IMPACTS OF TRASH RETENTION ON SOIL NITROGEN AND WATER: AN EXAMPLE FROM THE AUSTRALIAN SUGARCANE INDUSTRY

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Abstract

Conventional burnt and green cane harvesting-trash blanketing (GCTB) trash management systems were compared over 15 years (two crop cycles) at a site in north Queensland, where sugarcane yield and fertility of the 0-0,2 m soil layer were measured. The experiment was also simulated with a cropping system model (APSIM) and longer term (35 year) simulations preformed. There was little difference in yield between the two treatments, but soil organic carbon increased steadily in the GCTB treatment. These results, and their time trends were successfully reproduced by the model both during the experimental period and in the long term simulations. The impact of GCTB on the soil water and N balance were examined in the long term simulations. While deep drainage was higher, and runoff and soil evaporation lower under GCTB, average nitrogen losses (through denitrification and leaching) were similar to those in the burnt treatment because much of the soil nitrate was immobilised by the decomposing trash blanket. This study illustrates the utility of combining simulation modelling with traditional experimental approaches when studying complex crop-soil systems.

Introduction

The retention of a trash blanket following green cane harvesting can have a dramatic effect on soil carbon (C), nitrogen (N) and water cycles. As the trash decomposes, C and N (and other nutrients) will be released into the soil, and the soil organic matter will increase. Ultimately, there may be an improved N supply to the crop. The trash blanket will also reduce run-off and soil evaporation, and possibly increase the water available to the crop. However, there are other possible fates for the additional N and water made available by a trash blanket system. Water could be lost as deep drainage below the root zone, carrying with it nitrate. Higher soil moisture could also promote denitrification. Such losses of N are harmful to the environment, and of concern to the sugar industry in Australia (Keating *et al.*, 1997; Weier *et al.*, 1998). The partitioning of the additional N and water between that taken up by the crop and that lost to the environment will depend on the climate, which can vary markedly from year to year in Australia. Another complicating factor is the long time scale of the organic matter accumulation in trash blanketed soils.

Over the past 20 years there has been a widespread adoption of green cane harvesting-trash blanketing (GCTB) in the Australian sugarcane industry. However, little is known about the long term impact of GCTB on soil N and water processes. To date, results have been reported over a few seasons only (Page *et al.*, 1986; Wood, 1991; McMahon and Ham, 1996) and little attempt has been made to integrate yield responses with water and N dynamics of the whole profile. The situation is similar in most other countries (Cock *et al.*, 1996; Murombo *et al.*, 1997; Richard, 1998), with the exception of a long term experiment in South Africa (van Antwerpen and Meyer, 1998). The time scale of the organic matter accumulation (decades), climatic variability, and the complex interactions between soil hydrology and soil N limit the information that can be gained on GCTB systems from purely experimental approaches. Useful insights into the impacts of the GCTB system may be gained from the application of a cropping systems model (e.g. Vallis *et al.*, 1996).

This paper reports the application of the Agricultural Production Systems Simulator (APSIM, McCown *et al.*, 1996) for modelling soil N, C, water and crop dynamics in GCTB sugarcane systems in Australia. Simulations are based on a site where GCTB and burnt systems have been compared since the early 1980s. Yields, components of the soil water balance and losses of N from the profile over 35 years are compared in the simulations to indicate the likely beneficial or detrimental aspects of the GCTB system at this site.

Materials and methods

Field data

The study site, near Abergowrie (18° 28' 34" S, 145° 51' 49" E) in northern Queensland, was one of a series of GCTB demonstration sites established in the Herbert River Valley in 1980-81. Wood (1986; 1991) reported data from the first crop cycle (plant and five ratoon crops). Data from the first and second (plant and six ratoon crops) crop cycles were used in this study. The soil type was an alluvial silty loam, described as the Herbert Series by Wilson and Baker (1990). The study consisted of three unreplicated strips (10 rows wide by approximately 300 m long) which, following harvest of a plant crop in August 1981, had GCTB and green cane harvest-trash incorporated treatments imposed on two strips, while the third remained burnt. Only the burnt and GCTB treatments are examined here. In both treatments, 160 kg N/ha N was applied (as urea), approximately 45 kg/ha immediately following planting or harvest and the remainder three months later. Both treatments were harvested at the same time, 12-13 months after planting or harvest. Yields were taken from records of cane delivered to the mill. Total soil N and C were measured in the 0-0,2 m soil layer each year, as described by Wood (1986; 1991). In October 1998, total soil N and C, mineral N, bulk density and estimates of soil water holding capacity were made to 1,5 m depth in both treatments.

Model and parameterisation

The APSIM modelling framework (McCown *et al.*, 1996) was used in this study. The modules for soil organic matter, N, water and residue dynamics (Probert *et al.*, 1998) and sugarcane growth (Keating *et al.*, 1999) have been fully described elsewhere, but a short description of them follows. The modules are one-dimensional and driven by daily climatic data. The dynamics of water, N, C and roots are simulated in soil layers, with water (and associated nitrate) moving between layers where gradients exist. The soil organic matter is divided into three 'pools', with *fom* representing the fresh organic matter (i.e. roots and incorporated plant residues), *biom* representing the active biomass in the soil, and *hum* representing the humified material. Part of the *hum* pool is considered inert. The soil water module is a 'cascading bucket' water balance model, with water between the drained upper limit (*dul*) and saturation draining to the layer below. The drainage rate is controlled by the parameter *swcon*, which was set to 0,4 in all layers. The lower limit of plant available water is defined by the parameter *ll15*. Evaporation from the soil follows Ritchie's (1972) two-stage evaporation model. The presence of plant residues on the soil surface affects run-off (and hence infiltration) and evaporation. The sugarcane module uses intercepted radiation to produce assimilates, which are partitioned into leaf, structural stalk, roots and sugar. The processes represented in the module are responsive to radiation and temperature, as well as water and N supply. Farming operations (such as fertilisation, planting, incorporation of crop residues through cultivation, or burning of crop residues) can be specified through the MANAGER module, to represent actual or hypothetical conditions.

Model parameters were based, wherever possible, on measured data (soil parameter values are given in the Appendix). The initial soil organic C was set equal to measured values. For the top two layers (0-0,1 m and 0.1-0,2 m), the average of the values measured by Wood (1986) in the burnt and GCTB treatments was used, while the deeper measurements made in 1998 were used for the other soil layers. Soil C:N ratio was set to 10,5, from measurements of total N and C. Relevant data on the soil organic matter fractions were not available, so these were set equal to values used in previous APSIM simulations of soil N dynamics (Probert *et al.*, 1998), except for the top two layers. In these layers, the *biom* fraction was increased and the fraction of inert organic matter decreased to allow for the higher likely N mineralisation capacity of the tropical soil. The soil water parameters (bulk density, saturation, *dul* and *ll15*) were derived from measurements made in 1998, and general determinations of available water capacity in the Herbert soil series made by Wilson and Baker (1990). Default parameter values for the variety Q117 were used in the sugarcane model.

Simulations

Firstly, simulations of the experiment were performed. As planting and harvest dates had been recorded only approximately (i.e. ±2 weeks) at the site, crop length was set at 12,5 months, with crops planted on August 1st, 1980 and 1987. A planting depth of 150 mm and a stalk density of 10 plants/m2 was used in the sugarcane module. Fertiliser was applied as per management records allowing for a 40% loss of urea N via volatilisation (Freney *et al.*, 1994), a process not accounted for in the model. Weather data were obtained from the Australian Bureau of Meteorology. At the end of each crop in the burnt treatment, trash was ëburntí in the model, resulting in 95% removal of trash. After the final ratoon in a crop cycle, the sugarcane plants were 'killed', trash was 'burnt' in the burnt treatment, and then the soil was 'cultivated' in both treatments. 'Cultivation' resulted in the 50% of the trash being transferred into the *fom* pools in the top two soil layers (i.e. to a depth of 0,2 m).

Secondly, longer term simulations were performed to extrapolate the trial results through time. Management details were the same as used for the previous simulations, except that each crop cycle was limited to four ratoons. This resulted in a harvest date of the fourth ratoon in early October, followed by a 10-month fallow prior to replanting. Simulations were commenced in 1960, the year of the earliest reliable climate data, and run for seven crop cycles (finishing in 1995). To assess the effect of yearly weather patterns on simulation results, simulations were commenced also in 1961, 1962, 1963 and 1964, running for seven crop cycles.

Results

There was generally good agreement between the measured and simulated yields in both treatments (Figure 1), but with a tendency to over-predict yields in the burnt treatment in some years. This resulted in the mean simulated yield in the burnt treatment being 7 t/ha higher than the GCTB treatment, whereas it was 3 t/ha lower in the trial results. The higher simulated yields in the burnt treatment may have been due to factors such as weed competition, pest damage or lodging, which are not considered in the model, affecting the actual yields.

Increased soil C in the GCTB treatment relative to the burnt treatments was well predicted by the model (Figure 2).

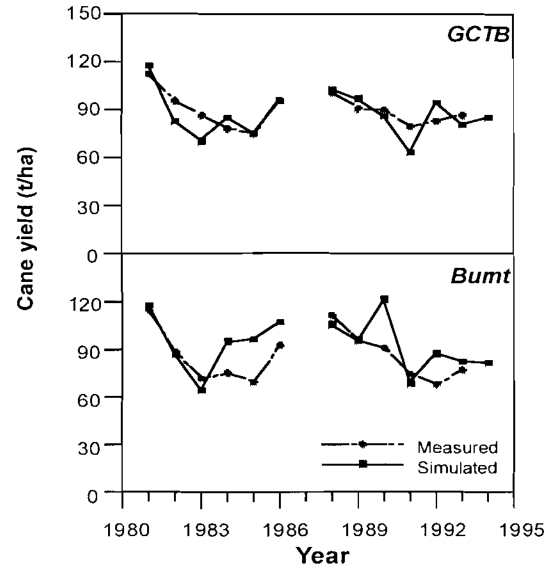

Figure 1. Measured and simulated sugarcane yields under two trash management treatments.

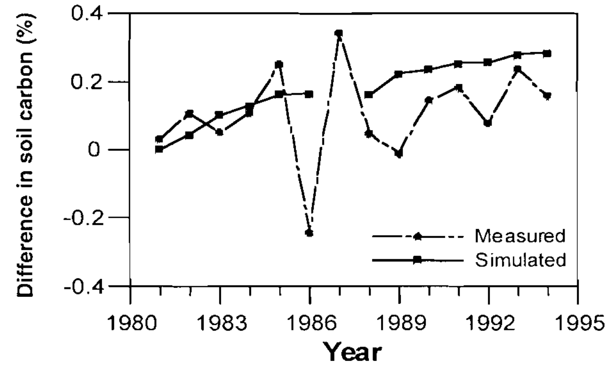

Figure 2. Measured and simulated differences in total soil carbon between GCTB and burnt trash management treatments over 0-0,2 m soil depth.

Presumably, the year to year variation in the measured differences reflects sampling and analytical variations.

In the 35 year simulations, soil C followed the same trend as in the short-term simulations and trial data, with the GCTB treatment being approximately 0,2% higher after 15 years (Figure 3). Soil C continued to increase in the GCTB treatment, being more than 0,5% higher than in the burnt treatment after 35 years. Soil C continually declined in the burnt treatment, although it appeared to be approaching an equilibrium value by the end of the simulation.

Simulated sugarcane yields (Figure 3) were variable from year to year and showed no long term trend in either treatment. Average yields were similar in both treatments (Table 1), although variability in the burnt treatment (standard deviation of 25 t/ha) was higher than in the GCTB (standard deviation of 17 t/ha). Much of this increased variability in the burnt treatment could be attributed to water stress. In some years, such as 1980 (Figure 3), water stress was markedly higher and yields lower in the burnt treatment than the GCTB. However, the small crop in the burnt treatment left more water and/or N in the soil, which resulted in a higher yield the following year. While the year in which the simulation was started impacted on the yearly pattern of the yields (data not shown), it had little effect on mean yields or the relativity between the treatments (Table 1).

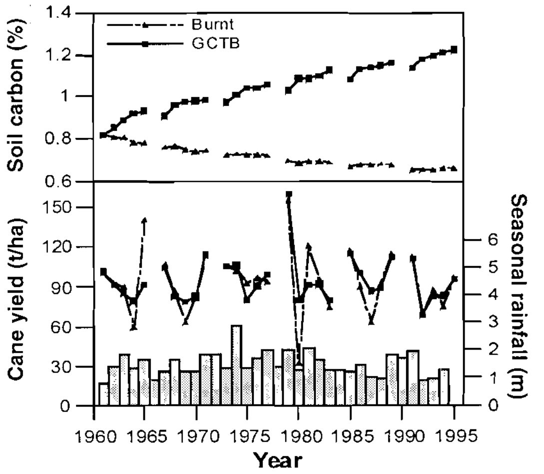

Figure 3. Simulated long term variations in total soil carbon (0-0,2 m depth) and sugarcane yield in response to two trash management treatments. Bars indicate rainfall during each crop and fallow.

Table 1. Mean sugarcane yield (t/ha) of 35 year simulations commenced in four different years.

Treatment	Year simulation commenced			
	1960	1961	1962	1963
Burnt	94,3	95,3	92,8	95,1
GCTB	94,9	95,1	93,1	93,7

Averaged over all years of the burnt simulation, losses of water though run-off, soil evaporation and deep drainage accounted for 17, 23 and 21% of rainfall, respectively. For GCTB, run-off and soil evaporation were lower (13 and 16% of rainfall, respectively) while deep drainage was higher (28%).

Losses of N from the soil, either through denitrification or leaching, were very low, averaging 2,6 and 1% of N applied, respectively. While the results were similar in both treatments despite extra N being recycled to the soil through retention of trash in the GCTB treatment, the pattern of N losses were markedly different (Figure 4). There was a higher frequency of denitrification and leaching events in the burnt treatment, although the magnitude of the events was generally smaller than in the GCTB treatment. Denitrification and nitrate leaching losses were more frequent in the burnt treatment because soil nitrate concentrations were generally higher than in the GCTB treatment, so more nitrate was available to be leached or denitrified. The relationship between soil nitrate and N losses, particularly denitrification, is clearly illustrated in the results from the

GCTB treatment. In that treatment, soil nitrate was highest during the plant crops with denitrification and, in the final two crop cycles, leaching losses correspondingly high (Figure 4). In the ratoon crops, however, soil nitrate levels were low due to the immobilising effect of the trash blanket.

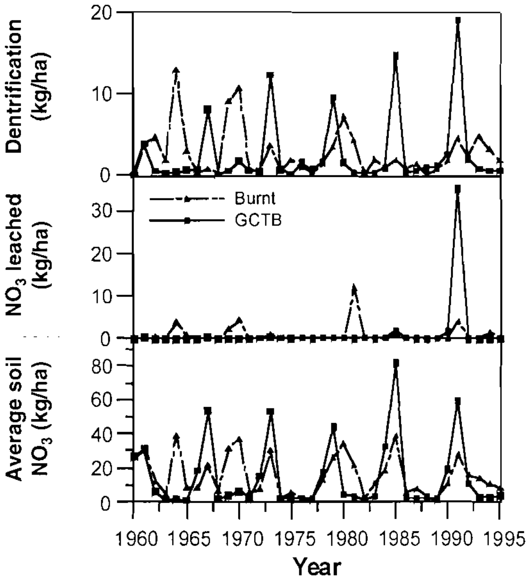

Figure 4. Total simulated loss of nitrate via denitrification and leaching, and the average simulated soil nitrate concentration (i.e. the average of daily values in the simulation) during each crop under two trash management treatments.

Discussion

The soil processes determining the fate of a GCTB system interact with each other, strongly depend on climate, and act over long time scales. In this situation, it is difficult to adequately compare agronomic systems through conventional experimentation alone. This study provides an example of the extra insights that can be gained by the application of a cropping systems model together with field experiments. Trial results were extrapolated through time, and information was acquired on the soil water balance and N cycle that could not be obtained in the field. A similar exercise was undertaken for the site by Vallis *et al.* (1996) with the CENTURY model. While both models describe soil water, C, N and the crop, they have important differences, such as: the CENTURY model ran on a monthly time step, considered soil C to only 0,2 m depth, and had a developmental sugarcane production model. These differences mean there is little to be gained in comparing simulation results.

The differences in sugarcane yield at the site, both experimentally and in the simulations (Figures 1 and 3), were small, a result consistent with the variable impact of GCTB on yields (Wood, 1991; Cock *et al.*, 1996; Murombo *et al.*, 1997; Richard, 1998). The simulated changes in the water balance, i.e. lower soil evaporation and run-off and higher deep drainage in the GCTB system, are consistent with experience of crop residue management in other cropping systems (Thorburn *et al.*, 1989; Probert *et al.*, 1995).

Of more interest was the fate of the N contained in the trash blanket. In both the experiment and simulations, soil C to 0,2 m depth increased by ~0,1% (equivalent to approximately 200 kg N/ha) through each cropping cycle in the GCTB system (Figures 2 and 3). Thus, most N accumulated in the soil organic matter, minimising losses through leaching or denitrification. However, as the soil organic matter comes into equilibrium with the inputs from the trash under GCTB, extra N should be available in the soil, and the risk of N losses will become higher. A trend towards this situation was evident, with average soil nitrate and total denitrification increasing with each crop cycle in the GCTB system (Figure 4).

Questions still unanswered by this study include:

- How long will it take to reach equilibrium soil organic matter levels?
- What will be the partitioning of the N in the trash blanket at equilibrium?
- Should N fertiliser management be different in the GCTB system?
- How will differences in soil and climate affect the answers to these questions?

The first two issues can be examined by performing simulations with longer climatic data. However, these data are not available at this site, so longer records from coastal towns (e.g. Ingham, 40 km east) would have to be used (as done by Vallis *et al.*, 1996), raising the issue of soil by climate interactions. Work is currently under way to examine this, and the other issues through the application of cropping systems models to a range of shorter term field studies comparing burnt and GCTB systems.

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APPENDIX
Soil parameter values

Parameter*	Value						
Layer number	1	2	3	4	5	6	7
Layer depth (mm)	100	100	200	200	300	300	300
ll15 (m^3/m^3)	0,18	0,18	0,18	0,18	0,18	0,16	0,14
dul (m^3/m^3)	0,32	0,32	0,32	0,32	0,32	0,3	0,28
Saturation (m^3/m^3)	0,52	0,52	0,5	0,5	0,49	0,49	0,48
Bulk density (Mg/m^3)	1,02	1,02	1,07	1,07	1,07	1,07	1,07
Organic C (%)	0,815	0,815	0,68	0,5	0,25	0,2	0,2
pH	5	5	5	5,5	6	6	6
Fraction of C that is inert	0,2	0,4	0,55	0,85	0,95	0,95	0,99
Fraction of non-inert C in the *biom* pool	0,1	0,07	0,05	0,025	0,015	0,01	0,01

*Defined in the text.

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

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[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 1st 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	

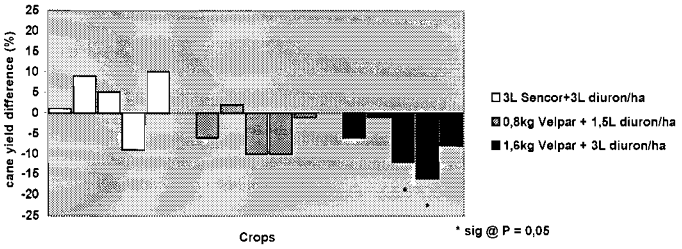

Figure 1. Treatment effects on first to fifth ratoon cane yield, expressed as percentage of unsprayed control – Trial 1.

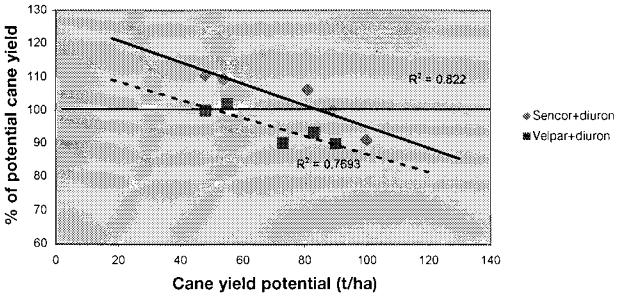

Figure 2. Influence on herbicide treatment by cane yield potential – Trial 1.

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.

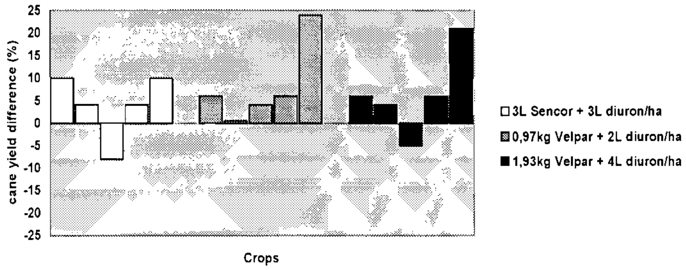

Figure 3. Treatment effects on plant to fourth ratoon cane yield, expressed as percentage of unsprayed control – Trial 2.

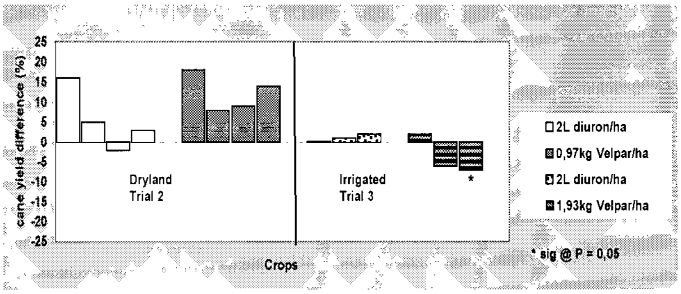

Figure 4. Treatment effects of diuron and Velpar on cane yield, expressed as percentage of unsprayed control – Trial 2 and Trial 3.

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

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[2] Velpar label instructions

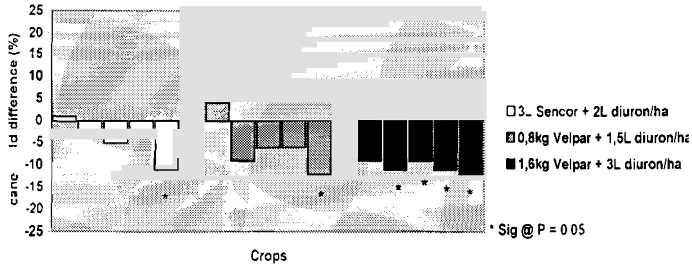

Figure 5. Treatment effects on plant to fourth ratoon cane yield, expressed as percentage of unsprayed control – Trial 3.

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.

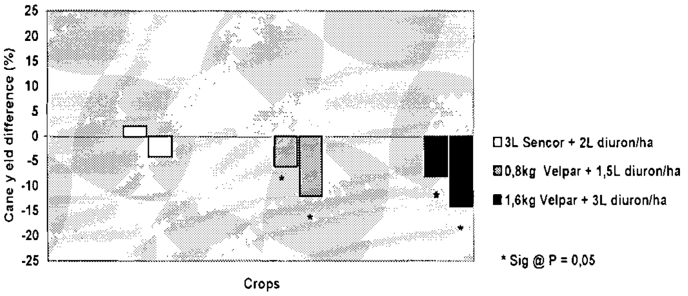

Figure 6. Treatment effects on third to fourth ratoon cane yield of directed interrow sprays, expressed as percentage of unsprayed control – Trial 3.

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.

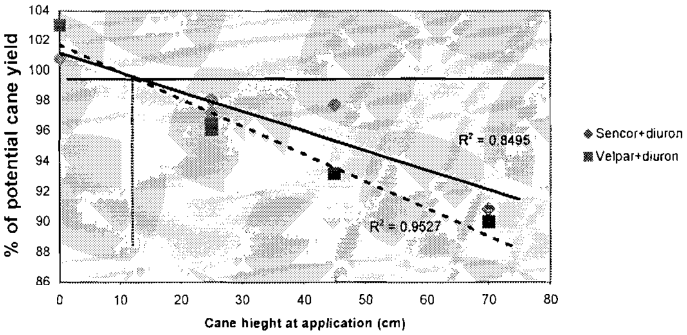

Figure 7. Influence on herbicide treatment effects by cane height at spraying (cm to uppermost leaf bend) – Trial 3.

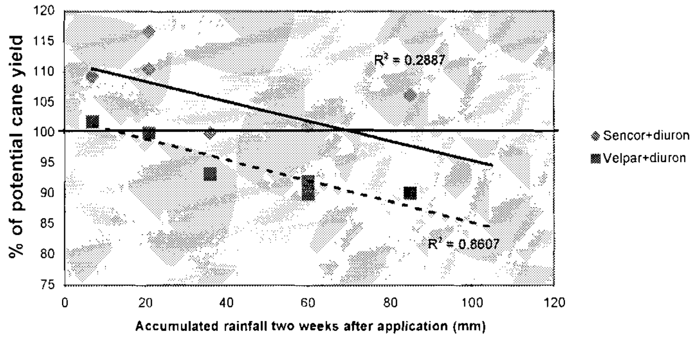

Figure 8. Influence on herbicide treatment effects by amount of accumulated rainfall within two weeks of spraying – Trial 1.

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

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[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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