Proceedings of The South African Sugar Technologists' Association – June 1990

THE PHYTOTOXIC EFFECTS OF HERBICIDES ON SUGARCANE IN SOUTH AFRICA

P. E. T. Turner,* N. B. Leibbrandt* and L. H. G. Wiehe**

* *South African Sugar Association Experiment Station, Mount Edgecombe, 4300*
** *C. G. Smith, Sezela*

Abstract

Herbicides that are effective in their control of weeds are tested for possible phytotoxic effects on sugarcane at the South African Sugar Association Experiment Station. Many results have shown small effects on cane yield without necessarily reaching levels of statistical significance in individual experiments. The results of experiments conducted with standard treatments and other commonly used combinations of herbicides on variety NCo376 are summarized. Other factors such as the amount of chemical used per hectare and the method of spraying, and whether it was a plant or ratoon crop, were investigated at different sites for their effects on the development of the crop and reductions in yield. Relatively small differences were apparent in the average effects of these factors. However, the average reduction in yield from all post-emergence applications was 3% while no reduction in yield was apparent with pre-emergence applications.

Introduction

Early experiments with sugarcane confirmed the need to control weeds and the efficiency of herbicide treatments for their control (Gosnell[1]). Some herbicides have little effect on crop growth in comparison with the effects of competition from weeds (Gosnell and Thompson[2]). However, herbicides may cause some damage to sugarcane, so before they are registered the new chemicals are tested on sugarcane by the SA Sugar Association Experiment Station. Plots treated with the chemicals are compared with untreated control plots that are free of weeds and plots sprayed with standard treatments. The results have shown that the effects of standard treatments can vary from one experiment to another. In some trials statistically significant differences in cane yield have occurred while in others there may have been no differences (Turner[5]). Data from a number of trials have been summarized in this paper and the average effects of different treatments determined.

Materials and methods

Field trials were conducted using a randomised block design with six replications. Plots consisted of five or six cane rows each 8 m long with 1 m at each end being discarded at the time of harvest. The two outer rows were also discarded, leaving net plots of three or four rows each 6 m long.

Experiments were conducted on plant or ratoon cane at Pongola in the northern irrigated areas and at Shakaskraal and Mount Edgecombe on the Natal north coast. A floodjet was used to apply the chemicals in all the experiments. The output was approximately 300 ℓ/ha and the pressure was 100 to 200 KPa. Treatments were applied either over the cane row, as directed sprays across the interrow, or over the row before the cane germinated.

NCo376, which has been the variety most widely grown in the South African sugar industry, was used in all the experiments. All unsprayed control plots were kept free from weeds either by hand or by cultivating.

All treatments were compared with an unsprayed control and with a standard treatment. The standard treatments were diuron + ioxynil + 2,4-D or diuron + 2,4-D + surfactant for the post-emergence experiments and Lasso + atrazine for the pre-emergence experiments. The amounts of herbicides used were usually at the rates intended for registration (single rates) as well as double these rates. Results are given in terms of cane yield as a percentage of the yields from the untreated control plots or from the plots sprayed with the standard treatment. Results obtained with a selection of herbicide treatments have been assessed.

Data obtained when using standard post-emergence herbicides have been selected to examine the factors that might possibly reduce yields because many results are available. However, no experiments were designed specifically to study these factors. Details of the chemicals and the rates used in the experiments are given in Appendix 1.

Results and discussion

Standard treatments

Diuron + ioxynil + 2,4-D or diuron + 2,4-D + surfactant: An average reduction in yield of 6% was obtained from all applications of this mixture (Table 1). The average effects of the rates of application, method of spraying, crop stage, and site are given in Table 2.

Rates:

The average reduction in yield from the use of double rates was 2% more than from the use of single rates. This relatively small increase in damage with a 100% increase in the amount of chemical used confirms previous work done by Richardson[4] with 2,4-D. This effect was more pronounced at Shakaskraal than at Pongola, especially in ratoon cane.

Spray method:

The average increase in yield from directed sprays compared with sprays applied onto the cane row was 3%. This was shown by Richardson[4] to be dependent on the growth stage of the cane when 2,4-D was applied. The mean height of the leaf canopy at the time of spraying was 400 mm in the experiments conducted at the SASA Experiment Station, and this small difference of 3% supports the previous findings. Richardson[4] suggested when the leaf canopy is higher than 500 mm, the crop is likely to be more affected by applications over the row than by those directed between the rows. Cane in which the height of the leaf canopy is 500 mm or less, is likely to be more affected by directed sprays. Damage from these treatments therefore appears to be related to the amount of foliar coverage rather than to the method of spraying.

Table 1

Yields of cane treated with diuron + ioxynil + 2,4-D or diuron + 2,4-D + surfactant expressed as a percentage of those from unsprayed control plots

Sites	Crop	Single Rates		Double Rates		Mean
		Directed	Over the row	Directed	Over the row	
Pongola	Plant	98(2)*	94(1)	93(1)	96(3)	95(5)
Pongola	Ratoon		94(8)		93(7)	94(17)
Shakaskraal	Plant		100(1)		100(3)	100(4)
Shakaskraal	Ratoon		92(1)	92(1)	88(5)	89(7)
Mean	-	98(2)	94(11)	93(2)	93(18)	94(33)

* Figure in brackets denote the number of results

Table 2

A comparison of rates of application, spray methods, crops and sites on cane yields expressed as a percentage of unsprayed control plots after treatment with diuron + ioxynil + 2,4-D or diuron + 2,4-D + surfactant

Factor	Treatment	% Control	No of results
Rates	Single	95	13
	Double	93	20
Spray method	Directed	96	4
	Over the row	93	29
Crop	Plant	97	9
	Ratoon	93	24
Site	Pongola	94	22
	Shakaskraal	93	11

Crop stage:

Plant cane appeared to be less affected than ratoon cane by these treatments (4% difference). No experiments were specifically designed to assess this difference and these results do not support those of Richardson,[4] who found that plant cane was slightly more sensitive than ratoon cane. An explanation for the lesser effect in plant cane could be the lower population of shoots in plant cane than in ratoon cane at the same growth stage. Thus, fewer shoots in the plant cane would have come into contact with the chemical. The age at harvest could also affect these results because a plant crop is usually harvested at an older age than ratoon cane, and would therefore have had the benefits of a longer period for growth.

Site:

There was very little difference between the average effects at the Pongola and Shakaskraal sites. However, the differences between plant and ratoon cane were greater at Shakaskraal than at Pongola. Ratoon cane at Shakaskraal appeared to be more severely affected (5% greater reduction) than the ratoon cane at Pongola. The soils and climate differ markedly between the two sites and this could affect the growing conditions.

Other factors:

Numerous other factors could affect the yield. The growth stage of cane at the time of spraying, weather conditions, age at harvest, soil type, and varietal sensitivity, could also influence the phytotoxic effects of herbicides. Examination of the current data has not been exhaustive and no one factor is obviously responsible.

Lasso + atrazine: (See Table 3)

When Lasso + atrazine was used at single rates, an average increase in yield of 3,5% was obtained. This result could reflect the effect of limited weed competition in the untreated plots, which could not be weeded before the weeds had emerged, and/or damage to the young crop by weeders. The average reduction in yield from use of double rates of the mixture was 1%. Phytotoxic effects were not noticeable in these experiments.

Some commonly used combinations

Dual + ametryne + S (Dopax + S): (See Table 4)

Pre-emergence applications of Dual + ametryne + S have shown no evidence of reductions in yield at the rates used in these experiments while post-emergence applications produced yields which were on average 98% of the yields obtained from the untreated control plots, and 102% of the yields obtained from the standard post-emergence treatment. When rates were doubled the effects were more damaging than those for single rates, i.e. an average of 96% of the yields from the untreated plot compared with 101% for the yields from plots sprayed with single rates.

Table 3

Yields of cane treated with Lasso + atrazine expressed as a percentage of those from unsprayed control plots

Timing	Site	Crop	Single rate	Double rate	Mean
			% control	% control	% control
Pre-	Pongola	Plant	103(2)*	99(5)	100(7)
Pre-	Shakaskraal	Plant	104(1)		104(1)
Post	Pongola	Ratoon	104(1)**		104(1)
Pre-emergence mean			103(3)	99(5)	100(8)

* Figures in brackets denote number of results
** Directed interrow

Table 4

Yields of cane treated with Dual + ametryne expressed as a percentage of those from unsprayed control plots and plots treated with a standard treatment

Timing	Site	Crop	Over the row application				Means	
			Single rate		Double rate			
			% control	% standard	% control	% standard	% control	% standard
Pre-	Pongola	Plant	100(2)*		105(1)		102(3)	
Post	Pongola	Plant	102(1)	103(1)**	98(1)	98(1)**	100(2)	100(5)
Post	Pongola	Ratoon	99(1)	103(1)	97(1)	101(1)**	98(2)	102(2)
Post	Shakaskraal	Ratoon			92(1)	112(1)**	92(1)	112(1)
Post-emergence mean			101(2)	103(2)	96(3)	104(3)	98(5)	102(8)

* Figures in brackets denote number of results
** % figure obtained by comparing with double standard i.e. double rate of diuron + ioxynil + 2,4-D

Dual + ametryne + paraquat: (see Table 5)

The results obtained from the two pre-emergence treatments suggest that no damage was caused by using the single rates, but when the rates were doubled there was an apparent reduction in yield of 7% in one experiment. However, the combination without paraquat, (which is not active in the soil) (Table 4), showed no effects when applied as a pre-emergence herbicide. Hence phytotoxicity due to the inclusion of paraquat seems doubtful.

Post-emergence applications caused yield reductions when used at both single and double rates, applied as directed sprays or over the cane row (mean yield reduction 5%). The effects of the application of double rates were similar to those of single rates except at Shakaskraal where a double rate applied over the cane row of ratoon cane caused a larger reduction in yield (27%). This treatment was generally more severe than the standard diuron + ioxynil + 2,4-D treatment. Paraquat is known to scorch any green areas of the plant that come into contact with the spray but recovery does occur. (Gosnell and Thompson[3]). Thus the stage of cane growth is likely to have a marked effect on possible yield reductions from this treatment, and applications in plant cane at the spike stage of growth are not likely to have any effect on yield. Applications in ratoon cane are not normally recommended, because when weeds are at the correct stage to spray, the proportion of green foliage is often high. This was seen when paraquat was applied to ratoon cane at Shakaskraal, but did not occur in the experiments conducted at Pongola.

Diuron + Sencor: (See Table 6)

In one experiment, a yield reduction of 4% was observed from a pre-emergence application of diuron + Sencor. This result was not expected and further research is needed before conclusions can be drawn. Post-emergence applications in 13 experiments at Pongola showed an average yield reduction of 2%, while the single experiment at Shakaskraal showed no effect. There appeared to be little difference between the effects of single and double rates.

Velpar + diuron: (See Table 7)

An average yield reduction of 4% was caused by this mixture and the effects of double rates appeared to be more harmful than those of single rates (7 and 3% respectively).

Bladex Plus + S: (See Table 8)

The average yields from 16 comparisons were 105% of the yields obtained from untreated control plots and from plots given the standard treatment. Treatments were applied at Shakaskraal and Pongola and included single and double rates, applied either as directed sprays or over the cane row in plant and ratoon cane. The yields from this treatment were never less than those obtained from the unsprayed control plots.

Table 5

Yields of cane treated with Dual + ametryne + paraquat expressed as a percentage of those from unsprayed control plots and plots treated with a standard treatment

Timing	Site	Crop	Single rate				Double rate			Means	
			Directed		Over the row		Directed	Over the row			
			% control	% standard	% control	% standard	% control	% control	% standard	% control	% standard
Pre-	Pongola	Plant	105(1)*				93(1)			99(2)	
Post	Pongola	Plant			97(1)	98(1)***		97(1)	98(1)***	97(2)	98(2)
Post	Pongola	Ratoon	98(1)	95(1)				98(1)	101(1)***	98(5)	98(2)
Post	Shakaskraal	Plant			98(1)			97(4)	97(4)***	97(2)	97(4)
Post	Shakaskraal	Ratoon						73(1)**	89(1)	73(1)	89(1)
Post-emergence mean			98(1)	95(1)	98(2)	98(1)	93(1)	94(7)	97(7)	95(10)	97(9)

* Figures in brackets denote number of results
** All treatments present in this trial depressed yields compared with the unsprayed control
*** Expressed as a % of double rate of standard treatment

Table 6

Yields of cane treated with diuron + Sencor expressed as a percentage of those from unsprayed control plots and plots treated with a standard treatment

			Single rate		Double rate			Means	
			Over the row		Directed	Over the row			
Timing	Site	Crop	% control	% standard	% control	% control	% standard	% control	% standard
Pre-	Pongola	Plant			96(1)			96(1)	
Post	Pongola	Plant	97(2)*		99(1)	97(2)		97(5)	
Post	Pongola	Ratoon	96(4)	104(3)		100(4)	108(1)	98(8)	105(4)
Post	Shakaskraal	Ratoon			105(1)	104(1)		105(2)	
Post-emergence mean			96(6)	104(3)	102(2)	100(7)	108(1)	99(15)	105(4)

* Figures in brackets denote number of results

Table 7

Yields of cane treated with Velpar + diuron expressed as a percentage of those from unsprayed control plots and plots treated with a standard treatment

			Rates applied over the row				Means	
			Single		Double			
Timing	Site	Crop	% control	% standard	% control	% standard	% control	% standard
Post	Pongola	Ratoon	97(8)*	101(8)	93(3)**	101(3)	96(11)	101(11)
	Shakaskraal	Ratoon	97(1)	93(1)			97(1)	93(1)
Mean			97(9)	100(9)	93(3)	101(3)	96(12)	100(12)

* Figures in brackets denote number of results
** The three treatments included the following combinations:
Velpar + diuron (1,35 + 1,01 ai/ha)
Velpar + diuron (1,80 + 1,01 ai/ha)
Velpar + diuron (0,90 + 1,61 ai/ha)

Table 8

Yields of cane treated with Bladex Plus + surfactant expressed as a percentage of those from unsprayed control plots and plots treated with a standard treatment

			Single rate			Double rate		Means	
			Directed	Over the row		Over the row			
Timing	Site	Crop	% control	% control	% standard	% control	% standard	% control	% standard
Pre-	Pongola	Plant	103(2)*	102(2)				103(4)	
Post	Pongola	Plant			106(3)	109(1)	110(1)**	109(1)	107(4)
Post	Pongola	Ratoon	111(2)	103(3)	102(4)	101(1)	105(1)**	105(6)	103(5)
Post	Shakaskraal	Ratoon			104(1)			104(1)	
Post-emergence mean			111(2)	103(5)	104(8)	105(2)	108(2)	105(12)	105(9)

* Figures in brackets denote number of results
** Standard treatment = double rate of diuron + ioxynil + 2,4-D

Bimate + S: (See Table 9 and 10)

No reduction in yield occurred when Bimate was applied as a pre-emergence herbicide to plant cane. However, post-emergence applications produced on average a 3% reduction in yield. Double rates were more severe than the single rates (7% and 1% reduction in yield respectively) and cane grown in the lighter soils at Shakaskraal was more affected (8% average reduction in yield) than the cane growing in heavier soils. Directed sprays appeared to be more damaging than those applied over the cane, but these treatments were not compared in the same experiment. Applications were usually made when the leaf canopy was 350 mm high. It is possible that a greater amount of chemical could contact the cane with a directed spray, due to the spray pattern from a floodjet nozzle. In four experiments where Bimate and the standard treatments were directly compared, (i.e. at the equivalent rates, and the same method of application) Bimate resulted in an average reduction in yield of 0,5%.

Table 9

Yields of cane treated with Bimate applied pre-emergence expressed as a percent of those from unsprayed control plots and plots treated with a standard treatment

Site	Crop	Over the row			Mean	
		Standard rate	Double rate		All rates	
		% control	% control	% standard	% control	% standard
Pongola	Plant	98(1)*	98(1)	100(1)	98(2)	100(1)
Shakaskraal	Plant	107(1)	111(1)	100(1)	104(2)	100(1)
Mt Edgecombe	Plant	100(1)	101(1)		101(2)	
Mean		102(3)	103(3)	100(2)	103(6)	100(2)

* Figures in brackets denote number of results

Table 10

Yields of cane treated with Bimate + surfactant applied post-emergence expressed as a percentage of those from unsprayed control plots and plots treated with a standard treatment

Site	Crop	Standard rate			Double rate			All rates	
		Directed	Over the row		Directed	Over the row		Mean	
		% control	% control	% standard	% control	% control	% standard	% control	% standard
Pongola	Ratoon		99(4)	104(2)				99(4)	104(2)
Shakaskraal	Plant		96(2)	96(1)				96(2)	96(1)
Shakaskraal	Ratoon		98(1)			83(1)	94(1)	83(1)	94(1)
Mt Edgecombe	Ratoon	97(1)*	102(1)		96(1)	98(1)		98(4)	
Mean		97(1)	99(8)	101(3)	96(1)	91(2)	94(1)	97(11)	100(4)

Table 11

Yields of cane treated with diuron + paraquat expressed as a percentage of those from unsprayed control plots and plots treated with a standard treatment

Site	Crop	Standard rate			Double rate		Mean	
		Directed	Over the row		Over the row			
		% control	% control	% standard	% control	% standard	% control	% standard
Pongola	Ratoon		93(7)*	100(7)	93(1)	112(1)	93(8)	102(8)
Shakaskraal	Ratoon	82(1)	78(1)**				80(2)	
Mean		82(1)	91(8)	100(7)	93(1)	112(1)	90(10)	102(8)

* Figures in brackets denote number of results
** Surfactant added at 2 l/ha

Diuron + paraquat: (See Table 11)

The average reduction in yield from applications of diuron + paraquat was 10% (10 trials). Most applications were made over the cane row at the recommended rate when the height of the leaf canopy was approximately 500 mm. This treatment is used when plant or ratoon cane is severely smothered by weeds. When the leaf canopy is about to close the mixture is directed onto the interrow as a "spot spray" treatment. In the directed sprays applied to the interrow in older cane where the leaf canopy was 850 mm in height, the nozzle was held well away from upper foliage but the chemical still penetrated the base of cane rows. This treatment unexpectedly reduced yields at Shakaskraal. Applications over the row at Shakaskraal had similar effects in another experiment. Insufficient data are available to be conclusive about the increased severity that was observed on cane grown at the Shakaskraal field station.

In an experiment carried out at Pongola where the cane was planted, sprayed and harvested at different times of the year, the crop was sprayed with standard rates over the cane rows (see Table 12). It appeared that the damage to cane sprayed in winter was greater than damage to cane that had been sprayed in summer. This effect was complicated by the growth stage of the cane because when the height of the leaf canopy was 400 mm or less, the cane was not affected.

Table 12

Seasonal experiment at Pongola

Treatments	Yield as % of control					
	Jan	Mar	Apr	Jun	Sep	Nov
Canopy height at spray (mm)	575	400	430	500	500	400
Diuron + Actril DS	97	105	102	96	87*	97
Diuron + paraquat	90	104	89*	89*	96	100

* differences in yields of cane reached a level of statistical significance (P = 0,05)

Table 13

Yields of cane treated with diuron + MSMA expressed as a percentage of those from unsprayed control plots and plots treated with a standard treatment

Site	Crop	Over the row				Directed				Mean	
		Single rates		Double rates		Single rates		Double rates			
		% control	% standard	% control	% standard	% control	% standard	% control	% standard	% control	% standard
Pongola	Ratoon			99(4)*	106(4)	101(1)	105(1)	94(1)	98(1)	99(6)	105(6)
Shakaskraal	Ratoon	104(1)	108(1)	96(2)	106(1)					99(3)	107(2)
Mean		104(1)	108(1)	98(6)	106(5)	101(1)	105(1)	94(1)	98(1)	99(9)	106(8)

* Figures in bracket denotes number of results

Table 14

Yields of cane treated with MSMA expressed as a percentage of those from unsprayed control plots and plots treated with a standard treatment

Site	Crop	Over the row				Mean	
		Single rate		Double rate			
		% control	% standard	% control	% standard	% control	% standard
Pongola	Ratoon	102(1)	105(1)	92(1)	92(1)	97(2)	99(2)
Shakaskraal	Plant	97(1)*	97(1)			97(1)	97(1)
Shakaskraal	Ratoon	90(1)	96(1)	94(1)	105(1)	92(2)	101(2)
Mean		96(3)	99(3)	93(2)	99(2)	95(5)	99(5)

* Figures in brackets denote number of results

Diuron + MSMA: (See Table 13)

All the experiments carried out to test the effects of this combination on cane growth, were done with the mixture at double the recommended rates or more, and it was applied over the cane row. The mixture is used primarily for the control of tillered grasses and it is therefore often necessary to apply it over the cane until a canopy is formed. It was therefore appropriate to investigate the effects on this stage of crop growth.

The results suggested that an average yield reduction of 1% could be expected, but that this mixture would be less damaging than the standard treatments. Investigations into the use of this treatment in plant cane are still required.

Table 15

Yields of cane from all treatments expressed as a percentage of those from unsprayed control plots

Treatments	Post emergence	Pre emergence
Diuron + ioxynil + 2,4-D/2,4-D + S	94*(33)	–
Lasso + atrazine	104 (1)	100 (8)
Dual + ametryne + S	98 (5)	102 (3)
Dual + ametryne + paraquat	95 (10)	99 (2)
Diuron + Sencor	99 (15)	96 (1)
Velpar + diuron	96 (12)	–
Bladex Plus + S	105 (12)	103 (4)
Bimate + S	97 (11)	103 (6)
Diuron + paraquat	90 (10)	–
Diuron + MSMA	99 (9)	–
MSMA	95 (5)	–
Mean	97 (123)	101 (24)

* Figures in brackets denote number of results

MSMA: (See Table 14)

MSMA applied on its own at single and double rates has reduced yields of plant and ratoon cane by an average of 3% and 5% respectively. On average these yields were 1% less than those of the standard treatments.

Conclusions

The average reduction in yield, based on results of 123 post-emergence applications to cane, was 3%. Results of 24 pre-emergence applications gave an average yield which was 101% of unsprayed plots. These results provide a useful guide to the effects of herbicide treatments on sugarcane crops, although they include some treatments applied over the cane rows at double rates and on cane at a late stage of growth. The summary of comparisons between methods of spraying, the amount of chemical used per hectare, plant and ratoon crops, and different experiment sites showed that these factors caused relatively small reductions in yield in comparison with the standard treatments. However, it appears that single rates applied away from the cane foliage are likely to cause less damage. The stage of growth of cane at the time of spraying is also likely to be an important factor in determining the extent of reductions in cane yield, but this factor needs to be studied further to eliminate the possible effects of the age of the crop at the time of harvest and the weather conditions at the time of spraying. From the available data there does not seem to be a relationship between the stage of cane growth when it is sprayed and the effect on yield.

REFERENCES

1. Gosnell, JM (1965). Herbicide trials in Natal sugarcane, 1964-65. *Proc S Afr Sug Technol Ass* 39: 171-181.
2. Gosnell, JM and Thompson, GD (1964). The results of herbicide trials 1963-64. *Proc S Afr Sug Technol Ass* 38: 166-174.
3. Gosnell, JM and Thompson, GD (1965). The effects of paraquat on the growth and yield of sugarcane. *Proc Int Soc Sug Cane Technol* 25: 493-500.
4. Richardson, FE (1972). Critical growth stages for 2,4-D phytotoxicity to sugarcane in South Africa. *Proc S Afr Sug Technol Ass* 46: 168-176.
5. Turner, PET (1981). The effects of post-emergence herbicide treatments on sugarcane in South Africa. *Proc S Afr Sug Technol Ass* 55: 99-105.

APPENDIX 1

Chemicals and rates used in the experiments

Treatments	Rates (kg or l ai/ha)	
	Single	Double
Diuron + ioxynil + 2,4-D/2,4-D + S	2,0 + 0,875-1,4	4,0 + 1,75-2,88
*Lasso **(alachlor) + atrazine	1,92-2,304 + 1,0-1,5	3,84 + 3,0
Dual (metolachlor) + ametryne + S	1,98-2,0 + 2,0-3,0	4,0 + 6,0
Dual + ametryne + paraquat	2,0 + 1,0 + 0,2	4,0 + 2,0 + 0,4
Diuron + Sencor (metribuzin)	1,6 + 1,4	3,2 + 2,8
Velpar (hexazinone) + diuron	0,675 + 1,0	0,675-1,8 + 1,0-1,6
Bladex Plus + S (cyanazine + atrazine)	2,0 – 6,0	9,0
Bimate (diuron + tebuthiuron) + S	3,0 – 3,75	7,5
Diuron + paraquat	1,6 + 0,4-0,5	3,2 + 1,0
Diuron + MSMA	4,68 + 2,0	4,68-9,36 + 4,0-4,8
MSMA	4,32	8,64

* Trade names
** Common chemical names in brackets