

AN ASSESSMENT OF APPLICATION TECHNIQUES FOR ROUNDUP[®] HERBICIDE FOR KILLING SUGARCANE

By J. CHEDZEY and J. B. R. FINDLAY

Monsanto South Africa (Pty) Ltd, P.O. Box 78025, Sandton 2146

Abstract

In an attempt to refine the dosage rates for Roundup[®] herbicide, the following aspects were evaluated: the addition of the surfactants Frigate[®] and G3780A to Roundup, reduced spray volumes, pre-harvest applications to the mature cane, post-harvest stubble treatments and split applications. Results show that the rate of Roundup and the time of year at which application is made are the most important factors affecting the efficacy of Roundup. The addition of Frigate, and reduced spray volumes improve the efficacy of Roundup under certain circumstances and split applications are an effective means of ensuring complete cover of all the foliage. Pre-harvest applications and stubble treatments were unacceptable as application techniques. The recommended rates for Roundup of 8 to 10 l ha⁻¹ are confirmed for spring to mid-summer applications and lower rates are indicated for the latter half of the growing season. A cane growth stage theory is proposed to explain the results obtained.

Introduction

Since Roundup[®] herbicide was registered in 1975 for killing sugarcane, the practice of minimum tillage has become a well established method of eradicating old sugar cane stools (Moberly and Meyer,⁹ Platford,¹² Turner¹³). The characteristics of Roundup which make it suitable for minimum tillage are well known (Iggo,⁸ Turner¹⁴). The soil and moisture conservation benefits and crop hygiene benefits of minimum tillage, using Roundup, have been identified and are accepted by growers and the South African Sugar Association Experiment Station (Anon,² Dicks *et al.*,⁷ Iggo,⁸ Moberly *et al.*,⁹ Turner¹⁴).

The cost of the 8 to 10 l of Roundup ha⁻¹ currently recommended for killing sugarcane, relative to mechanical methods of land preparation, has limited the use of the Roundup-based minimum tillage system to the steep, rocky areas which are erodible and difficult to replant (Moberly *et al.*,⁹ Platford¹²). The high awareness of soil conservation practices in the cane industry has resulted in a move away from deep tillage operations to improved, cost effective tillage systems (Anon,¹ Dicks *et al.*,⁷ de Robillard,⁶ Platford¹²). Where labour is available an alternative form of minimum tillage to Roundup, known as chipping, is sometimes used. In this system the stools are dug out by hand (Moberly *et al.*⁹).

If minimum tillage, using Roundup, were to become more widely accepted the system would have to be cost effective even on flat lands that are easy to work. A project was initiated in the 1982 season to evaluate alternative methods of Roundup application in minimum tillage.

Results from earlier work with Roundup have shown that for killing sugarcane the addition of a surfactant had a variable effect on efficacy: low spray volumes marginally increased efficacy; complete spray cover of the ratoon foliage was important, and application had to be made at the correct growth stage (Turner¹⁴).

Despite the small response due to (1) the addition of surfactants and (2) reduced spray volumes on ratoon regrowth reported by Turner,¹⁴ it was decided to evaluate these two variables, and also to evaluate (3) pre-harvest applications to ma-

ture cane, (4) application to the stalk stumps or stubble soon after cutting and (5) split applications on ratoon regrowth.

Surfactants

The development of the surfactants Frigate and more recently G3780A, for use with Roundup to improve efficacy in specific situations has renewed interest in surfactants (Orson,¹⁰ Richardson *et al.*¹³).

Reduced spray volumes

Reports on other uses of Roundup have shown that its efficacy is consistently increased by reducing the spray volume (Casely *et al.*⁵). Reducing the spray volume from the industry standard of 300 l ha⁻¹ would be in keeping with world-wide trends for Roundup usage. This technique is aimed at an even droplet coverage on the spray target while avoiding droplets coalescing to the point of runoff.

Pre-harvest applications

Earlier work had shown that applying Roundup to the cane canopy two to three weeks before harvesting could improve the profitability of minimum tillage. Killing the cane prior to harvesting would make it possible to replant immediately after harvesting, thus eliminating the waiting period for ratoon regrowth when Roundup is normally applied (de Robillard⁶).

Stubble treatments

Application of Roundup to the cane stubble immediately after harvesting was evaluated since this technique would also eliminate the waiting period for regrowth to occur. This technique is used for stump eradication in forestry.

Split applications

Reports from the South Coast of Natal indicated that it was possible to reduce the rate of Roundup for killing cane stools by using split applications, i.e. applying half the desired rate twice.

Materials and Methods

The compound used was Roundup (359 g ae glyphosate l⁻¹). The surfactants used were Frigate (800 g tallow amine ethoxylate l⁻¹) and G3780A (Genamine[®], 785 g ethoxylated tallow alkyl amine l⁻¹). Roundup[®] and Genamine[®] are the registered trademarks of Monsanto South Africa (Pty) Ltd. Frigate is the registered trademark of SDS Agrochemical Products Corporation.

All trials were laid out in randomised complete blocks except for Trials 12, 15 and 16, which were single replicates. Treatments otherwise were replicated 3 or 4 times. Plots comprised 4 or 5 cane rows 7 to 10 m long, the centre 2 or 3 rows being used for assessment. Growth stage at the time of application was that which was thought to be optimum, i.e. foliage 0,4 to 0,7 m high and the stools fully tillered, with the possible exception of Trial 7, which was sprayed when the foliage height was 0,1 to 0,3 m and probably before tillering was complete. Trials 5 and 7 received rain within 6 hours of applying the chemical. All treatments were applied using a hand-held CO₂ precision sprayer, except in Trials 1, 2 and 3 where a lever-operated CP-3 knapsack sprayer was used. In all the trials on

TABLE 1
Surfactant, spray volume and split application trial details

Trial no.	Spray volume (ℓ/ha)	Pressure (bar)	Nozzle size	Row spacing (m)	Soil texture	Air temperature (°C)	Relative humidity (%)	Cloud cover (0-8)	Wind (km/h)	Locality
1	300	—	TK-5	1,2	Sand	25,0	70	0	0	Coast
2	250	—	TK-5	1,2	Sand	28,0	54	2	2	Coast
3	300 75	—	TK-5 D-1	1,2	Sand	32,0	70	0	0	Coast
4	300	2,0	TK-5	1,1	Sandy clay	19,0	84	8	0-10	Midlands
5	309 110	2,2 1,7	TK-4 TK-1,5	1,2	Sand	22,0	80	6	11-15	Coast
6	301 105	2,3 1,8	TK-5 TK-1,5	1,2	Sand	24,5	71	6	0-10	Coast
7	257 82	2,0 2,0	TJ8003 TJ8001	1,0	Sandy clay	26,0	72	0	0-10	Midlands
8	309 136 102	2,2 1,8 1,8	TK-4,0 TK-2,0 TK-1,5	1,2	Sandy loam	24,0	84	0	0-10	Coast
9	257 82	2,0 2,0	TJ8003 TJ8001	1,0	Sandy clay	28,0	72	0	0	Midlands
10	309 148 112	2,0 1,8 1,8	TK-4,0 TK-2,0 TK-1,5	1,1	Sandy loam	28,0	66	2	0-10	Midlands
11	340 163	2,0 1,8	TK-4,0 TK-2	1,0	Clay	34,0	48	0	0-10	Midlands
12	160	—	—	1,2	Sand	—	—	—	11-15	Midlands

ratoon regrowth a single nozzle hand-lance was used, except in Trials 7 and 8 where a 6 nozzle hand-held boom was used. In the pre-harvest trials a Pamro lance was fitted to a CO₂ precision sprayer, as described by de Robbillard,⁶ the only variation being that the single nozzle directed towards the base of the cane was not used since there were no live basal shoots at the time of spraying.

Details of surfactant, spray volume and split application trial sites and application parameters are presented in Table 1.

Visual ratings of percent foliar kill and percent regrowth were made by comparing treated with untreated plots.

All dosage rates are expressed as litres of formulated product per hectare.

Results

Surfactants

The mean visual percent foliar kill and the mean visual percent regrowth resulting from Roundup treatment with and without surfactant added are reported in Tables 2 and 3.

Visual assessments made within 50 days of application show that the rate of Roundup applied was the most important factor affecting foliar kill. The addition of Frigate or G3780A to the Roundup treatments in the range 4 to 8 ℓ ha⁻¹ had little or no effect on percent foliar kill.

From Table 3 it can be seen that there was a response to increased dosages of Roundup in terms of the percent regrowth in all the trials applied before December, ie Trials 2, 3, 5, 6 and 7. The 8 and 10 ℓ ha⁻¹ rates of Roundup, depending on variety, were the most effective for this period. The addition of Frigate to the 6 and 8 ℓ ha⁻¹ rates of Roundup increased the efficacy of the relevant Roundup rates in Trial 3. The amounts of regrowth in Trial 7 were unacceptably high.

After December, all Roundup applications in the range 4 to 10 ℓ ha⁻¹ caused regrowth to be 2% or less. Where 3 ℓ of Roundup ha⁻¹ was used in Trial 4, there was 12% regrowth. There was no response to the addition of Frigate or G3780A to Roundup at rates from 4 to 10 ℓ ha⁻¹.

Reduced spray volumes

The mean visual percent regrowth of cane treated with Roundup applied in various spray volumes is reported in Table 4.

From Table 2 it can be seen that spray volumes had no effect on percent foliar kill for the rates of Roundup evaluated.

In Table 4 it can be seen that, in the trials established before December, Roundup at 4 to 10 ℓ ha⁻¹ was generally more effective when applied at high spray volumes (171 to 340 ℓ ha⁻¹) than when applied at low spray volumes (75 to 110 ℓ ha⁻¹). In Trial 3 the low spray volume was more effective than the high spray volume for Roundup applications at 6 ℓ ha⁻¹, but the 10 ℓ ha⁻¹ rate of Roundup at low volume was less effective than the 10 ℓ ha⁻¹ rate in a high spray volume. The response to different rates of Roundup in terms of percent regrowth can be seen for high and low spray volumes.

After December there was no difference in the percent regrowth with different rates of Roundup or different spray volumes. All the treatments caused regrowth to be 2% or less.

Pre-harvest applications

The mean visual percent regrowth of cane treated with Roundup prior to harvest is reported in Table 5. All the treatments evaluated delayed regrowth compared with the untreated control, with the high rates delaying regrowth longer than the low rates applied. There was a small, erratic response to increasing amounts of Roundup, but the kill obtained was unacceptable for all the rates evaluated.

TABLE 2

The mean percent foliar kill of sugarcane regrowth by Roundup treatments in various spray volumes with and without surfactants added

Trial no.	6	8	8	9	10	10	11	12		
DAT*	46	9	61	30	42	224	20	20		
Variety	NCo 376	NCo 376	NCo 376	NCo 291	NCo 376	NCo 376	N 12	NCo 376		
Treatment	ℓ/a	Spray Vol. ℓ/ha								
Roundup	4.0	75-115	84	—	—	—	77	96	—	—
Roundup	6.0		92	75	98	—	77	98	—	—
Roundup	8.0		93	62	96	—	87	100	—	—
Roundup	10.0		97	—	—	—	—	—	—	—
Roundup	4.0	116-170	—	—	—	—	—	—	68	—
Roundup	6.0		—	70	99	—	83	98	71	80
Roundup	8.0		—	86	100	—	89	99	74	—
Roundup	10.0		—	—	—	—	—	—	75	—
Roundup	4.0	171-340	—	—	—	92	65	97	70	—
Roundup	6.0		95	72	98	96	78	99	74	—
Roundup	8.0		97	75	99	97	88	100	75	—
Roundup	10.0		99	82	100	—	85	99	81	—
Roundup + Frigate (0.5% v/v)	4.0	171-340	—	—	—	—	—	—	71	—
Roundup + Frigate (0.5% v/v)	6.0		97	68	99	93	75	99	73	—
Roundup + Frigate (0.5% v/v)	8.0		—	82	99	—	87	100	80	—
Roundup + G3780A (0.5% v/v)	4.0	171-340	—	—	—	—	—	—	66	—
Roundup + G3780A (0.5% v/v)	6.0		—	82	99	—	—	—	76	80
Roundup + G3780A (0.5% v/v)	8.0		—	—	—	—	—	—	80	—

* DAT: days after treatment

TABLE 3

The mean percent regrowth of sugarcane treated with Roundup with and without the addition of Frigate or G3780A

Trail no.	5	6	3	7	2	8	4	10	11	12
DAT*	72	84	90	82	60	122	134	224	186	56
Variety	N55/ 805	NCo 376	NCo 376	NCo 293	N55/ 805	NCo 376	NCo 376	NCo 376	N 12	NCo 376
Date applied	6 Oct.	3 Nov.	4 Nov.	18 Nov.	30 Nov.	3 Jan.	6 Jan.	16 Jan.	7 Feb.	1 Mar.
Spray volume ℓ/ha	309	301	300	257	250	309	300	309	340	160
Treatment	ℓ/ha									
Roundup	3.0	—	—	—	—	—	12	—	—	—
Roundup	4.0	100	—	—	61	—	3	2	0	—
Roundup	6.0	60	6	15	42	20	0	0	0	0
Roundup	8.0	27	4	—	24	12	0	1	0	—
Roundup	10.0	4	3	5	25	—	0	0	0	—
Roundup + Frigate (0.5% v/v)	3.0	—	—	—	—	—	14	—	—	—
Roundup + Frigate (0.5% v/v)	4.0	59	—	—	68	—	8	0	—	—
Roundup + Frigate (0.5% v/v)	6.0	56	5	4	50	23	0	0	1	—
Roundup + Frigate (0.5% v/v)	8.0	41	—	2	33	—	1	0	0	—
Roundup + G3780A (0.5% v/v)	4.0	—	—	—	—	—	—	—	0	—
Roundup + G3780A (0.5% v/v)	6.0	—	—	—	—	0	—	—	0	0
Roundup + G3780A (0.5% v/v)	8.0	—	—	—	—	0	—	—	0	—

* DAT: days after treatment

TABLE 4

The mean percent regrowth of sugarcane treated with Roundup, with and without the addition of Frigate, at various spray volumes

			5	6	3	7	8	4	10	11	12
Trial no.			72	84	90	182	122	134	224	186	56
DAT*			N55/	NCo	NCo	NCo	NCo	NCo	NCo	N	NCo
Variety			805	376	376	293	376	376	376	12	376
Date applied			6 Oct.	3 Nov.	4 Nov.	18 Nov.	3 Jan.	6 Jan.	16 Jan.	7 Feb.	1 March
Treatment	ℓ/ha	Spray Vol. ℓ/ha									
Roundup	4.0	75-110	91	24	41	35	—	—	0	—	—
Roundup	6.0		100	17	7	22	0	—	0	—	—
Roundup	8.0		78	9	7	30	0	—	0	—	—
Roundup	10.0		25	2	15	13	—	—	—	—	—
Roundup	6.0	111-170	—	—	—	—	0	—	2	1	0
Roundup	8.0		—	—	—	—	0	—	0	1	—
Roundup	10.0		—	—	—	—	—	—	—	0	—
Roundup	4.0	171-340	100	—	—	61	—	3	2	0	—
Roundup	6.0		60	6	15	42	0	—	0	0	—
Roundup	8.0		27	4	—	24	0	1	0	1	—
Roundup	10.0		4	3	5	25	0	0	0	0	—
Roundup + Frigate (0.5% v/v)	4.0	75	—	—	30	—	—	—	—	—	—
Roundup + Frigate (0.5% v/v)	4.0	171-340	59	—	—	68	0	—	—	—	—
Roundup + Frigate (0.5% v/v)	6.0		56	5	4	50	0	—	0	0	—
Roundup + Frigate (0.5% v/v)	8.0		41	—	2	33	—	—	0	0	—

*DAT: days after treatment

TABLE 5

The mean percent regrowth of sugarcane (NCo 376) treated with Roundup prior to harvest

		Trial no.	13	18	14	16	17	15
DAT*		68	68	141	120	103	90	110
Date applied		18 Aug.	18 Aug.	13 May	2 Sept.	7 Sept.	10 Sept.	16 Sept.
Date harvested		—	—	20 June	—	19 Oct.	3 Oct.	—
Soil Texture		Sand	Sand	Clay	Sand	Sand	Clay	Clay
Treatment	ℓ/ha							
Roundup	6.0	33	—	53	—	52	60	
Roundup	8.0	15	51	58	—	34	80	
Roundup	10.0	17	78	36	45	22	60	
Roundup	12.0	—	59	39	35	32	85	
Roundup + Frigate (0.5% v/v)	6.0	—	—	—	—	—	70	
Roundup + Frigate (0.5% v/v)	8.0	—	—	50	—	—	63	

*DAT: days after treatment

TABLE 6

Analyses of juice samples from mature sugarcane treated pre-harvest with Roundup

Trial no. Variable		14*			17			18		
		Cane g/stalk	ers % cane	ers g/stalk	Cane g/stalk	ers % cane	ers g/stalk	Cane g/stalk	ers % cane	ers g/stalk
DAT†		0 11 27	0 11 27	0 11 27	0 14 21	0 14 21	0 14 21	0 13 27	0 13 27	84 13 27
Treatment	ℓ/ha									
Untreated control	0	412 381 367	10,9 10,4 9,7	45 40 36	723 677 608	11,5 11,2 11,9	83 76 72	655 759 782	12,7 13,4 13,4	84 101 102
Roundup	8,0	— — —	— — —	— — —	766 625 517	10,9 11,3 11,1	83 70 57	752 737 710	13,0 12,3 12,3	98 90 88
Roundup	10,0	435 367 340	11,0 9,7 9,0	48 35 31	777 719 573	10,9 10,6 10,9	85 77 62	742 747 772	12,6 12,3 12,4	93 92 95
Roundup	12,0	429 367 373	10,8 9,4 9,2	47 34 34	834 715 587	11,6 11,1 11,3	97 79 66	700 697 737	12,1 11,8 11,9	85 82 88

* Trial 14 severely droughted

† DAT: days after treatment

TABLE 7

The mean percent regrowth of sugarcane receiving split applications of roundup at 0,3 and 6 day intervals

Trial no. DAT		1		3	4	6
		120		90	134	84
Split (days)		3	6	0*	3	0*
Spray volume l/ha		300	300	300	300	105
Date applied (first)		28 Sept.	28 Sept.	4 Nov.	6 Jan.	3 Nov
Treatment	l/ha					
1. Split application						
Roundup	3,0 + 2,0	25	48	—	—	—
Roundup	2,2 + 4,4	11	27	—	9	—
Roundup	3,0 + 3,0	3	17	18	6	5
Roundup	4,2 + 2,0	11	12	28	2	—
Roundup	4,3 + 3,2	12	10	—	—	—
2. Single application						
Roundup	2,0	—	—	—	35	—
Roundup	4,0	—	—	—	3	24
Roundup	6,0	—	—	15	—	7
Roundup	8,0	6	—	—	1	9
Roundup	9,0	—	—	5	—	—
Roundup	10,0	2	—	—	0	2

* 1½-4 hr interval between treatments

Cane samples from the pre-harvest treatments were analysed for sucrose and the results are summarised in Table 6. There was no ripening effect due to the pre-harvest treatments and there appeared to be a deterioration in cane quality in Trials 14 and 17.

Stubble treatments

The application of Roundup to cane stubble immediately after the previous crop had been cut proved to be unreliable due to soil and trash covering the surface to be treated. Possible solutions to this problem were impractical, and the development of the technique was therefore terminated.

Split applications

The results of the split application trials are summarised in Table 7. Trial 1 indicated that a 6-day interval between Roundup applications was too long and initial applications of 3,0 l and less Roundup ha⁻¹ resulted in the most regrowth. In general, there was more regrowth when the split applications were applied at a 3-day interval than there was when a single application of 8 l Roundup ha⁻¹, the recommended rate for NCo 376, was used.

In Trial 4, where a 3-day interval was evaluated, the plots which received an initial application of 3,0 l Roundup ha⁻¹, ie 3,0 + 3,0 l ha⁻¹ and 2,2 + 4,4 l ha⁻¹, had more regrowth than the plots receiving a split application of 4,2 + 2,0 l Roundup ha⁻¹ and the single application of 4,0 l Roundup ha⁻¹.

In Trials 3 and 6, where the second application was made on the same day as the first application, there was no difference between the effects of the 3,0 + 3,0 l ha⁻¹ and the single 6,0 l ha⁻¹ application.

In Figure 1 the lowest rate of Roundup giving 10% or less regrowth in the various trials has been plotted against the time of year at which the application was made. The data show that high rates of Roundup were required to kill cane before December and that the variability was high. By contrast the applications made after December, until April, consistently indicated that rates as low as 4,0 l Roundup ha⁻¹ were sufficient to give acceptably low amounts of regrowth.

Discussion

The results obtained in the trials sprayed before December confirm the findings of Turner¹⁴ that 10,0 l Roundup ha⁻¹ is

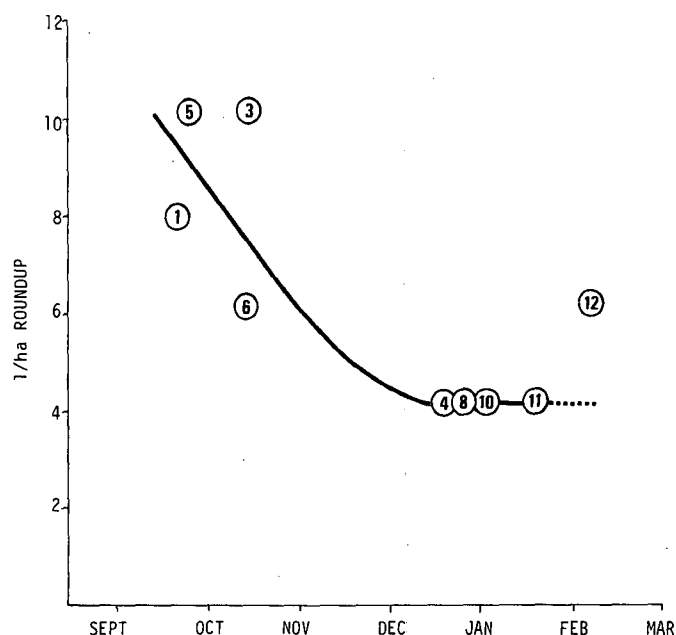


FIGURE 1 The relationship between rate of Roundup required to give 10% and less regrowth and month of the year.

the most effective rate for killing cane, and that the rate of Roundup is the most important factor affecting the kill. The data from trials sprayed after December indicate that 4,0 to 6,0 l Roundup ha⁻¹ is required to give consistently acceptable results from January to April. Surfactants, spray volumes and split applications, had a variable effect on the results of applications made before December and little or no effect on the applications made after December.

Surfactants

There is no evidence from Trials 5 and 7, which received rain within 6 to 8 hours after application of the chemical, to indicate that the rain-fastness of Roundup treatments was improved by the addition of Frigate.

In Trial 3, the addition of Frigate to the 6 l Roundup ha⁻¹ increased the efficacy of the treatment. This indicates that Frigate as an additive to Roundup is effective under a particular combination of climatic conditions and the stage of ratoon

growth in the period before December. There is no evidence to show that the addition of Frigate to Roundup treatments improves the efficacy of Roundup on varieties such as N55/805, which is difficult to kill.

Reduced spray volumes

The only trial in which there was a significant increase in efficacy of Roundup due to reduced spray volumes was in Trial 3. Since the concentration of the surfactant, which is part of the Roundup formulation, is higher in low spray volumes, the observed effect was probably a result of particular conditions under which the trial was conducted.

In Trials 5 and 6 spray volumes of 75 to 110 l ha⁻¹ were less effective than the higher volumes in the range 250 to 350 l water ha⁻¹. The reason for the reduced efficacy of the low spray volumes in these trials is probably inadequate cover of the foliage at a time of the season and at a growth stage of the crop when the rate required for effective kill is high. The low spray volume applications were sensitive to wind interference, particular when the row spacing was 1,2 m. Winds of 10 km h⁻¹ and more distort the spray distribution by blowing away the liquid at the extremities of the spray pattern. This interferes with a feature that has always been considered an essential part of Roundup application in minimum tillage in sugarcane, ie that the base of the rows adjacent to the target row are sprayed at the same time, ensuring coverage of the small shoots that are otherwise shaded by larger shoots.

Pre-harvest applications

The large amounts of regrowth observed in the pre-harvest treatments were unacceptable and evaluation of this application technique was terminated.

Stubble treatments

Stubble treatments were abandoned due to practical application problems.

Split applications

Where the two applications were made on the same day, or at a 3-day interval, the split applications were as effective as, or marginally better than the single application of the equivalent rate of Roundup. The results of split applications with a 6-day interval were unacceptable. On the estate where the technique was developed, split applications are used as a means of achieving complete cover in extremely difficult terrain. This estate also reduces the amounts applied as the season advances, with rates as high as 5,0 + 5,0 l ha⁻¹ early in the season, and then 4,0 + 4,0 l ha⁻¹, 3,0 + 3,0 l ha⁻¹, and finally 2,5 + 2,5 l ha⁻¹ as the season advances through the summer (Watt¹⁵). This is in line with the findings illustrated in Figure 1.

Good cover of all the foliage is an important factor in achieving a complete kill of the cane stool. It is essential that all the shoots in the stool receive glyphosate.

Theory

An explanation for the high rates of chemical required and variability of the data in trials established before December, and for the low rates required after December, could be that there is limited translocation of glyphosate in the cane plant. Observations made in many experiments have shown that this is likely to be so.

The implications are that if Roundup is applied before tillering is complete there will be buds and shoots below ground level that do not receive a direct dose of the chemical. Glyphosate will be taken up by the leaves of established shoots and translocated to the actively growing parts of the plant, but not necessarily to the basal buds which still have the capacity to germinate. The extent of the translocation of glyphosate into the base of the shoots probably depends upon the rate applied. If the glyphosate is not able to move into the base of the stalk,

then the part not reached will remain alive. The tops of established shoots will be killed, and because apical dominance has been removed, the germination of basal buds could even be stimulated.

Growth stage

Five growth stages of the ratooning cane stool up to the completion of tillering are proposed in Figure 2.

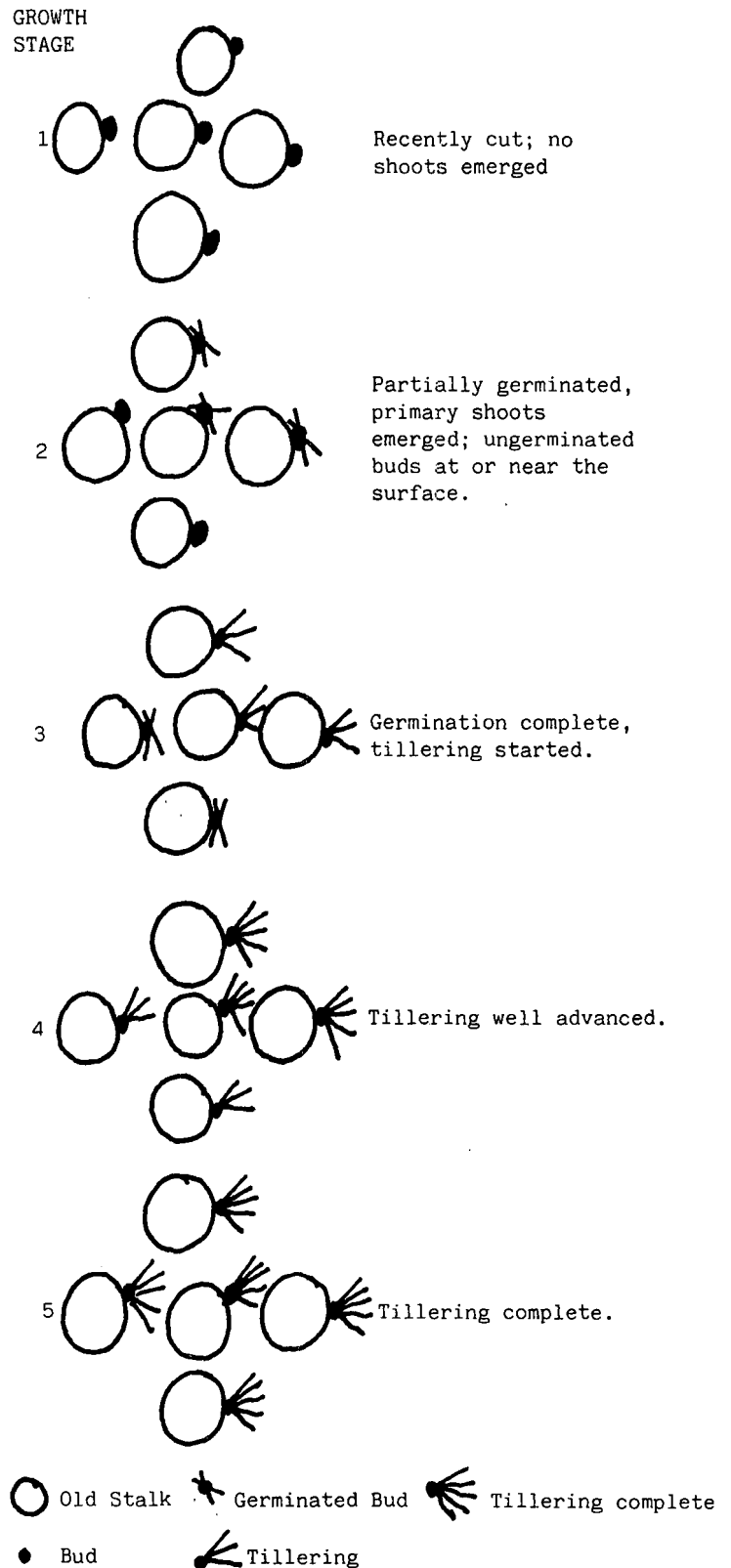


FIGURE 2 The growth stages of a ratooning sugarcane stool.

The rate of progress through the growth stages is influenced by climatic and soil conditions and varies with variety (Peng¹¹), eg N55/805 has the reputation of germinating unevenly and being slow to tiller. During winter, progress through the growth stages will be slow and uneven. In summer, progress will be faster and more even.

The five proposed growth stages and the implications for Roundup are discussed below.

Growth stage 1

Recently cut and most of the stalk buds ungerminated and below the soil surface. Roundup applied at this stage will have little or no effect.

Growth stage 2

A proportion of the buds germinated, with primary shoots and possibly secondary shoots emerged as tillering starts. Roundup applied at this stage will kill the exposed shoots. Some translocation of glyphosate into the base of the stool will take place. No uptake by or translocation of glyphosate to the stubble with ungerminated buds is possible. Roundup applied, even at high rates, will result in large amounts of regrowth. Surfactants will not increase the efficacy of Roundup at this stage.

Growth stage 3

Germination of buds completed and tillering well progressed. High rates of Roundup, eg 9 to 10 l ha⁻¹, are required to achieve less than 5% regrowth since translocation of glyphosate into basal buds that could still germinate is required. Frigate could improve the efficacy of a marginal rate of Roundup applied at this stage.

Growth stage 4

Tillering almost complete. Lower rates of Roundup, eg 6 to 8 l ha⁻¹, are required to achieve acceptable levels of control since there is only a small proportion of the basal buds that can still germinate. Frigate could improve the efficacy of a marginal rate of Roundup applied at this stage.

Growth stage 5

Tillering is completed. The live stool now consists of small plants, each shoot having its own leaf canopy. A low rate of Roundup, eg 4 to 6 l ha⁻¹, is required for an effective kill since only the established shoots need to be killed. Frigate and G3780A, could improve the efficacy of marginal rates of Roundup at this stage.

Most of the commercial applications on NCo 376 before December are probably made at growth stage 4, and a small proportion at growth stage 3. The recommended 8 l ha⁻¹ rate of Roundup is too low for applications at growth stage 3 and could explain regrowth encountered in early commercial applications.

N55/805, being slower to germinate and tiller, is probably always one growth stage behind NCo 376 in the period before December and so requires 10 l Roundup ha⁻¹ for control.

Because of the rapidity with which the cane stool progresses through the growth stages in summer under good growing conditions, it is likely that all the trials sprayed after December were at growth stage 5 and required lower rates of Roundup for an effective kill. Most commercial applications during this period are probably also made at growth stage 5.

Conclusions

Provided Roundup is used correctly, growth stage is the most important factor to consider when applying the chemical to ratoon cane regrowth.

The recommended rates of 8 to 10 l Roundup ha⁻¹ are correct for applications before December when it is difficult to judge accurately the growth stage of the cane. Lower rates of Roundup are indicated for applications in the period from December to April, provided the ratoon is at growth stage 5, ie completely tillered.

The reliability of the Roundup treatments can be improved by adding Frigate under certain circumstances.

Spray cover of the foliage can be improved by applying the Roundup in split applications, ie spraying the field twice on the same day, with half the required rate of Roundup at each application.

Spray volumes can be reduced to 75 l ha⁻¹ provided full cover of all the target foliage is obtained with the correct equipment under ideal conditions.

Pre-harvest applications of Roundup to mature cane are not successful. Post-harvest stubble treatments are impractical.

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