

EFFECTS OF MOISTURE REGIME, AMOUNT OF NITROGEN APPLIED AND VARIETY ON THE RIPENING RESPONSE OF SUGARCANE TO GLYPHOSATES

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Abstract

Results from 30 trials were used to test the effect of moisture regime (rainfall and irrigation), level of nitrogen fertilizer or variety on the ripening response to glyphosate. The results showed that adequate moisture was required at the time of spraying and between spraying and harvesting to produce good ripening responses. At least five hours should elapse between spraying and heavy rainfall or irrigation, however, varieties appear to react differently. The level of nitrogen applied did not affect the response to the ripener but did affect both cane yield and quality. The current recommendations on timing and level of fertilizer application appear to be adequate to ensure that good ripening responses are obtained with glyphosate. Varieties N52/219 and N8 appear to be more susceptible than other varieties to early chlorosis and stunting in the following ratoon crop. The full effects on ratoon regrowth will only be known once the subsequent ratoon crop has been harvested. Practical implications of the results are discussed.

Introduction

Results from recent trials in South Africa have shown (Clowes^{4, 5}) that glyphosates were effective in improving cane quality during the growing period in each of the three main ecological regions, while during the cooler ripening period responses were only obtained in the northern semi-arid region where cane is irrigated. Good ripening responses from Polaris, a chemical ripener related to glyphosate, were obtained on clay but not on sandy soils in Hawaii (Mason⁹). It was suggested that the poor ripening response on sandy soils was the result of the poor soil water holding capacity, which favoured natural ripening. The nitrogen content of leaves has also been shown to be associated with ripening responses. In addition, all varieties treated with glyphosate have responded over a wide range of climatic conditions experienced in Hawaii (Anon.¹).

Glyphosates sometimes increase tillering of the following ratoon crop, (Anon.²) probably as a result of inhibition of indole acetic acid (IAA) transport (Baur³), and may even cause chlorosis and early stunting (Clowes⁴), particularly if higher rates are used. The effects on regrowth are complex and not fully understood. However, Greshoff⁶ found that inhibition of crop regrowth by glyphosates was transitory, except in plant roots, and that phenylalanine and tyrosine acted synergistically to reverse this growth inhibition. The inhibition of growth probably results from the interference of glyphosate with aromatic amino acid metabolism (Jaworski⁸; Haderlie, Widholm and Slife⁷).

The effects of different management practices on the response to growth regulators needs to be ascertained under local conditions because these effects are likely to depend on complex genotype: environment interactions. This paper is a report of the results from 30 trials designed to provide information on the effects of soil moisture regime, level of applied fertilizer and sugarcane variety on the ripening response to glyphosate. The glyphosate salts used were either Roundup at a rate of 1 litre per hectare, or Mon 8000 applied at a rate of 0,67 kg per hectare. These treatments both represent an application of approximately 0,4 kg active ingredient per hectare.

Materials and Methods

Details describing each trial, excluding the 20 trials at Tongaat, are shown in Table 1 and more detailed information on each trial is presented below:

Trial 1 at Pongola: was designed to determine the effects of glyphosate on cane which was either irrigated or not-irrigated after the application of the ripener. Two 3,2 hectare blocks received different irrigation treatments while eight 0,4 hectare sub-plots within each block were divided into four replicates, each one comprising a treated and an untreated sub-plot. Figure 1 shows the design, and the dates of irrigation, ripener application, sampling and harvesting, and the daily rainfall.

TABLE 1
Description of trials (excluding the series of 20 trials at Tongaat)

Trial	Region†	Site	Variety	Moisture regime	Main treatments			Crop‡	Month sprayed	Crop condition at spraying		
					●Irrigation	Fertilizer	Variety			Age (months)	Suc % cane	Juice purity %
1	NI	Pongola	NCo376	Irrigated	●			P	March	11	7,1	67
2	NI	Pongola	Various	Irrigated	●		●	P	July	10	11,0*	82*
3	NI	Pongola	Various	Irrigated			●	R	January	9	7,8*	71*
4	NI	Pongola	Various	Irrigated			●	P	March	11	8,9*	70*
5	NI	Pongola	NCo376, N55/805	Irrigated			●	R	August	8	12,4*	89*
6	C	Shakaskraal	NCo376	Irrigated	●	●		R	April	14	14,4	90
7	C	Mtunzini	Various	Rainfed			●	P	September	11	13,2*	89*
8	C	Umdloti	Various	Rainfed			●	P	October	12	13,4*	91*
9	C	Mount Edgecombe	Various	Rainfed		●	●	R	October	11	11,7*	88*
10	M	Paddock	Various	Rainfed			●	P	October	12	11,9*	90*

* For variety NCo 376

† NI = Northern irrigated; C = Coastal; M = Midlands

‡ P = Plant crop; R = Ratoon crop

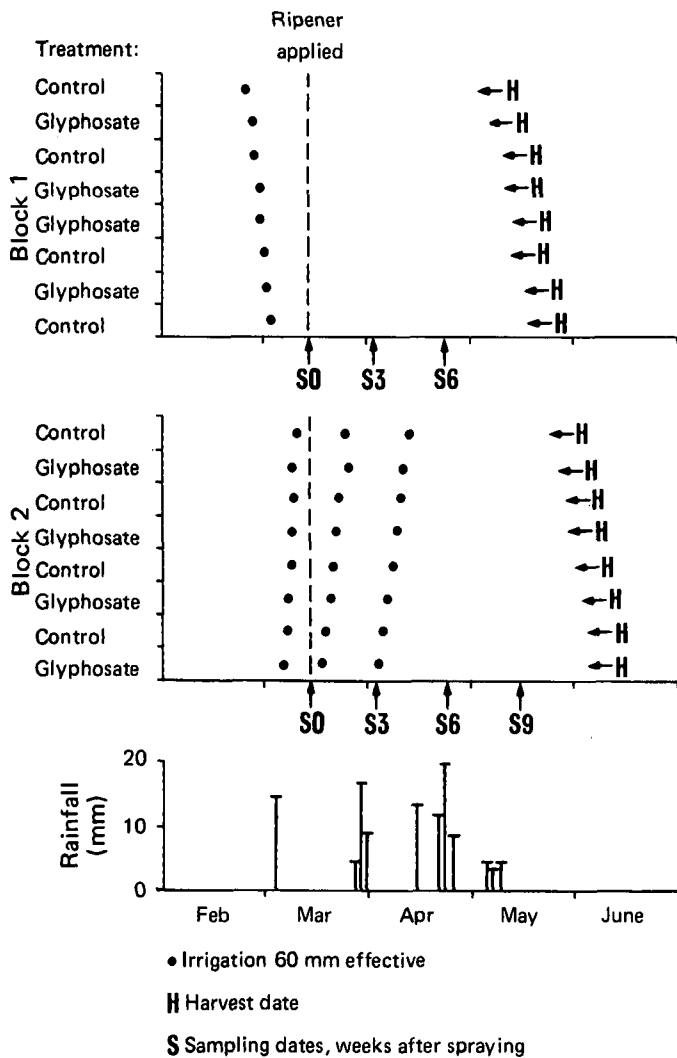


FIGURE 1 Dates of irrigation, ripener application, sampling and harvesting for each block and daily rainfall in trial 1.

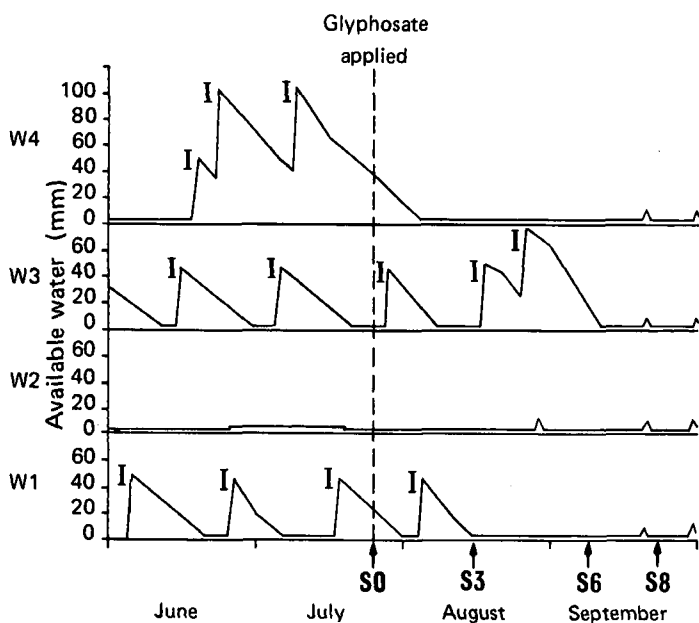


FIGURE 2 Available soil moisture from June in trial 2, using the profit and loss account. The dates of irrigation (I), glyphosate application and sampling occasions (S) are also indicated.

Trial 2 at Pongola: Glyphosate was applied to this irrigation x variety trial eight weeks before harvest. Four different irrigation regimes were applied to the three varieties (NCo376, N52/219 and N11). The available soil moisture indicated

by the soil profit and loss account from June onwards, and the spraying and sampling dates are shown in Figure 2.

Trial 3 at Pongola: Glyphosate was applied to two commercial varieties (NCo376 and NCo310) and four non-commercial varieties (67W25, 67W73, 69F636 and 69F107). The object was to determine the effects of glyphosate on unreleased varieties which were relatively high yielding, but which had a low sucrose content. Two of the varieties, 67W25 and 69F636, were lodged and had to be pushed upright by hand before spraying. Twenty-two millimetres of heavy rain were recorded within five hours of spraying. Cane stalks were sampled at the time of spraying and thereafter at three weekly intervals up to nine weeks.

Trial 4 at Pongola: Glyphosate was applied with an overhead boom to two predetermined lengths of cane row in each of the two guard rows per plot of an existing variety trial. Irrigation was suspended too early in this trial and all five varieties (NCo376, NCo334, N52/219, J59/3 and N11) showed signs of moisture stress at the time of spraying. Irrigation water was applied 11 days after spraying when drought symptoms were severe. The estimated amounts of available moisture in the soil profile before and after spraying glyphosate and the sampling occasions are shown in Figure 3.

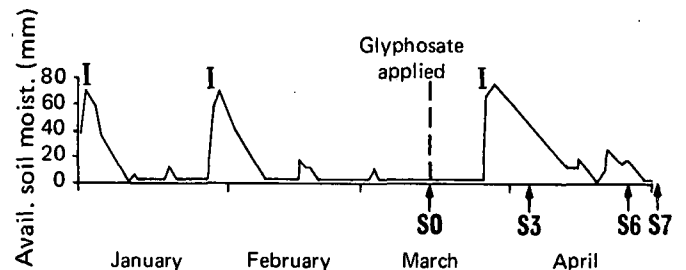


FIGURE 3 Available soil moisture calculated from the profit and loss account in trial 4. The dates of treatment and irrigation (I) and the sampling occasions (S) are indicated.

Trial 5 at Pongola: Glyphosate was applied to three replications of varieties NCo376 and N55/805 growing adjacent to one another in the same irrigation lateral. The standard farm irrigation cycle was used but no drying off was practised. Cane samples were taken at the time of spraying and four and eight weeks later.

Trial 6 at Shakaskraal: this trial was originally designed to test the effects of different irrigation and nitrogen treatments on NCo376 growing on a Waldene series soil at Shakaskraal. Figure 4 shows details of the nitrogen treatments, and rates of applied potassium and phosphorus together with dates of rainfall and irrigation. Overhead sprinklers were used to irrigate all plots similarly until 3 April when 'perforain' pipes were installed in each interrow in order to apply water each week to the two irrigated blocks while the other two blocks were dried off. A soil auger was used to check that the soil was approximately at field capacity after each irrigation. Cane stalks were sampled at the time of spraying and at 3½ and 6½ weeks thereafter.

Trials 7, 8, 9 and 10 at various sites: Glyphosate was applied to one row of the net plot and to an adjacent guard row in each gross plot in four variety trials. Details of the varieties and sampling occasions are shown in Table 2. Trial 9 differed from the other trials because it included ten extra plots of NCo376. All six rows in each of these ten plots were treated with glyphosate. Half of these plots received a late application of nitrogen (46 kg/ha) seven weeks before spraying. Rain (30 mm) fell within 11 days of applying the nitrogen. Glyphosate was applied late in 1979 once good rains had fallen at the end of the relatively dry winter.

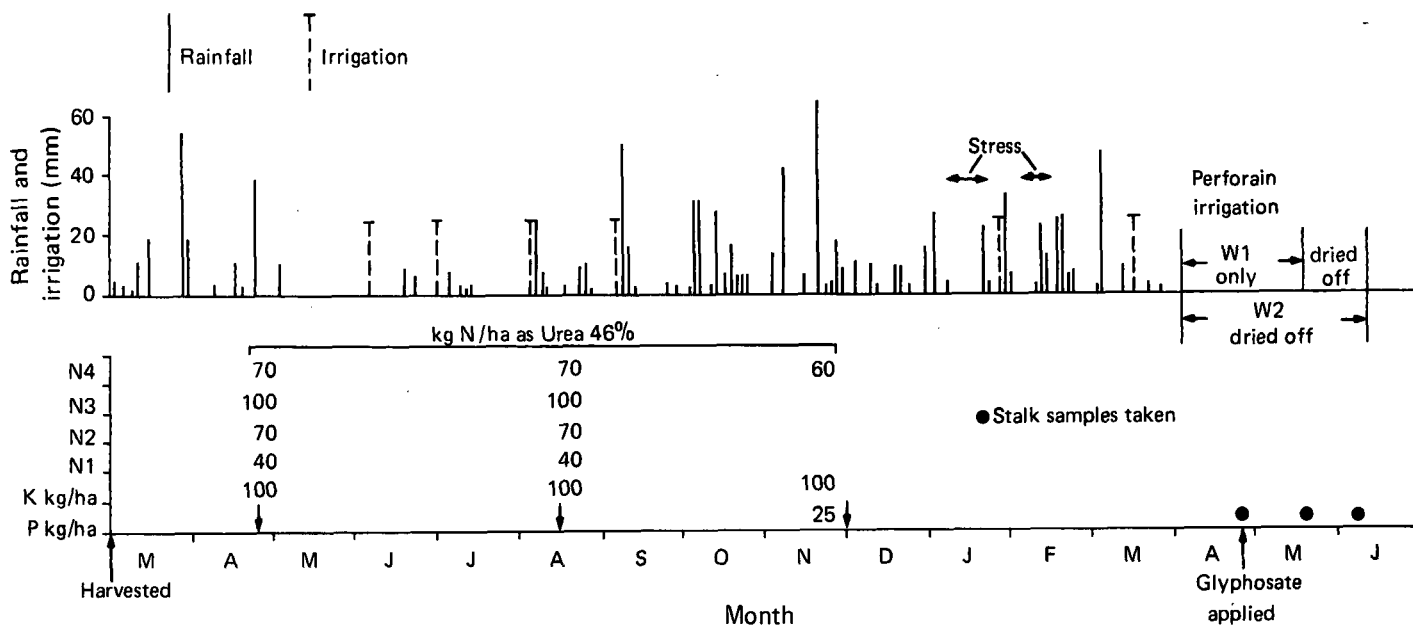


FIGURE 4 Time of N, P and K application, stalk sampling occasions, glyphosate treatment and daily rainfall and irrigation data.

Figure 5 shows rainfall in relation to spraying and harvesting and planting dates.

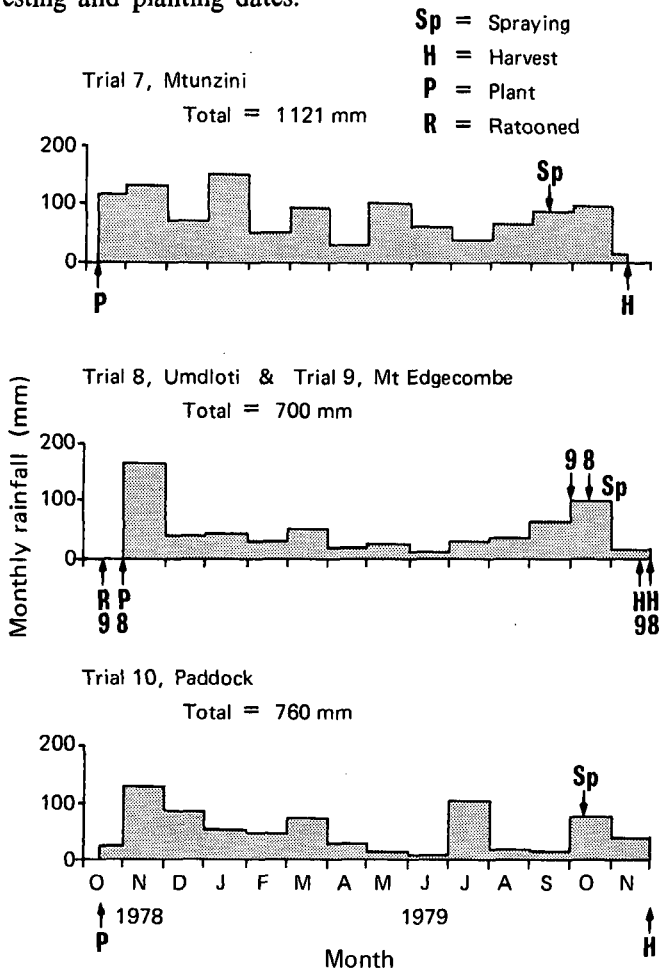


FIGURE 5 Rainfall data and spraying occasions for trials 7, 8, 9 and 10.

20 Trials at Tongaat: Glyphosate was applied to two, or sometimes one trial each month through the 1978/79 season to determine the effect of season on ripening response. Cane stalk samples were taken at the time of spraying and between 3 and 5 weeks after spraying. The cane, mainly variety NCo376, was about 15 months old at the time of spraying.

The spraying and sampling methods used for the thirty trials are described in a previous paper by Clowes⁵.

TABLE 2 Varieties grown and sampling occasions in Trials 7, 8, 9 and 10

Trial	Varieties	Sampling occasions, weeks after spraying
7	NCo 376, N12, 67E1507, N11, J59/3 and N52/219	0 and 4
8	NCo 376, N55/805, N8, N11, N12 and 67E1507	0 and 5
9	NCo 376, NCo 310, N55/805, N52/219, J59/3 and N7	0 and 6½
10	NCo 376, N55/805, N52/219, N11, N12 and 67E1507	0 and 5½

Results

Trial 1: Table 3 shows that continuing irrigation after the application of glyphosate greatly increased the response to glyphosate by improving both cane quality and cane mass.

Table 4 shows that there was a significant (P = 0,01) interaction between the irrigation and ripener treatments. The processing of cane from each sub-plot was done commercially at the Pongola mill. The data obtained are in close agreement with the sampling data. The application of glyphosate to dried off cane produced an additional ton of sucrose per hectare. This response was doubled when irrigation was continued after glyphosate had been applied.

TABLE 4 Main effects and interactions on sucrose % cane six weeks after ripeners were applied

Treatment	Sucrose % cane		Interaction effect
	Dried-off	Irrigated	
Control	10,31	10,28	
Glyphosate	10,90	12,37	
Difference	0,59**	2,09**	1,5**
LSD (P = 0,05) . .	0,28		0,40

TABLE 3
The effects of glyphosate with and without irrigation following ripener application in Trial 1

Treatment	Weeks	Sucrose % cane				Juice purity %				Stalk Mass				g/stalk											
														Mass sucrose				Mass ers							
		0	3	6	9	0	3	6	9	0	3	6	9	0	3	6	9	0	3	6	9				
Control — Dried-off	Dried-off	6,4	8,8	10,3	—	64,8	74,2	79,0	—	1 022	1 176	1 161	—	65,6	103,2	119,5	—	43,5	80,0	98,4	—				
		6,8	8,8	10,9*	—	66,6	73,6	79,6	—	1 014	1 165	1 140	—	69,5	102,1	124,2	—	47,5	78,6	103,4	—				
Control + Irrigation	Irrigation	7,0	9,2	10,2	11,8	68,2	76,6	80,0	84,5	1 090	1 139	1 248	1 273	77,2	105,0	128,0	150,4	54,4	83,4	106,0	129,9				
		7,3	10,0	12,4*	14,2*	69,0	77,5	84,8*	89,4*	1 054	1 118	1 203	1 229	77,3	110,6	148,6*	173,8*	55,4	89,2	129,4*	157,1*				

* significantly different from control (P = 0,05)

Trial 2: The only consistent response three weeks after spraying glyphosate was an increase in sucrose % cane of 0,6 units in all three varieties in the W4 treatment, which was the wettest at the time of spraying (see Figure 2). Results of sampling six weeks after applying glyphosate are shown in Table 5. Significant improvements in cane quality were obtained in the W4 and W1 treatments which were the only treatments with a reservoir of available moisture in the soil at the time of spraying. Treatment W2 produced no ripening response but small responses were evident in treatment W3, which was the wettest treatment in the period following glyphosate application. The lack of a ripening response in treatments W4 and W1 at the final sampling, and the apparent decrease in cane mass when compared with untreated cane, is likely to have been due to the dry conditions towards the end of the experiment.

TABLE 5
The increase in sucrose % cane and changes in stalk mass and mass of estimated recoverable sugar following the application of glyphosate to cane in Trial 2

Treatment	6 weeks after spraying			
	Suc % cane	Mass stalk	Mass ers	
NCo 376	W1 . . .	+ 1,29*	- 9	+ 1
	W2 . . .	+ 0,16	- 6	- 4
	W3 . . .	+ 0,49	- 3	+ 1
	W4 . . .	+ 1,32*	-14	- 3
N52/219	W1 . . .	+ 0,92*	- 3	+ 5
	W2 . . .	0	+ 9	+ 8
	W3 . . .	+ 0,46	+ 8	+13
	W4 . . .	+ 0,42	- 1	+ 2
N11	W1 . . .	+ 0,96*	0	+ 8
	W2 . . .	+ 0,31	- 2	0
	W3 . . .	+ 0,62	- 9	- 4
	W4 . . .	+ 1,26*	+ 2	+12

* significantly different from control (P = 0,05)

Trial 3: The effects of glyphosate on sucrose % cane are shown in Table 6. There was a statistically significant interaction between variety and glyphosate. Glyphosate produced a significant ripening response only in varieties 67W25 and NCo376. Stalk mass was not affected by glyphosate and consequently the mass of estimated recoverable sugar in the varieties which responded to treatment was increased by about 20 per cent. The glyphosate x ripener interaction on sucrose yield was significant (P = 0,05).

TABLE 6
The effects of glyphosate on sucrose % cane on some released and unreleased varieties in Trial 3

Variety	Treatment	Weeks after spraying			
		0	3	6	9
67W25 . . .	Control . . .	5,8	7,6	7,8	8,6
	Glyphosate . . .	5,8	8,2	9,4*	9,4
67W73 . . .	Control . . .	5,6	7,6	8,9	10,7
	Glyphosate . . .	6,2	8,4	9,7	11,4
69F636 . . .	Control . . .	5,4	7,0	7,9	8,6
	Glyphosate . . .	5,6	6,0	7,4	9,2
69F107 . . .	Control . . .	7,0	9,0	10,1	11,4
	Glyphosate . . .	7,3	9,5	10,3	11,3
NCo376 . . .	Control . . .	7,7	9,7	10,7	11,5
	Glyphosate . . .	8,0	10,4	11,6	13,6*
NCo310 . . .	Control . . .	8,0	10,2	11,8	12,5
	Glyphosate . . .	7,9	10,1	11,7	12,4

* significantly different from control (P = 0,05)

Trial 4: The variety x ripener interaction was significant in terms of sucrose % cane, NCo376 being the only variety that responded ($P = 0,05$) to the ripener treatment (Table 7). Cane mass was not affected by chemical ripener although treated stalks of J59/3 tended to be heavier than untreated stalks six and seven weeks after spraying. The mass of estimated recoverable sugar (ers) from NCo376 was increased by 13 per cent.

TABLE 7

Increase in sucrose % cane following the application of glyphosate in Trial 4

Variety	NCo376	NCo334	N52/219	J59/3	N11	Mean
Increase in sucrose % cane	+ 1,2*	+ 0,4	+ 0,4	+ 0,65	+ 0,45	0,64

* significantly different from control ($P = 0,05$)

Trial 5: Table 8 shows that glyphosate increased the cane quality but not cane mass of both varieties with the greatest response occurring eight weeks after spraying when yields of estimated recoverable sugar were increased by between 11 and 14 per cent.

TABLE 8

The effects of glyphosate on varieties NCo376 and N55/805 in Trial 5

Treatment	NCo376			N55/805		
	Sucrose % cane			Sucrose % cane		
	0 weeks	4 weeks	8 weeks	0 weeks	4 weeks	8 weeks
Control	12,4	13,3	14,1	13,1	14,6	15,3
Glyphosate	12,4	14,3	15,8	13,1	15,6	17,5

Trial 6: The effects of nitrogen, irrigation and ripener treatments on sucrose % cane, are shown in Figure 6.

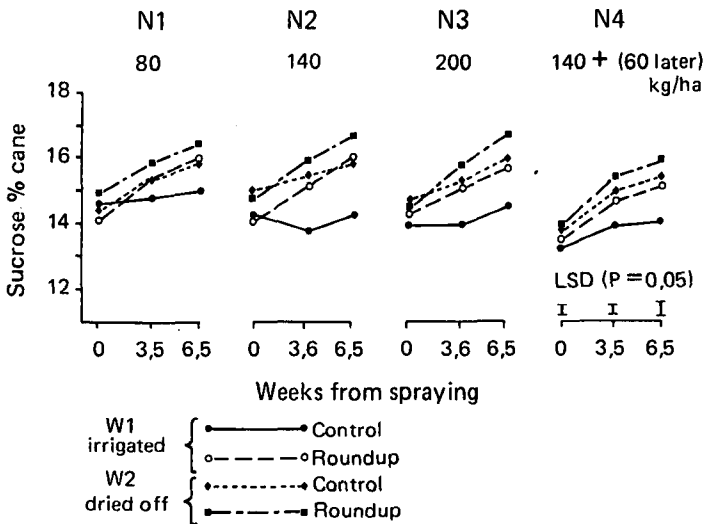


FIGURE 6 The effects on sucrose % cane of Roundup when applied to cane subjected to different nitrogen and irrigation treatments.

The response in terms of sucrose % cane to ripener application was much greater where irrigation was continued after spraying than when it was suspended. The sucrose % cane of untreated, dried-off cane and irrigated cane treated with ripener was similar. However, irrigation increased cane mass which resulted in higher sucrose yields in the latter treatment.

It can be concluded from the main effects of treatments (Table 9) that the highest sucrose yield was obtained from a combination of applying glyphosate, the highest rate of nitrogen when applied early (see Figure 4) and no drying off. There was no interaction between the irrigation and nitrogen treatments.

TABLE 9

The main effects of nitrogen, irrigation and ripener treatment on tons ers per hectare and tons cane per hectare (in brackets)

Nitrogen	Irrigation	Ripener
Treatment Tons ers ha ⁻¹	Tons ers ha ⁻¹	Tons ers ha ⁻¹
N1 11,8 (87)	W2 (dried off) 13,9 (98)	Untreated 13,9 (107)
N2 14,8 (108)	W1 (irrigated) 15,2 (117)	Glyphosate 15,2 (108)
N3 16,5 (118)		
N4 15,1 (116)		
LSD ($P = 0,05$) 1,18 (8,80)	— —	0,63 (3,96)

Trials 7, 8, 9 and 10: Results from samples taken between 4 and 6½ weeks after applying glyphosate (Table 10) show that the cane quality of all varieties was significantly improved by glyphosate. The mean overall response from all varieties in the four trials was an 11 per cent increase in the mass of estimated recoverable sugar.

TABLE 10

Responses from applying glyphosate to four rainfed variety trials

Trial	Variety	Change from control		
		Units Suc % cane	%	
			Stalk mass	Mass ers
7 Mtunzini (4 weeks after spraying)	NCo376	+ 1,2*	- 6	+ 4
	N12	+ 2,2*	0	+ 18
	67E1507	+ 1,8*	+ 13	+ 30
	N11	+ 1,6*	+ 3	+ 16
	J59/3	+ 1,5*	- 2	+ 10
	N52/219	+ 1,8*	- 1	+ 13
8 Umdloti (5 weeks)	NCo376	+ 1,4*	+ 22	+ 36
	N55/805	+ 1,2*	- 8	0
	N8	+ 1,2*	0	+ 11
	N11	+ 1,1*	- 2	+ 6
	N12	+ 1,4*	- 5	+ 6
	67E1507	+ 1,6*	- 10	+ 1
9 Mt. Edgecombe (6½ weeks)	NCo376	+ 1,5*	- 4	+ 8
	NCo310	+ 1,2*	- 20	- 12
	N55/805	+ 1,6*	+ 2	+ 21
	N52/219	+ 1,7*	- 7	+ 6
	J59/3	+ 1,9*	- 8	+ 9
	N7	+ 2,3*	- 10	+ 12
10 Paddock (5½ weeks)	NCo376	+ 1,5*	+ 3	+ 18
	N55/805	+ 2,4*	- 11	+ 8
	N52/219	+ 0,9*	- 1	+ 7
	N11	+ 1,5*	- 4	+ 8
	N12	+ 1,4*	- 10	+ 2
	67E1507	+ 1,6*	0	+ 15

* significantly different from control ($P = 0,05$)

Table 11 comprises the additional data collected from Trial 9. The table shows that glyphosate significantly improved cane quality while the additional and very late application of nitrogen had little effect on either cane quality or mass.

TABLE 11
Additional data from Trial 9

Treatment	Sucrose % cane	Stalk mass, g	Mass ers, g/stalk
NCo376	12,3	345	37,5
NCo376 + Glyphosate	13,8	359	44,5
NCo376 + Glyphosate + late N	13,6	349	42,7
LSD (P = 0,05)	0,94		

20 Trials at Tongaat : The results are summarized in Figure 7 which shows that ripening responses occurred only when there was adequate rainfall and sufficiently high temperatures.

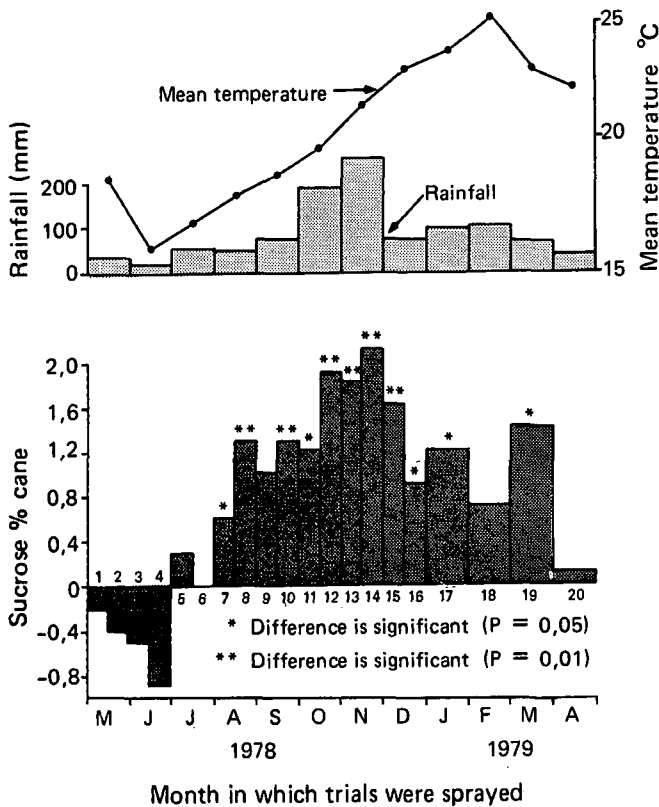


FIGURE 7 Mean monthly rainfall and temperature for Tongaat (top) and the change in sucrose % cane from control after applying glyphosate (bottom) to each of the 20 trials.

Discussion

The results show that soil moisture regime has a large effect on the response to glyphosate. The various forms of moisture stress which occurred in Trials 2 and 6 were : stress at the time of and after spraying ; stress at the time of spraying only; stress after spraying, and no stress. The results were consistent in that good and reliable responses to glyphosate were obtained only when soil moisture before and after spraying was adequate. The high sensitivity of the ripening response to moisture stress is shown by the poor response obtained when the moisture deficit at spraying was relieved shortly afterwards (Trial 2, treatment W3). The moisture profit and loss account for this treatment showed that there was no available moisture just before spraying, although the plants did not appear to be severely stressed. The lack of a ripening response in Trial 2 eight weeks after ripener application, and the small effect of treatment on sucrose yield after six weeks, even when cane quality was significantly improved, could have been due to a lack of soil

moisture. This suggestion is supported by results from Trial 6 which showed that good ripening responses and increases in sucrose yield were obtained when adequate moisture was supplied up until the time of harvest (12 weeks after spraying). Glyphosate application resulted in an improvement in cane quality similar to (see Figure 6) or more effective than (see Table 5) that obtained when a period of drying off was imposed on untreated cane. The advantage of using an artificial ripener without suspending irrigation was that both cane yield and quality were improved. The series of 20 rainfed trials at Tongaat confirmed the importance of soil moisture as well as air temperature on the response to glyphosate (Figure 7). These two factors overshadowed the effects of varying soil types, crop age and other management factors. In rainfed areas where moisture conditions are unpredictable, glyphosate should be applied after good rains when soils are close to field capacity. Soils with a high total available moisture (TAM) should be preferred to soils with a low TAM because of the unpredictability of future rainfall. Poor sandy soils should perhaps be avoided.

Varieties appeared to respond to glyphosate differently only when there was a long period of moisture deficit before spraying (Trial 4) or when heavy rainfall occurred within five hours of spraying. Variety NCo376 appeared to be less sensitive to these conditions than the other varieties. However, the different stress treatments in Trial 2 did not result in varying ripening responses in the three varieties NCo376, N52/219 and N11. When moisture was adequate at and after the time of spraying in Trials 7 to 10, all ten varieties treated with glyphosate produced similar ripening responses (Table 10); this was despite the severe winter drought experienced earlier in three of the trials (see Figure 5).

The application of different amounts of nitrogen had a small and not statistically significant effect on the ripening response (Figure 6). However, the amount of nitrogen applied did affect cane yield and cane quality. (See Figure 6 and Table 9). There was no advantage in applying 46 kg of nitrogen seven weeks before applying glyphosate to Trial 9 on a Milkwood series soil. The results in Trial 6 on a Waldene series soil, which supplies very little nitrogen through mineralization, showed that it was important to provide adequate nitrogen during the early establishment period. A trial near Eshowe on an Inanda series soil and one on the Umhlatuzi flats near Felixton have shown (unpublished data) that cane and sucrose yields and responses to glyphosate were not increased by applying more than the currently recommended levels of nitrogen and potassium.

Results from Trial 5 indicate that when glyphosates are applied during the ripening phase in the northern irrigated region, the optimum period between the times of spraying and harvesting may extend from six (see Clowes⁴) to about eight weeks after spraying.

The effects of glyphosate on the regrowth of the following crop are being monitored and results will be reported once the following untreated ratoon crop is harvested. There is evidence that N52/219 and N8 appear, at least from visual observations, to be more susceptible than other varieties to chlorosis and early stunting in trials where cane has shown these symptoms.

Conclusions

1. There must be adequate moisture at and after the time of spraying to ensure good ripening responses from glyphosates. It is an advantage if irrigation water can be applied to ensure that there is available moisture present up until about a week prior to harvest.

2. All varieties tested responded to glyphosate provided there was adequate moisture at and after the time of spraying.
3. At least five hours should elapse between the time of spraying and the first irrigation or any rainfall for variety NCo376, and preferably a longer time for other varieties.
4. Nitrogen level did not influence the response to applied glyphosate but it did affect both cane yield and quality. Adequate nitrogen should be applied early in the life of the crop to maximise cane yield. There was no advantage in applying more nitrogen than was needed to maximise cane growth.
5. The current Fertilizer Advisory Service (FAS) recommendations are not likely to require any major changes when glyphosates are used.
6. Under rainfed conditions glyphosate should be applied when cane is actively growing, and the soil moisture content is close to field capacity. Soils with a high total available moisture (TAM) should be selected in preference to soils with a low TAM because rainfall after glyphosate application is not predictable.
7. The succeeding ratoon crops of varieties N52/219 and N8 appear to be more susceptible than those of most other varieties to chlorosis and early stunting following treatment of the previous crop with glyphosates.
8. The full effects of treatment on regrowth will be published once the following ratoon crops have been harvested.

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