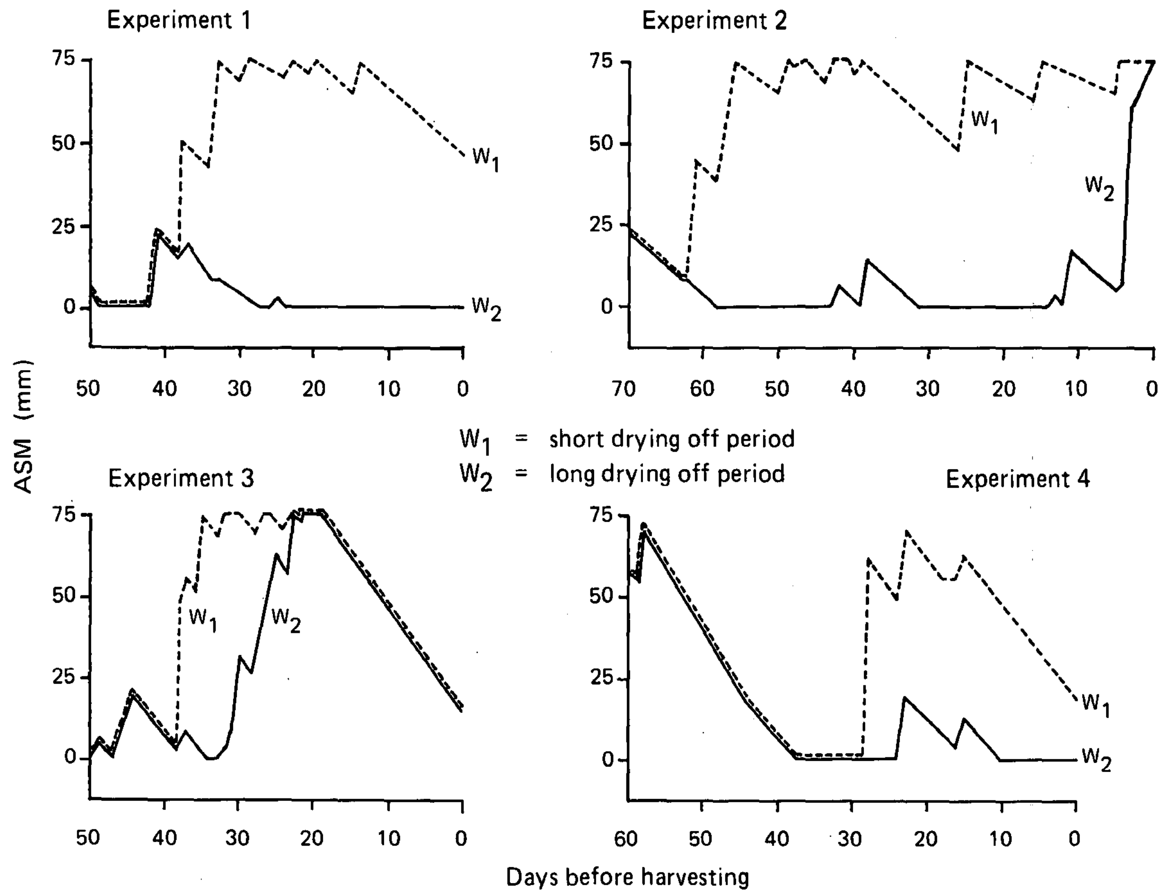

FIGURE 1 Available soil moisture according to the profit and loss account in W_1 and W_2 plots from the time of spraying to the time of harvesting.

Table 1
Details of the ripener experiments

Experiment no	Ratoon no	Rates of applied nutrients (kg ha⁻¹): N and months of application		Total	K	P	Ripeners: Product and rate (g ai ha⁻¹)	Date applied	Interval between spray & harvest (weeks)	Average juice purity % at spraying	Month of harvest & age at harvest (mths)
			Jul Sep Nov	Total							
1	5	N1	40 + 40	80	150	34	Glyphosate at 328 g ai	9 May	8	86	Jul 13
		N2	70 + 70	140							
		N3	100 + 100	200							
		N4	70 + 70 + 60	200							
			Aug Oct								
2	6	N1	40 + 40	80	200	23	Glyphosate at 378 g ai	18 Jun	10	88	Aug 13
		N2	70 + 70	140							
		N3	100 + 100	200							
		N4	130 + 130	260							
			Oct Nov								
3	7	N1	40 + 40	80	375	0	Glyphosate at 415 g ai	15 Oct	6	94	Nov 15
		N2	70 + 70	140							
		N3	100 + 100	200							
		N4	130 + 130	260							
			Aug Oct								
4	9	N1	70 + 70	140	300	21	Ethrel at 624 g ai	20 Mar	12	82	Jun 13
		N2	85 + 85	170							
		N3	100 + 100	200							
		N4	115 + 115	230							

Results

Effects of nitrogen, drying-off and ripeners

The effects of the increasing amounts of applied N, drying-off over a long or short period, and the effect of ripeners on cane quality and yields, are shown in Table 2.

Nitrogen: the optimum level of applied N under these conditions was about 200 kg ha^{-1}. Only in Experiment 2, the 6th ratoon crop, was there an increase of 3 tc ha^{-1} and 0,3 t ers ha^{-1} (tons estimated recoverable sugar per ha) by applying 260 rather than 200 kg N ha^{-1}. Cane quality declined with increasing levels of N in Experiments 1 and 2, but in Experiments 3 and 4, the different N levels had no noticeable effect on ers % cane.

Yields in terms of ers ha^{-1} followed the same trend as cane yields. Where 200 kg N ha^{-1} was applied, the levels of the third leaf N analyses generally remained adequate up to seven months of age but then gradually declined, indicating inherently low levels of N in the Longlands form soil.

Length of drying-off period: in Experiments 1 and 2, the ASM in the W_2 plots was effectively depleted for several weeks before harvesting, while irrigation continued in the W_1 plots to maintain a high soil moisture content until the time of harvesting (Figure 1). Table 2 shows that cane yields in Experiments 1 and 2 were only slightly depressed in the W_2 plots and because cane quality was improved by the longer drying-off period, this treatment resulted in yields that were similar, in terms of t ers ha^{-1}, to those that were obtained in the W_1 plots. In Experiments 3 and 4 the yields from the W_2 plots were considerably lower than those from the W_1 plots (18 and 15 tc ha^{-1} respectively), in spite of the soil moisture differences between W_1 and W_2 plots having been maintained for a shorter period than in Experiments 1 and 2 (Figure 1). Cane quality differences between W_1 and W_2 plots were small in Experiments 3 and 4, yields being reduced by 2,5 and 1,5 t ers ha^{-1} respectively in W_2 plots.

Ripeners: the cane yields in Experiments 1, 2 and 3 were, on average, 2,3 tc ha^{-1} lower in the plots treated with glyphosate than in the untreated plots. The difference in cane yields between untreated and treated cane was statistically significant ($P = 0,05$) only in Experiment 1. Responses to glyphosate, in terms of ers % cane, were statistically significant ($P = 0,05$ and $P = 0,01$) in Experiments 1, 2 and 3, but increases in sucrose yields were relatively small and were not statistically significant. Cane quality and yields of t ers ha^{-1} were improved significantly by Ethrel ($P = 0,05$) in Experiment 4.

Interactions between the various treatments

The effects of short versus long drying-off periods and varying the levels of applied N and on untreated cane or cane treated with either glyphosate (Experiments 1, 2 and 3) or Ethrel (Experiment 4) are shown in Tables 3 and 4.

The average response to glyphosate was 0,7 t ers ha^{-1} on W_1 treated cane (Table 3) while there tended to be a reduction in sugar yield when glyphosate was applied to W_2 treated cane (Table 4). Glyphosate reduced cane yields in the W_2 treated cane on average by 4,7 t ha^{-1} but had no effect on cane yields in the W_1 treated cane. There appeared to be no residual effect from glyphosate on cane yields of successive crops irrespective of the length of the drying-off period.

The response in terms of cane quality in Experiment 4, when Ethrel was used as a ripener was twice as great in the W_1 plots as it was in the W_2 plots. Ethrel had little if any effect on cane yields and the responses in terms of t ers ha^{-1} were similar for the long and the short drying-off periods. Analyses of the samples of cane taken at intervals after spraying with Ethrel (Figure 2) indicate that the response (g ers $stalk^{-1}$) to Ethrel after eight weeks was greater in W_2 plots than in W_1 plots. Soil moisture content was similar in W_1 and W_2 plots up to four weeks after spraying (Figure 1), after which the W_2 plots were drier than the W_1 plots. After eight weeks, the responses in W_2 plots were substantially reduced (Figure 2).

The response to glyphosate, in terms of t ers ha^{-1}, at different levels of N were variable, the averages being 1,2 t (N1); 0,0 t (N2); 0,7 t (N3) and 1,5 t (N4). In Experiment 4 the average response to Ethrel was better (1,2 t ers ha^{-1}) at the higher rates of applied N (N3 and N4) than at the lower rates of applied N (0,25 t ers ha^{-1} for N1 and N2). This pattern of response was more evident in cane from W_1 plots than in cane from W_2 plots (Tables 3 and 4).

Table 2

Effects of applied nitrogen, drying-off and ripener treatments on cane quality and yields

Treatments	Experiment 1			Experiment 2			Experiment 3			Experiment 4		
	Tons cane ha^{-1}	Ers % cane	Tons ers ha^{-1}	Tons cane ha^{-1}	Ers % cane	Tons ers ha^{-1}	Tons cane ha^{-1}	Ers % cane	Tons ers ha^{-1}	Tons cane ha^{-1}	Ers % cane	Tons ers ha^{-1}
N1	67	13,0	8,6	59	12,1	7,1	53	13,4	7,2	80	11,7	9,4
N2	71	12,8	9,0	73	11,7	8,5	66	13,2	8,7	90	12,0	10,8
N3	82	12,3	10,1	83	11,5	9,4	74	13,4	9,9	96	11,4	11,0
N4	78	11,8	9,1	86	11,4	9,7	71	13,2	9,4	95	11,6	11,0
Mean	74	12,8	9,2	75	11,7	8,7	66	13,3	8,8	90	11,7	10,6
LSD (P=0,05)	9,1	0,32	0,62	8,2	0,4	0,97	7,6	0,39	0,96	7,4	0,55	1,1
W_1	75	12,1	9,1	77	11,5	8,8	75	13,4	10,0	98	11,6	11,3
W_2	73	12,8	9,3	73	11,8	8,6	57	13,2	7,5	83	11,8	9,8
Mean	74	12,5	9,2	75	11,7	8,7	66	13,3	8,8	91	11,7	10,6
C	76	11,9	9,1	76	11,4	8,6	67	13,0	8,7	89	11,4	10,2
R	72	13,0	9,4	75	11,9	8,9	65	13,6	8,8	91	11,9	10,8
Mean	74	12,5	9,2	75	11,7	8,7	66	13,3	8,8	90	11,7	10,5
LSD (P=0,05)	2,84	0,23	0,44	2,29	0,26	0,33	3,4	0,36	0,49	4,0	0,3	0,5

Table 3

The effect of ripener and nitrogen levels on cane yield and quality for W_1 treated cane

N rates	Experiment 1						Experiment 2						Experiment 3						Experiment 4					
	Tons cane ha^{-1}		Ers % cane		Tons ers ha^{-1}		Tons cane ha^{-1}		Ers % cane		Tons ers ha^{-1}		Tons cane ha^{-1}		Ers % cane		Tons ers ha^{-1}		Tons cane ha^{-1}		Ers % cane		Tons ers ha^{-1}	
	C	R	C	R	C	R	C	R	C	R	C	R	C	R	C	R	C	R	C	R	C	R	C	R
N1	66	69	12,3	13,4	8,2	9,2	58	64	11,8	12,3	6,8	7,8	55	63	13,0	14,0	7,3	8,9	85	84	11,4	12,0	9,7	10,2
N2	75	70	11,6	13,0	8,8	9,1	84	70	11,5	11,7	9,6	8,2	84	73	13,3	13,8	11,1	10,1	103	100	11,9	11,8	12,2	11,6
N3	80	79	11,3	12,5	9,0	10,0	84	85	10,5	11,8	8,9	10,0	83	80	12,8	13,6	10,7	10,8	103	102	10,6	12,2	10,8	12,6
N4	79	84	11,0	12,1	8,7	10,2	81	90	10,7	11,6	8,6	10,4	78	85	13,0	13,4	10,2	11,4	98	105	11,3	11,6	11,1	12,2
Mean	75	76	11,6	12,8	8,7	9,6	77	77	11,1	11,9	8,5	9,1	75	75	13,0	13,7	9,8	10,3	97	98	11,3	11,9	10,9	11,6
LSD (P=0,05)	-		-		-		5,38		0,42		0,33		15,1		0,44		0,83		8,2		0,6		1,1	

Table 4

The effect of ripener and nitrogen levels on cane yield and quality for W_2 treated cane

N rates	Experiment 1						Experiment 2						Experiment 3						Experiment 4					
	Tons cane ha^{-1}		Ers % cane		Tons ers ha^{-1}		Tons cane ha^{-1}		Ers % cane		Tons ers ha^{-1}		Tons cane ha^{-1}		Ers % cane		Tons ers ha^{-1}		Tons cane ha^{-1}		Ers % cane		Tons ers ha^{-1}	
	C	R	C	R	C	R	C	R	C	R	C	R	C	R	C	R	C	R	C	R	C	R	C	R
N1	66	65	12,7	13,4	8,4	9,7	58	56	11,7	12,5	6,8	7,0	45	48	12,9	13,7	5,9	6,6	72	79	11,6	11,6	8,3	9,2
N2	73	65	12,7	14,0	9,2	9,1	69	69	12,1	11,6	8,3	8,1	53	53	12,6	13,0	6,8	6,9	81	78	11,8	12,5	9,6	9,8
N3	89	79	12,6	12,7	11,3	10,1	81	80	11,5	11,9	9,3	9,5	66	66	13,2	14,1	8,6	9,3	89	90	11,0	12,0	9,8	10,8
N4	81	68	11,3	12,6	9,1	8,5	90	83	11,3	11,9	10,1	9,9	69	52	13,3	12,9	9,1	6,8	84	92	11,8	11,6	9,9	10,7
Mean	77	69	12,3	13,2	9,5	9,1	75	72	11,7	12,0	8,5	8,6	58	55	13,0	13,4	7,6	7,4	82	85	11,6	11,9	9,4	10,1
LSD (P=0,05)	-		-		-		5,4		0,42		0,33		15,1		0,44		0,83		8,2		0,6		1,1	

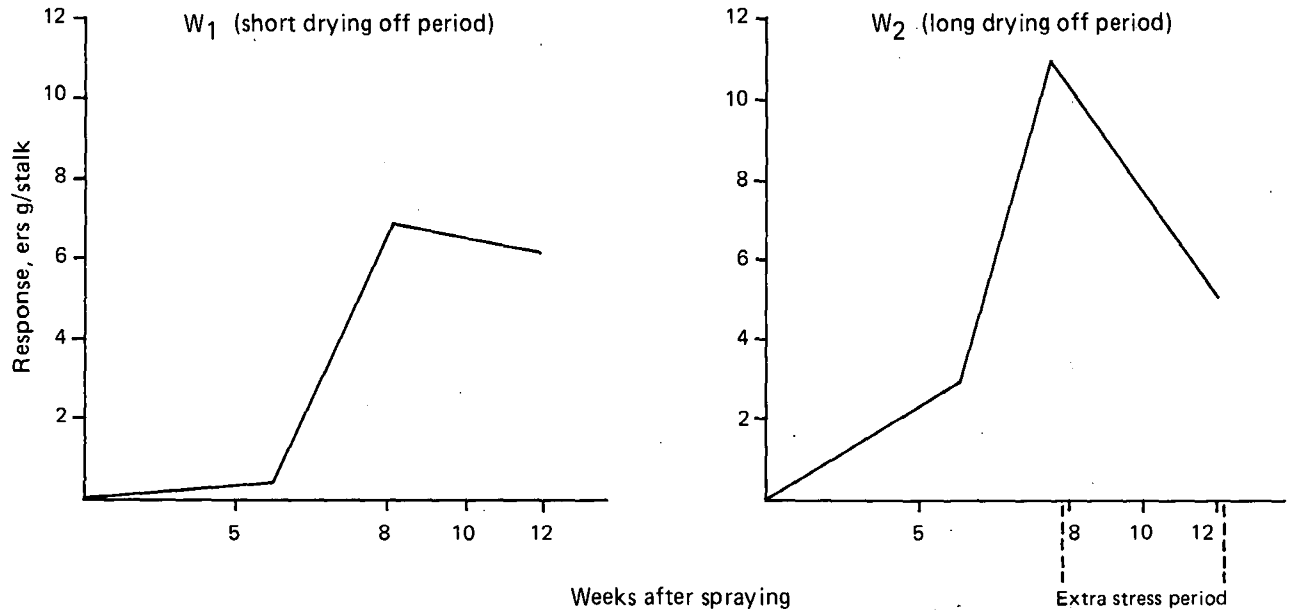

FIGURE 2 The effect of moisture stress after ripener treatment on the response to Ethrel in Experiment 4.

Discussion

The responses to N in these four experiments confirm that the optimum rate at which N should be applied to a Longlands form soil is about 200 kg ha^{-1} under irrigated conditions (Clowes and Inman-Bamber)[1] which is higher than the 160 kg N ha^{-1} suggested by Meyer *et al*[3] for rainfed cane. The increases in cane yields and decreases in cane quality, in response to the higher rates of N in Experiments 1 and 2, had no effect on the size of the response to glyphosate. The results suggest that responses to Ethrel may be greater at the higher levels of applied N (200 to 230 kg ha^{-1}) than at the lower levels (140 to 170 kg N ha^{-1}).

The moisture stress that occurred in the W_2 plots in Experiments 1 and 2 may have contributed to the large decrease in cane yields in the W_2 plots in Experiment 3. Glyphosate and Ethrel had no effect on cane yields in the W_1 plots but in the W_2 plots, glyphosate reduced cane yields by 4,7 t ha^{-1} whilst Ethrel may have increased cane yields slightly. The response to glyphosate in terms of cane quality was 50% lower in the W_2 plots than in the W_1 plots.

The data shown in Figure 2 indicate that responses to Ethrel may have been affected by the moisture stress that occurred after spraying. During the final four weeks before harvesting, the crop in W_2 plots showed approximately a 50% reduction in the response to treatment with ripener. Rostron[4] showed that responses to Ethrel were not eliminated by post-treatment stress provided the crop was actively growing at the time of treatment.

These results confirm that glyphosate has no residual effect on cane yields of subsequent ratoons (Donaldson and Inman-Bamber[2]) provided conditions are suitable for chemical ripening at the time of spraying. After a crop has been sprayed with a ripener, conditions suitable for vigorous growth should be maintained for as long as possible, but not during the period immediately prior to harvesting. At this stage, the soil should be allowed to dry out to the extent that is necessary for compaction to be avoided when using heavy transport for infield operations. Critical moisture contents for various soil forms have been provided by Swinford.[6]

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