EFFECTS ON SUGARCANE YIELDS OF REPEATED ANNUAL APPLICATIONS OF SOME STANDARD HERBICIDES USED IN THE SOUTH AFRICAN SUGAR INDUSTRY

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Sugarcane growers often only use a few selected herbicides, re-applied annually to the same fields. The long-term effects from repetitive herbicide treatments on cane growth are a cause for concern, particularly where soil residual products are used.To address these concerns, long-term field trials were initiated in 1992 on both rainfed and irrigated sites. Soils in the trials contained between 21 and 46% clay and five crops were harvested from each. Due to their wide-spread use, Velpar (hexazinone 240g a.i./l or 750g a.i./kg), Sencor (metribuzin 480g a.i/l) and Diuron 800 SC (diuron 800g a.i/l) were selected for investigation. They were applied to sugarcane annually, both in combinations and in some cases as single product treatments. Initial applications were made as pre-emergence treatments over the cane rows, and in subsequent ratoons as post-emergence treatments. In later ratoons, inter-row treatments were also applied.

One trial conducted under irrigation produced yield losses that were statistically significant for both standard rates of Sencor + Diuron and Velpar + Diuron in one crop only. The speculated detrimental effects from repetitive use of herbicides was not validated by these trials. Yield suppression trends for all treatments correlated well with plant growth stage at spraying and with potential crop yield, as phytotoxicity increased in severity where treatments were applied late or to crops with a high yield potential. Velpar was found to produce similar levels of cane damage irrespective of site of placement, and appeared more phytotoxic in the presence of water soon after spraying. Sencor was safer when directed into the interrow and phytotoxicity levels did not appear to be associated with available water. The results suggest that both metribuzin and hexazinone are responsible when yield losses occur from mixtures with diuron, but that neither are unduly harmful to sugarcane when used at recommended rates.

Keywords: hexazinone, metribuzin, phytotoxicity, sugarcane

Introduction

Long-term herbicides play a crucial role in weed control programmes in the South African sugar industry. With correct use, certain herbicides have potential to significantly increase cane yield by reducing weed competition for long periods. Early research conducted by Gosnell and Thompson[3] showed that even highly phytotoxic short-term products such as Gramoxone (paraquat 200g a.i/l) used at high concentrations, can still increase cane yields due to the control of weeds. Herbicides such as Velpar (hexazinone) and Sencor (metribuzine) are two long-term products that are used extensively in the industry. Both are triazines that inhibit photosynthesis by interfering with light dependant processes mainly in plant chloroplasts. The half life of metribuzin is between 30 and 60 days while hexazinone has a half life that can be as long as 180 days. The solubility of hexazinone is high at 33,000 ppm., while that of metribuzin is 1200 ppm. The plant uptake of metribuzin is mainly by roots with upward translocation via the xylem vessels. There is little or no downward movement of this product in the plant. Hexazinone is readily absorbed by both roots and foliage but translocation is primarily upwards via the xylem. This product has more contact activity than metribuzin (Anon[1]).

Velpar has been tested in South African Sugar Association Experiment Station sugarcane phytotoxicity trials since 1975, where the product was used alone or in combination with diuron. Turner *et al.*[5], (1990) summarised results from numerous field phytotoxicity trials and showed single applications of Velpar + Diuron to reduce yields by an average of 4%., while Sencor + Diuron produced a 2% loss of yield. The average reduction for all post-emergence herbicide treatments was only 3%. Although applications were made over the cane foliage, yield reductions from Velpar or Velpar + Diuron at standard rates reached statistically significant levels in only two out of eleven field trials (1990 results updated from [1]unpublished data).

The use of Velpar has grown to such an extent that it is now one of the most widely used herbicides in the industry. Approximately 160 tons of Velpar DF was sold into the South African sugar industry during the 1997/1998 season (Cackett, personal communication). Velpar was registered for use on sugarcane in South Africa in 1979, and Sencor in 1973 (Bromilow, personal communication). It is therefore-possible that certain fields in the industry may have been treated with these products regularly for up to 26 years. This practice has raised the question of possible accumulated phytotoxic effects from continuous exposure of sugarcane to

[1] NB Leibbrandt, Agronomy Deparment, SASEX, Mt Edgecombe.
[3] South Africa Sugar Association Experiment Station – Senior certificate course notes.

these products. This would be difficult to determine in field situations as large areas would be similarly affected making comparisons impossible. For this reason, field trials were initiated in 1992 and 1993 in an attempt to answer this question.

- The primary objective of this paper is to determine whether repeated annual applications of the same herbicides have an accumulative effect on cane yield.
- Secondary objectives include the identification of other factors that may influence herbicide effects on cane yields in any one season. These include growth stage of cane at spraying, water availability and the crop's yield potential. Herbicides were considered as a possible contributing factor to falling soil pH levels in the industry (Meyer, personal communication). This was investigated in one trial.

Methods

Four trials were established on soils of the Longlands (8% clay), Westleigh (21% clay), Rensburg (36% clay) and Hutton (>40% clay) forms. The results from the trial on the Longlands form had to be abandoned after one crop due to unacceptable cane growth variability. The trial on the Hutton form soil was under irrigation in the lowveld, while the remainder were rainfed and situated on the KwaZulu-Natal north coast. NCo376 as plant cane (two trials) and first ratoon (one trial) was the variety used, and five crops were harvested from each site. Details for each trial are given in Table 1 below.

Gross trial plots included six cane lines ten meters long, with net plots comprising four lines eight meters long. A one meter break was left between the ends of gross plots.

Spraying was carried out using a South African Sugar Association Experiment Station built battery driven knapsack or a Matabi Super Agro 16 lever operated knapsack. These systems were either fitted with an APM (green) or Lurmak AN (4.0) floodjet nozzle. Knapsacks were set at one bar to deliver between ± 200 and 250L of spray mixture per hectare.

The liquid formulation of Velpar (hexazinone 240g a.i/L) was used in the first three crops of each trial, but was replaced with a dry flowable (DF) hexazinone (750g a.i/kg) formulation in the following two ratoons. Only suspension concentrate formulations (SC) of Sencor (metribuzine 480g a.i/L) and Diuron 800 SC (diuron 800g a.i/L) were used in the programme. All three trials contained treatments that were applied directly over the cane line every season, while interrow applied applications were introduced as extra treatments after a few years. Velpar and Sencor were used in mixtures with Diuron, while both Velpar and Diuron were also included as single product treatments. Standard Velpar rates ranged from 600 to 728g a.i/ha., Diuron between 1 200 and 1 600g a.i/ha., while Sencor remained constant at 1 440g a.i/ha. Velpar + Diuron was also included at double rates. An important point to note is that the Velpar rates used were in excess of those recommended in two trials on summer cutting cycles (Trials 1 and 3). Velpar rates for Trial 1 in particular were very high, being up to 60% more than currently recommended for these conditions. To investigate the effects of herbicides on soil pH., sampling was done on a plot by plot basis in Trial 2 (Category 2 soil).

The cane growth stage at spraying ranged between pre - emergence and 70cm to the uppermost leaf bend. Stalk populations and height measurements (to top visible dewlap) were carried out regularly during the crop cycle. At approximately twelve months of age, the cane was cut by hand, weighed and sampled for quality evaluation.

Analysis of variance with restricted maximum likelihood (REML/ANOVA) analysis was done to find significant differences for treatments (Anon[2]). Only results within a crop were compared with the corresponding control group.

Cane yield difference (Y′), expressed as a percentage of the potential yield (Y_c), was calculated as the relative difference between the control and the sprayed treatment (Y_t):

$$Y' = \frac{Y_t - Y_c}{Y_c} \times 100$$

Trends between cane yield differences (Y′) and other parameters were investigated by fitting a 1[st] order polynomial curve using a least square method:

$$Y' = \alpha \pm \varepsilon_\alpha + (b \pm \varepsilon_b)x$$

where x is the investigated dependancy (eg. cane height at spray), $\alpha \pm \varepsilon_\alpha$ is the 95% confidence interval of the intercept, the slope (b) was considered statistically significant if the 95% confidence interval, $[b-\varepsilon_b, b+\varepsilon_b]$ did not include null.

Results

Cane and sucrose yields

Trial 1 at La Mercy(dryland on a Westleigh soil form – 21% clay)

Five crops from the first to the fifth ratoon were harvested in

Table 1. Trial information.

Trial No.	Location	Soil Clay %	Cycle	Treatment	Range of rates used L or kg product/ha	Year trial established / re-established						
						1992	1993	1994	1995	1996	1997	1998
1	La Mercy	21	Summer	Sencor + Diuron Velpar + Diuron Velpar + Diuron	3,0L + 2,0L (3,0L + 2,0L) – (0,8kg + 1,5L) (6,0L + 4,0L) – (1,6kg + 3,0L)		Ratoon 1		Ratoon 2	Ratoon 3	Ratoon 4	Ratoon 5
2	Mt Edgecombe	36	Winter	Sencor + Diuron Velpar + Diuron Velpar + Diuron	3,0L + 2,0L (3,0L + 2,0L) – (0,97kg + 2,0L) (6,0L + 4,0L) – (1,93kg + 4,0L)	Plant		Ratoon 1	Ratoon 2	Ratoon 3	Ratoon 4	
3	Pongola	46	Summer	Sencor + Diuron Velpar + Diuron Velpar + Diuron	3,0L + 2,0L (2,5L + 1,5L) – (0,8kg + 1,5L) (5,0L + 3,0L) – (1,6kg + 3,0L)		Plant	Ratoon 1	Ratoon 2	Ratoon 3	Ratoon 4	

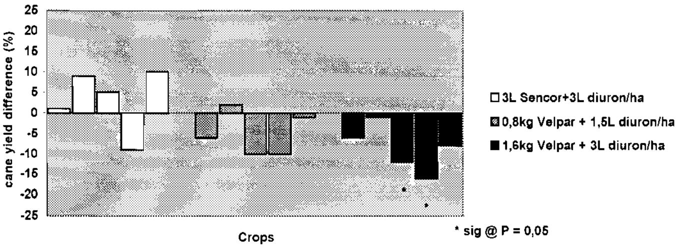

Figure 1. Treatment effects on first to fifth ratoon cane yield, expressed as percentage of unsprayed control – Trial 1.

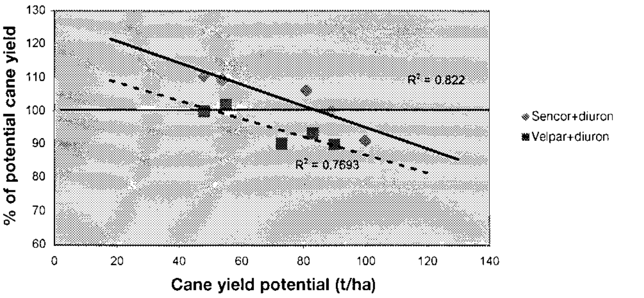

Figure 2. Influence on herbicide treatment by cane yield potential – Trial 1.

November each season. All treatments were applied at the post-emergence stage of cane growth. In addition to the on-row repeated treatments, interrow applications of the standard Sencor + Diuron and Velpar + Diuron mixtures were introduced in the fourth and fifth ratoon crops. Velpar rates used ranged from 0,80kg/ha to 0,96kg of product per hectare which is notably higher than the 0,60kg to 0,70kg of product recommended for mid-season spraying on these soils ([2]unpublished data).

Cane yield differences between the over row treatments and the non-sprayed control are shown in **Figure 1**. Losses only reached statistically significant levels for the double Velpar + diuron rate applied to the third and fourth ratoon crops. Sucrose yield reductions were statistically significant (P=0,05) for this treatment. Although **Figure 1** appears to show an apparent yield loss trend with advancing ratoon age for the two Velpar + Diuron treatments, these were statistically non-significant. There was however a significant negative correlation between cane yield potential of the crop, and yield reduction related to herbicide treatment **Figure 2.** Herbicide induced losses were higher on high yielding crops with the trends reaching statistical significance (P=0,05) for both Sencor + Diuron and standard Velpar + Diuron treatments. Statistical analysis showed that differences between the two trend lines were non-significant for both vertical placement and slope.

Trial 2 at Mt Edgecombe (dryland on a Rensburg soil form – 36% clay)

This trial was established on plant cane in 1992. The plant and four ratoon crops were all harvested on winter cycles. Spraying was carried out when the cane was at the pre-emergence stage of growth for the plant crop, and post-emergence for the subsequent ratoons. This trial included single product treatments of Diuron and Velpar applied at standard rates from the plant to the third ratoon. This was done to establish the responsible product in the event of yield suppression from mixtures.

Figure 3 shows the cane yield effects from the standard rates of Sencor + Diuron and Velpar + Diuron, as well as the double Velpar + Diuron rate applied over the rows. None of these treatments resulted in cane or sucrose yield suppression that approached statistical significance. The comparatively higher yields for herbicide treatments recorded in the fourth ratoon, may have resulted from excessive weed pressure in the handweeded control plots. Cane yields for the single product treatments applied over the rows are shown in **Figure 4**, where results for similar treatments applied under irrigated conditions in Trial 3 are included for comparison. Neither Velpar nor Diuron as repeated single product treatments resulted in significant changes to sugarcane yield under dryland conditions.

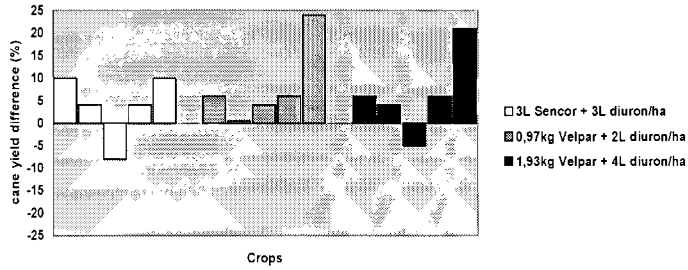

Figure 3. Treatment effects on plant to fourth ratoon cane yield, expressed as percentage of unsprayed control – Trial 2.

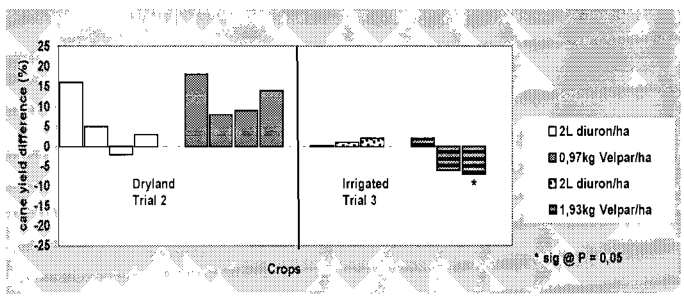

Figure 4. Treatment effects of diuron and Velpar on cane yield, expressed as percentage of unsprayed control – Trial 2 and Trial 3.

Trial 3 at Pongola (irrigated on a Hutton soil form – >40% clay)

Trial 3 was established on an irrigated plant crop at Pongola and included four ratoons. Spraying was carried out when the cane was pre-emergence for the plant crop, and post-emergence at various stages of growth in subsequent ratoons. **Figure 5** shows the harvest data for the five crops that were all cut on summer cycles. Both Sencor + Diuron and the recommended rates of Velpar + Diuron applied over the row, appear to have suppressed cane yield only from the

[2] Velpar label instructions

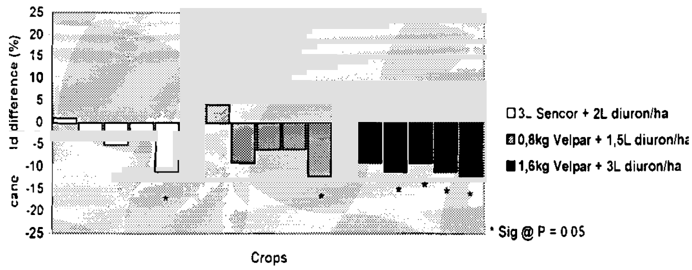

Figure 5. Treatment effects on plant to fourth ratoon cane yield, expressed as percentage of unsprayed control – Trial 3.

first ratoon onwards. However, losses in yield only reached statistical significance (P=0,05)) for these mixtures in the fourth ratoon. Double rates of Velpar + Diuron were very damaging with significant losses recorded in all but the plant crop.

Results for single product treatments of Velpar and Diuron applied over the row from plant to second ratoon are shown in Figure 4 (irrigated Trial 3). Losses reached statistical significance (P=0,05) for Velpar only after the third application. There was no evidence of a negative effect from repeated applications of Diuron.

Interrow applied treatments were introduced in the third and fourth ratoon crops and results are shown in **Figure 6**. Both the standard and double standard rates of Velpar + Diuron reduced cane and sucrose yield significantly (P = 0,05), whereas Sencor + Diuron proved safer when applied to cane interrows.

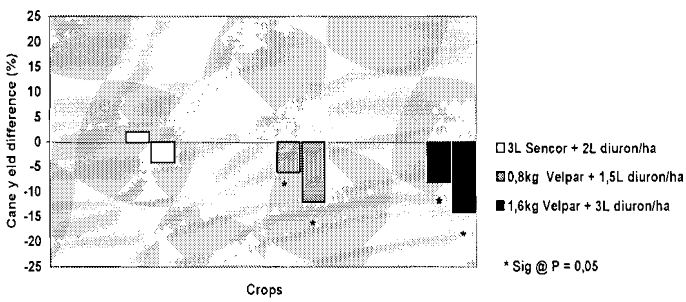

Figure 6. Treatment effects on third to fourth ratoon cane yield of directed interrow sprays, expressed as percentage of unsprayed control – Trial 3.

There was a statistically significant positive correlation between stage of crop growth at spraying and yield loss for both Sencor + Diuron and Velpar + Diuron standard treatments (see **Figure 7**). Both trend lines suggest that cane growth should not exceed ±10cm (to uppermost leaf bend) at spraying to prevent yield loss. This is far less than the South African Sugar Association Experiment Station recommendation of 40cm to the uppermost leaf bend, permissible before spraying need be directed into the interrow ([3]unpublished data).

Effects of water on levels of herbicide phytotoxicity

Two trials showed increased levels of herbicide phytotoxicity after sufficient amounts of water were received within two weeks of spraying. These trends appeared real, but statistical significance was reached for Velpar + Diuron in Trial 1 only (**Figure 8**). Although the slope for Sencor + Diuron also appeared negative, analysis showed the trend to be non-significant. All trends generally weakened when time after spraying was extended beyond two weeks.

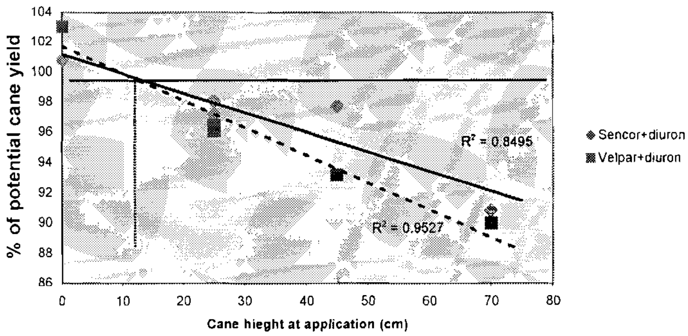

Figure 7. Influence on herbicide treatment effects by cane height at spraying (cm to uppermost leaf bend) – Trial 3.

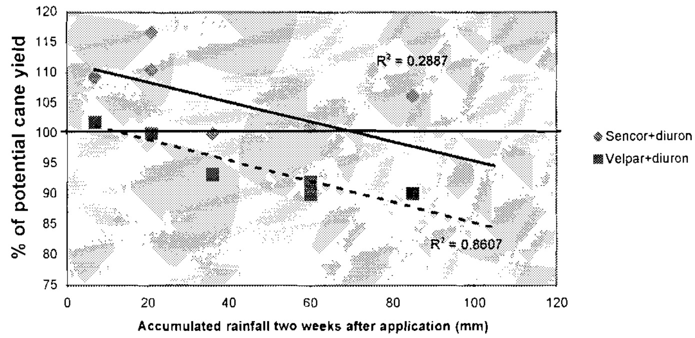

Figure 8. Influence on herbicide treatment effects by amount of accumulated rainfall within two weeks of spraying – Trial 1.

Effects of treatments on soil pH status

Table 2 shows soil sample pH results for Trial 2 expressed as treatment averages. Soil pH levels were all similar after treating four successive crops with the same herbicide treatments.

Table 2. Treatment effects on soil pH after four seasons – Trial 2.

Treatment	T1	T2	T3	T4
	Control	Sencor + diuron	Velpar + diuron	Velpar + diuron
Rate (kg or L product/ha	-	3,00 + 2,00	0,97 + 2,00	1,93 + 4,00
Soil pH (water)	6 28	6 21	6 23	6 47

Discussion and conclusions

Treatment interaction with ratoon age

Statistically significant yield loss from over the row herbicide treatments was only recorded in the fourth ratoon for the summer cycle irrigated trial (Trial 3). Although yield suppression trends appear real, it is important to note that the low fourth ratoon yields were attributed to cane growth stage

[3] South African Sugar Association Experiment Station - Senior certificate course notes

at spraying (70cm to uppermost leaf bend) and not to an accumulative effect over five seasons.

Because there might still be the possibility of an accumulative effect on yield with advancing ratoon age beyond five crops, it may be beneficial to growers to alternate with other products of different modes of action after a few seasons. This would also reduce the possibility of weeds becoming resistant to certain herbicides.

Treatment interaction with herbicide placement

Results showed that cane phytotoxicity from Velpar + Diuron did not decrease when application was directed away from the foliage into the interrows, as levels of damage were similar to where the mixture was sprayed over the rows. Presumably this is due to the high solubility and efficient root absorbtion of this product. Sencor + Diuron was less damaging when applied in this manner. It must be appreciated that herbicides were accurately applied under trial conditions, and that in practice, more leaf contact occurs even where spraying is directed into interrows.

Treatment interaction with cane height at spraying and crop yield potential

Cane height at spraying and yield potential of the crop were factors that influenced levels of cane phytotoxicity from both Sencor + Diuron and Velpar + Diuron. Based on these results, limitations regarding maximum cane height for over the row applications of these products should be reduced from 40cm to 10cm (to uppermost leaf bend). These findings strengthen the case for herbicides to be used pre to early post-emergence of weeds. On average, cane would also be at an early growth stage which would limit chemical damage.

Treatment interaction with available water

One trial showed statistically higher yield losses from Velpar + Diuron with increasing amounts of available water received within two weeks of spraying. These losses could be attributed to increased root absorption of highly soluble hexazinone, and may justify irrigating a crop prior to spraying, and then withholding water for a short period afterwards. This would enable the product to reach shallow weed seed but prevent excess contact with cane roots. These observations oppose those made by Mc Intyre[4] (1977)., who reported greater crop damage from Velpar following dry conditions. However, conclusions were based on total water received over far longer periods of time than the critical first two weeks identified and discussed in this paper. Both conclusions could be correct. This paper showed Velpar phytotoxicity to increase in accordance with sufficient water early on. But the product may be equally damaging following extended dry conditions which could cause an accumulation of the chemical in the root zone until sufficient moisture is received to leach it to depth. However, as negative trends were only produced in one trial, there is insufficient data to draw conclusions and further investigation is required.

General

Statistical analyses of certain parameters affecting degree of herbicide damage to sugarcane showed the lower Velpar + Diuron rate to be slightly more harmful than Sencor + Diuron. However, cognizance should be paid to the fact that apart from the last crop in the irrigated trial, results from fifteen sets of harvest data showed neither treatment to reduce cane yields significantly. This was in spite of the fact that Velpar was on average, used at higher rates than recommended. It is also important to note that the yield decline trend associated with sugarcane height at spraying, and crop yield potential, were statistically significant for both treatments, but that differences between them were not statistically significant. Soil sample data showed that it is unlikely that herbicides contribute significantly to soil pH changes.

In conclusion, the authors feel that neither Sencor + Diuron or Velpar + Diuron are unduly damaging to cane when used at recommended rates. On the contrary, results from plant crops proved Velpar + Diuron safe when applied early, and supports the initiative for registration of this mixture on plant cane in heavier soils. Attention should be paid to the parameters that affect degree of herbicide damage to the crop of which cane height at spraying is the most important.

Although trial data was inconclusive with regards to accumulative effects of these products after continuous use, growers are advised to be cautious until further research is completed. Both summer cycle trials have been re-sprayed for the sixth time as further results are needed to determine whether there are accumulative herbicidal effects after five crops.

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