Proc. Aust. Soc. Sugar Cane Technol., 21: 139–148 1999

EFFECTS OF WET SOIL DURING EARLY SEASON RATOON ESTABLISHMENT ON SUGARCANE GROWN UNDER DIFFERENT TRASH MANAGEMENT SYSTEMS IN SOUTHERN CANELANDS

By

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Abstract

Green cane trash blanketing (GCTB) has been rapidly adopted by the Queensland sugar industry on the wet tropical coast, but adoption has generally been much slower in the southern canelands. The slower adoption in these areas appears due largely to perceptions of lower productivity under a GCTB system, particularly when ratooning occurs under cool and/or wet conditions. This work was initiated to examine the interactive effects of trash management and soil moisture status on ratoon establishment of early harvested Q150 near Bundaberg. The paper also contrasts the Bundaberg results with data from similar experiments using Q124 in the Northern Rivers Region of NSW. Treatments were imposed during the establishment phase of three successive ratoon crops at Bundaberg, and on successive ratoons at Harwood and Broadwater. Trash management systems included burnt cane harvesting and green cane harvesting, with trash removed from the stool (stool raking), trash removed from the stool followed by incorporation of trash in the inter-row (trash incorporation, Bundaberg only) and a standard green cane trash blanket. Soil moisture during ratoon establishment was manipulated using trickle tape, micro-jet sprinklers and flood irrigation. After the establishment phase, all treatments at Bundaberg were irrigated until maturity on a common schedule using surface trickle tape. Trash management and soil moisture status during ratoon establishment significantly affected shoot numbers and crop growth at all sites. Early shoot numbers could be related to differences in accumulated thermal time and also to the rate of shoot addition per unit of thermal time, with thermal time calculated from soil temperatures at stool depth. There was no evidence of any interaction between soil moisture status and trash management on ratoon establishment at any site. There were no significant correlations between shoot numbers at 3.5 months and the numbers of mature stalks at harvest in any site. There were no correlations between early shoot numbers and yield at Bundaberg.

Introduction

Green cane trash blanketing (GCTB) has been adopted rapidly by the sugar industry on the wet tropical coast, and with the exception of the Burdekin Irrigation Area, the overwhelming majority of the north Queensland crop is now harvested green (85% in 1993: Ridge, 1995). Adoption has been much slower in the southern Queensland canelands, although the recent string of dry seasons has resulted in a significant increase in the past few years (i.e., from 24% in 1993 to 55% in 1997: Anon., 1998). The slower adoption in these southern areas, and on heavier soils with poorer internal drainage, appears due largely to concerns about lower productivity under this system. The perception that GCTB crops ratoon poorly under cool and/or wet conditions is of particular concern to growers in

KEY WORDS: Trash Management, Thermal Time, Soil Moisture, Shoot Establishment.

these regions (Norrish, 1996; Kingston *et al.*, 1998).

Recent studies investigating the effects of trash management on cane productivity in the southern areas of Queensland (Ridge, 1998) and northern NSW (Kingston *et al.*, 1998) have so far not clearly determined the interactive effects of trash management and soil moisture conditions on ratoon establishment and subsequent crop performance. For example, both studies have reported early negative effects of trash blanketing on ratoon establishment being countered by subsequent positive effects resulting from better soil moisture retention in rainfed crops. While these observations reflect the real situation encountered in cane fields in the southern areas, they do not improve the understanding of the biophysical interactions of water and trash on crop establishment.

Cooler soils and resultant slower accumulation of thermal time under trash blankets are commonly observed (Wood, 1991; Kingston *et al.*, 1998; Ridge, 1998), and this is offered as at least part of the reason for slower ratoon establishment under GCTB. Indeed, average soil temperatures at *ca.* 5 cm depth can be up to 5 °C cooler under GCTB (Ridge, 1998). In environments like southern Queensland and northern NSW, this differential may cause soil temperatures to fall below the minimum temperature required for germination to occur. Frequent rainfall and/or impaired drainage will help maintain lower soil temperatures, as well as causing additional stresses associated with periodic waterlogging.

In addition to effects of trash blanketing on soil temperature, Hurney and Ridge (1992) suggested that cane trash produced allelopathic effects that negatively affected cane germination and subsequent root growth. These effects were variety specific, seemed to be enhanced by poor internal drainage and were transient in nature.

There has been little work directly targeting the interactions between soil water status and trash management in the southern canelands. Ridge (1998) was unable to address this issue due to dry seasonal conditions and a resultant lack of waterlogging at Childers and Rocky Point during the experimental period. The research at Bundaberg was specifically designed to investigate the hypothesis that green cane trash blanketed crops ratooning under cool wet conditions would ratoon poorly and show reduced crop yields. Early (winter) harvests were undertaken to ensure cool temperatures during ratoon establishment. Irrigation was used to create soil moisture differentials during this period, while trickle irrigation was used during the rest of the season. Treatment effects on ratoon establishment were compared with those from early harvested first ratoon experiments with Q124 in NSW (Kingston *et al.*, 1998). Final yields from the NSW experiments are not discussed, as crops were rainfed after ratoon establishment and varying soil moisture status under the different trash regimes might have confounded subsequent crop growth.

Materials and methods

Cultural practices

The Bundaberg experiment was established on a yellow podzolic soil at Calavos in an autumn plant-cane block of Q150. Plots were 30 m long, with six 1.5 m rows in each plot, and each treatment had three replicates. The plant crop was harvested green on 25 June 1996, during the first week of the crushing season, while the first and second ratoons were harvested during the same week in consecutive seasons. The early harvest was undertaken to ensure the longest possible period of low temperatures during the ratoon establishment period, taken as the interval between harvest and mid-October. Site details for the Harwood and Broadwater studies are provided in Kingston *et al.* (1998). Briefly, experiments were established on alluvial and clay soils at Harwood, and on a clay soil at Broadwater. Four replicates of each trash management were established in one-year cane (Q124) at each site, with hilled rows used to improve drainage. Harvests in August and December 1997 were used to provide different temperature environments during ratoon establishment.

Each ratoon crop was fertilised using Nitra K S at the end of the ratoon establishment period (*ca.* 3.5 months after harvest) to supply N, K and S at 162, 98 and 26 kg/ha, respectively. Fertiliser was banded 10–15 cm deep behind coulters positioned either side of the stool and followed by press wheels to close the furrow. Burnt cane plots were then inter-row cultivated approximately one week after fertiliser application.

Trash management

Trash was managed using four different strategies—(i) burnt, (ii) full trash blanket, (iii) trash blanketed with stool raked and (iv) trash blanketed with stool raked and trash incorporated. In the burnt cane (BC) treatments at Bundaberg, practical considerations meant that trash was burnt on the ground as soon as possible after a green harvest, rather than prior to harvest in standing cane. Rain delayed the burning of trash until two weeks after harvest of the plant crop, but in the next two seasons burning was carried out in the same week as harvest. The simulated burnt cane treatments in the NSW trials had all trash removed from plots by raking and dumping.

In the stool raked (SR) and trash incorporated (TI) treatments, stool rakes were used to remove trash from a 40 cm wide band over the stool within seven days of harvest. In the TI treatments, trash was subsequently incorporated using a set of ratooning offsets in the interspace in the first ratoon and a rotary hoe with the centre gang of blades removed in subsequent ratoons. The rotary hoe with long shank blades ensured uniform trash incorporation in the inter-row to a depth of 15 cm. There was no trash incorporation treatment at the NSW sites.

Management of soil moisture

Various irrigation frequencies and application methods were used to manipulate soil moisture conditions and the mode of wetting during ratoon establishment at Bundaberg, while 'wet' treatments on the alluvial and cracking clay sites in NSW were maintained at field capacity with generally bi-weekly irrigation from overhead sprinklers. Subsequently, all plots at Bundaberg were fully irrigated to eliminate residual differences in soil moisture profiles and returned to a common irrigation schedule (70% deficit) and method of application (surface trickle tape). The NSW crops were rainfed.

At Bundaberg, treatments imposed in the first ratoon crop involved irrigating to maintain soil moisture content in the hill at field capacity, or replenishing soil moisture once deficits of 30% and 70% of the available soil moisture in the top 70 cm (equivalent to 60 mm) had been depleted. There was also a rainfed control. The field capacity and 70% deficit treatments were established using surface trickle tape, while the 30% deficit treatment used micro sprinklers. After the ratooning period, all treatments were maintained through to harvest using a common irrigation schedule (70% deficit) and surface-applied trickle irrigation.

Irrigation schedules were modified in the second and third ratoons to increase the emphasis on the wet end of the soil moisture regimes and to ensure that all the 'wet' treatments experienced regular leaching of trash. To that end, treatments in the second ratoon were scheduled to achieve continual waterlogging, field capacity and 70% deficits, with a rainfed control. In the third ratoon, a 30% deficit treatment was included at the expense of the rainfed control. Micro sprinklers were used for the waterlogged and field capacity treatments in the second ratoon and for the field capacity and 30% deficit treatments in the third ratoon, while surface trickle tapes were used for the 70% deficit treatment in both years. The waterlogged treatment in the third ratoon was achieved by damming the inter-row in those plots and flood irrigating.

The waterlogged treatments differed in severity between the second and third ratoons. Sprinklers were used every second day to maintain visible water in the bottom of the inter-row in the second ratoon. However, in the third ratoon flooding every second day was used to maintain water levels between the bottom of the inter-row and the germinating stool (approx. 8 cm from the top of the mound). Typical gravimetric moisture contents for soil at the depth of the stool during an irrigation cycle are shown in Table 1.

Table 1—Gravimetric soil moisture content (g/g) in the hill at the depth of the stool for selected combinations of trash management and soil moisture regime. Measurements were made immediately prior to irrigation and 24 h after irrigation.

Soil moisture regime	Trash management	Gravimetric moisture (g/g)	
		Prior to irrigation	After irrigation
Waterlogged	GCTB	0.20	0.21
	Stool raked	0.21	0.21
	Trash incorporated	0.20	0.21
	Burnt cane	0.17	0.18
Field capacity	GCTB	0.16	0.18
	Stool raked	0.13	0.15

Monitoring of soil temperature and ratoon establishment

Two soil temperature sensors were inserted into the hills at stool depth (approx. 8 cm) in each plot, and hourly temperatures were continuously recorded during the ratoon establishment period. Heat unit accumulation (degree-days) was calculated by summing the hourly temperatures minus an estimated base temperature of 11.5 °C (Liu *et al.* 1998) and dividing the daily total by 24. Shoot numbers were recorded at regular intervals during the ratoon establishment period, at less frequent intervals during subsequent crop growth and finally at harvest. A biomass sample (5 m x 2 rows) was taken at the end of October in the second and third ratoons to quantify the effect of treatments on crop growth.

Yield and CCS determinations

Crop yields at Bundaberg were determined using 5 m × 2 row, hand harvested quadrats, while yields in NSW were determined from net sub-plots of 3 rows × 1.5 m × 14 m after cane was chopper harvested. Sub-samples of 14 stalks were taken to determine biomass components (trash, millable stalk and CCS) and the respective moisture contents. The millable stalk was defined as that part of the cane below the fifth dewlap from the top.

Results and discussion

While seasonal temperatures fluctuated somewhat around the mean, all seasons at Bundaberg were reasonably representative of the long-term average. Rainfall varied markedly, with the second ratoon period characterised by very dry conditions during the ratooning period and the third ratoon notably wetter than average.

Trash returned to the plots averaged 12.6 t DM/ha after the plant crop, and 14.1 and 13.5 t DM/ha after the first and second ratoon crops, respectively. Moisture level during the ratoon establishment period influenced the rate of decomposition of the trash blanket, with more rapid rates of decomposition in the wetter treatments (data not shown). However, these differences were relatively small when considered across the whole crop season and there were no significant differences between moisture treatments and residual trash within a given trash management. Observations of moisture fluctuations during the irrigation cycles (Table 1) were consistent with the observations of Wood (1991) and others, in that soil moisture levels at the end of each cycle tended to be higher in trash blanketed systems.

Burning reduced trash cover to less than 30% of the original trash returned at Bundaberg, compared with complete removal in the 'simulated' burnt system in NSW. Incorporation of trash with the rotary hoe left a similar proportion of the original blanket on the soil surface, mainly in the inter-row, while the ratooning offsets used in the first ratoon were less successful, incorporating less than 50% of the trash.

Treatment effects on ratoon establishment

Trash management produced highly significant effects on shoot numbers at the end of the establishment period in all ratoon crops at Bundaberg (Figure 1) and the NSW sites (data not shown), with the GCTB treatments always lower than all other management systems. Soil water status had no significant effects on shoot numbers and there were no significant treatment interactions.

Both trash management and soil moisture status affected dry matter production during the ratooning period, but again there were no significant treatment interactions. Trash blanketed plots in the second and third ratoons at Bundaberg produced an average of 1.25 t DM/ha by the end of October—significantly less than that produced in the trash incorporated (2.04 t/ha) or the burnt or stool raked treatments (both 2.16 t/ha).

Effects of soil moisture on biomass production during the ratooning period were slight, with the greatest biomass always produced in the plots maintained at field capacity (Figure 2). However, while the waterlogged plots produced consistently less biomass than those at field capacity, the only statistically significant differences ($P<0.05$) were between plots at field capacity and 70% deficit in the second ratoon. These data suggest that water deficits (particularly in the drier second ratoon year, when 70% deficit was regularly attained) have a greater impact on early ratoon growth than waterlogging.

There were distinct differences in the amount of biomass produced per shoot in the various treatments in the second ratoon, with the drier soil water treatments (70% deficit and rainfed) obviously limiting growth during the ratooning period (Figure 3). There were no such limitations evident in the third ratoon. It was interesting to note that the normal irrigation method (70% deficit) produced significant growth limitations in all treatments during a dry ratooning period (second ratoon), and that there were no apparent

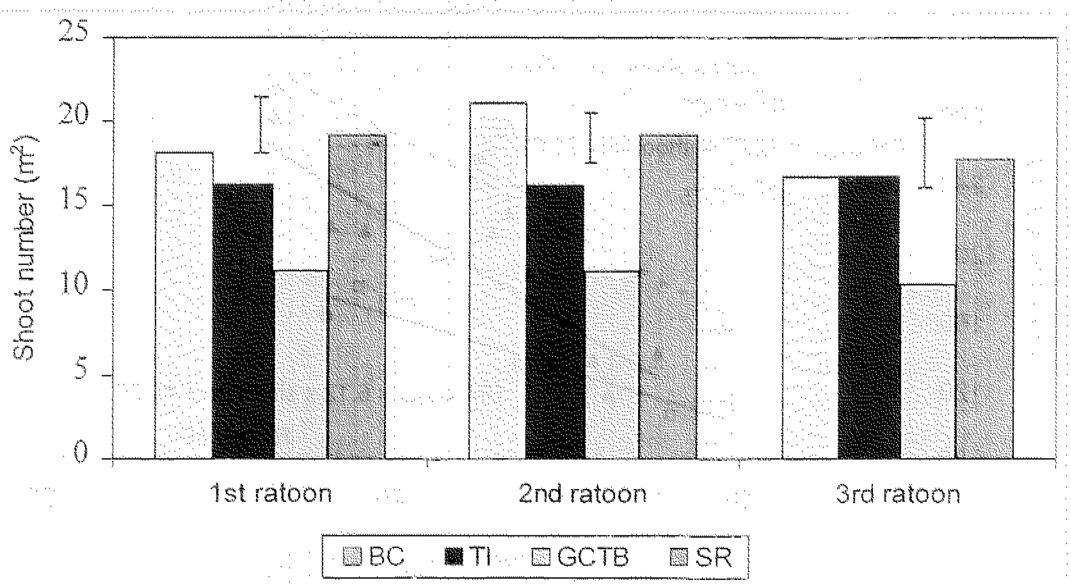

Fig. 1—Effects of trash management on shoot numbers (m^2) at the end of the ratoon establishment period. Vertical bars indicate lsd (0.05) values for each ratoon.

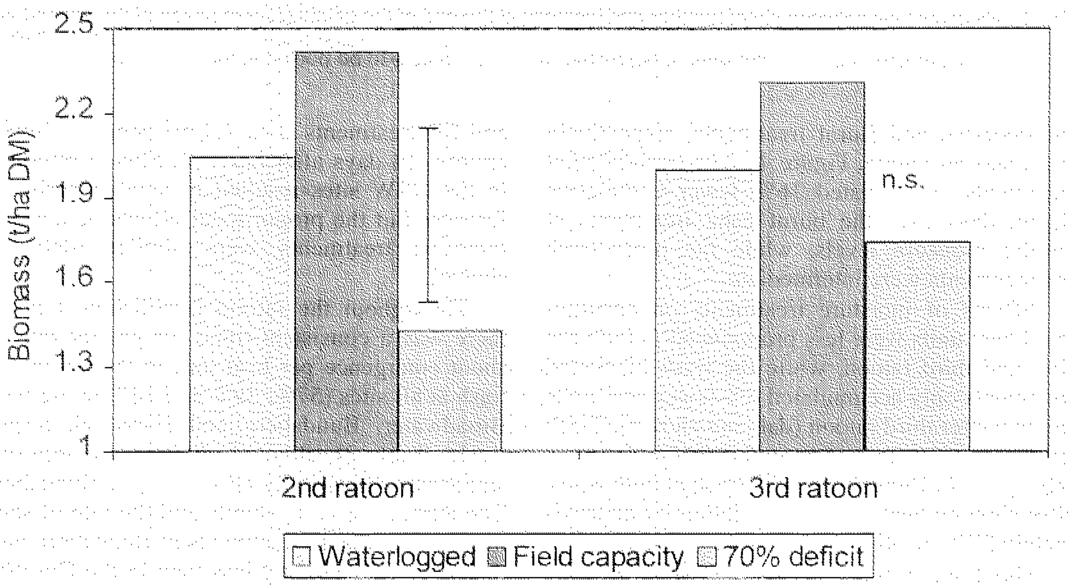

Fig. 2—Effect of soil moisture status on biomass accumulation during establishment of the second and third ratoons. The vertical bar denotes the lsd (0.05) for the second ratoon; n.s. indicates no significant difference.

effects of trash on growth per shoot. This suggests that trash management did not affect growth *per se*, so that if allelopathic effects of trash are important (Hurney and Ridge, 1994), they are likely to be affecting shoot number (e.g., by inhibiting germination) rather than reducing growth of individual shoots.

Both trash management and soil moisture significantly influenced soil temperature and accumulation of heat units, although the effects of moisture status were noticeably less under the trash blanket. Waterlogging reduced heat unit accumulation only minimally under the trash blanket, but by 19% and 25% in the Trash

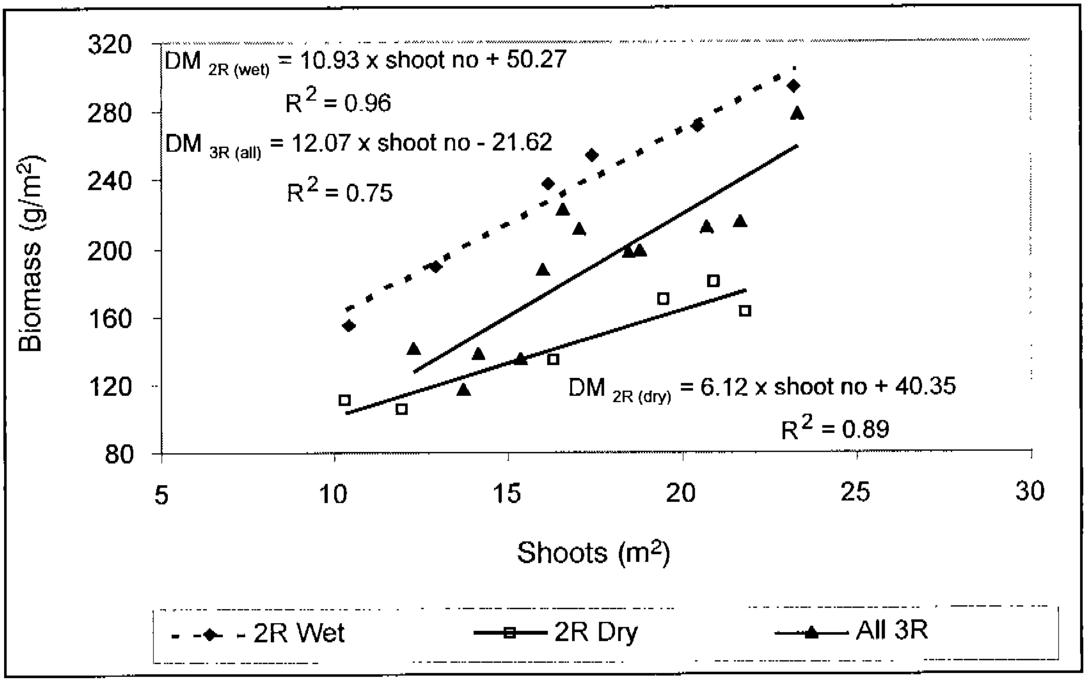

Fig. 3—Relationships between shoot number and biomass at the end of the establishment phase of the second and third ratoons. Wet (waterlogged and field capacity) and dry (70% deficit and rainfed) moisture regimes were separated in the second ratoon, but all treatments were able to be pooled in the third ratoon.

Incorporated and Burnt treatments, respectively (e.g., second ratoon, Figure 4). The trash blanket treatments accumulated 16% fewer cumulative degree-days than the burnt cane treatments at similar moisture levels, while the other trash managements were intermediate.

Effects of moisture treatments on accumulated heat units were less pronounced in both the first and third ratoon, while the trash blanketed treatments only accumulated 6% fewer heat units in the wetter third ratoon (data not shown). Trash had a stronger effect on heat unit accumulation in NSW than in Bundaberg, with trash at both NSW sites slowing heat unit accumulation by approximately 27%, relative to the bare treatment.

Shoot numbers and accumulated thermal time were strongly correlated within each trash management system ($R^2 > 0.85$) in all locations (Table 2). Data from the first and second ratoons at Bundaberg were able to be pooled for the common field capacity treatment, but the slight water stress experienced in the 70% deficit treatments in the second ratoon precluded pooling for this moisture level.

Differences in trash management caused similar responses in all ratoons at all sites. The GCTB treatment at Bundaberg produced less than half the number of early shoots than the BC and SR treatments (i.e., 1.4/m^2 versus 4.0/m^2 at approx. 14 days after harvest). Slower ratooning in the NSW sites resulted in smaller early differences but the proportional effects of the trash removed treatments were similar (data not shown).

Throughout the ratoon establishment period there was a consistent trend for greater rates of shoot emergence per heat unit in the absence of trash at all sites (57%, 39% and 14% increases at Broadwater, Bundaberg and Harwood, respectively; Table 2), although differences were only significant statistically ($P < 0.05$) at Bundaberg. The number of early shoots and the rate of shoot initiation in the TI treatments at Bundaberg were generally only slightly less than in the Burnt/SR treatments.

Meaningful comparisons cannot be made between the Bundaberg and northern NSW sites in terms of the rates of shoot emergence per heat unit, due to both varietal differences and concern about the validity of using a T_b of 11.5 °C for calculating thermal time. Liu *et al.* (1998) drew the distinction between tropical and sub-tropical varieties on the basis that the former needed to accumulate more heat units before reaching the emergence threshold. They showed Q124 and Q150 shoots emerged after 208 and 154 heat

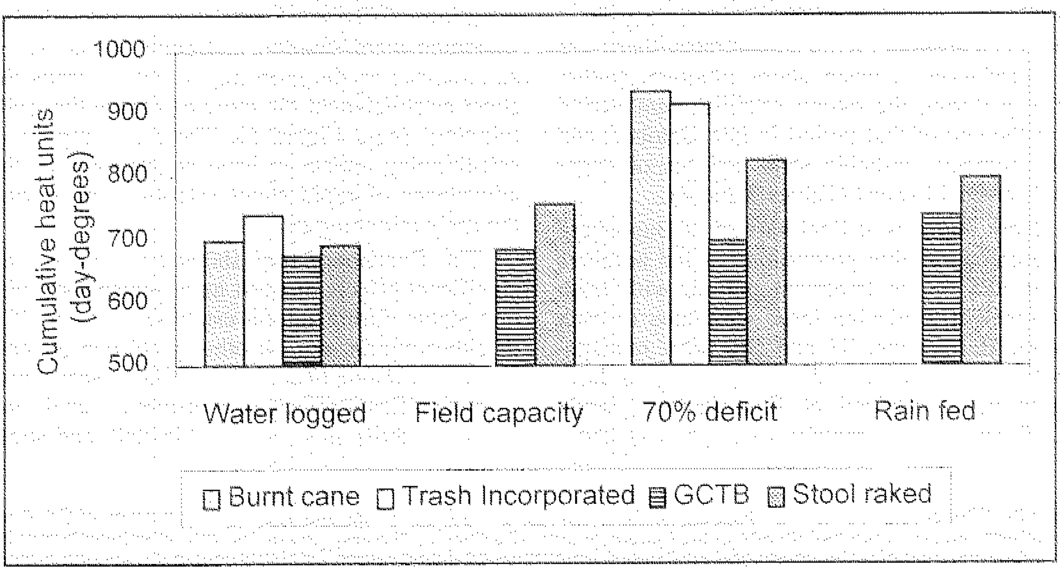

Fig. 4—Effects of trash management and soil moisture status on accumulated heat units during the second ratoon crop.

Table 2—Effects of trash management on rate of shoot emergence of Q150 (Bundaberg) and Q124 (Broadwater and Harwood). Values in brackets indicate standard errors of regression coefficients.

Location and variety	Trash management	Rate of shoot emergence (shoots/degree-day)
Bundaberg (Q150)	Burnt/stool raked GCTB	0.025 (± 0.002) 0.018 (± 0.001)
Broadwater (Q124)	Burnt/stool raked GCTB	0.011 (± 0.001) 0.007 (± 0.002)
Harwood (Q124)	Burnt/stool raked GCTB	0.008 (± 0.0003) 0.007 (± 0.0004)

units respectively, and this finding was consistent with the lower numbers of early shoots in the NSW sites in this paper. However, Liu *et al.* (1998) noted that even these comparisons were made on the basis of an untested premise of a common T_b for both varieties.

The T_b of 11.5 °C derived by Liu *et al.* (1998) was based on air temperatures. While there should be a general correlation between the air and soil temperatures at any site, variation in trash cover or soil moisture status would vary this relationship markedly. It was therefore not surprising that thermal time calculated from soil temperatures was found to be a more effective method of accounting for differences in shoot accumulation between trash managements or soil moisture conditions at a site. Any differences in apparent heat use efficiency between sites (Table 2) could simply be due to errors in the calculation of daily heat units. Further definitive studies on soil T_b for shoot establishment in different varieties would seem warranted before variation in ratoon establishment in cool, wet conditions can be better understood.

The response to stress at Bundaberg (either too much water or too little) was similar in all trash management systems, with shoot initiation rates reduced by approx. 15% (e.g., 0.014, 0.017 and 0.014 shoots/degree-day for the second ratoon GCTB waterlogged, field capacity and 70% deficit treatments, respectively). The reasons for these differences are unclear, but overall the data suggest cane trash over the stool inhibited shoot germination to a greater extent (*ca.* 30%, Table 2) than adverse soil moisture conditions.

Treatment effects on final yields at Bundaberg

The dynamics of stalk population development had no impact on yield at the Bundaberg site. Despite quite large differences in early shoot numbers and shoot establishment rates, there was no correlation between shoot numbers (either partway during the ratoon establishment period or at the end of that period in late October) and stalk numbers, millable stalk weights or sugar yields at final harvest (Tables 3 and 4).

Shoot numbers at final harvest in Bundaberg represented variable proportions of the numbers at the end of the treatment period, with trash management producing large variations in each ratoon. Burnt cane, TI and SR trash managements resulted in approx 50% (45–57) of early shoots being retained at final harvest, while GCTB saw approximately 75% (70–81) shoot retention. Effects of moisture status during ratooning were smaller, and could generally be summarised as the more rapid and vigorous the shoot establishment the more extensive the 'self-thinning' (e.g., Figure 5). These differences in self-thinning appear to have negated any of the advantages of rapid shoot establishment during the early ratooning period.

The Bundaberg trial showed there were no significant effects of trash management or moisture status during ratoon establishment on CCS in either ratoon, nor on other yield components in the first ratoon (Tables 3, 4). There were, however, significant effects of moisture status during ratoon establishment on millable stalk and sugar

Table 3—Effects of trash management on stalk number, yield and CCS of first and second ratoon crops of Q150 at Bundaberg. Values represent means of field capacity and 70% deficit water regimes during ratoon establishment in the first ratoon, and of waterlogged and 70% deficit water regimes during ratoon establishment in the second ratoon.

Trash management	Shoot no. at end of October	Millable stalk no.	Millable stalk (t/ha)	CCS (%)	Sugar yield (t/ha)
	First ratoon				
Burnt cane	18.1	9.3	145.9	11.82	17.2
Trash incorp.	21.1	9.6	145.9	12.23	17.9
GCTB	14.4	9.3	135.4	11.93	16.1
Stool raked	21.1	9.4	141.8	11.62	16.5
lsd (0.05)	2.36	n.s.	n.s.	n.s.	n.s.
	Second ratoon				
Burnt cane	21.1	9.3	108.8	12.19	13.3
Trash incorp.	16.2	9.3	109.5	12.36	13.6
GCTB	11.2	9.0	110.5	11.67	12.9
Stool raked	19.2	9.4	119.7	12.77	15.3
lsd (0.05)	3.1	n.s.	n.s.	n.s.	n.s.

Table 4—Effects of soil moisture status during the ratooning period on stalk number, yield and CCS of first and second ratoon crops of Q150 at Bundaberg. Values represent means of Stool Raked and Green Cane Trash Blanket management systems.

Moisture regime	Stalk no. at end of October	Millable stalk no.	Millable stalk (t/ha)	CCS (%)	Sugar yield (t/ha)
	First ratoon				
Field capacity	17.5	9.5	139.6	11.7	16.2
30% deficit	17.8	9.3	145.7	12.3	17.9
70% deficit	18.1	9.2	137.6	11.9	16.3
Rainfed	16.7	9.5	148.7	12.0	17.9
lsd (0.05)	n.s.	n.s.	n.s.	n.s.	n.s.
	Second ratoon				
Waterlogged	13.9	9.2	128.5	12.2	15.9
Field capacity	18.0	9.2	120.8	12.1	14.6
70% deficit	16.4	9.2	101.9	12.2	12.4
Rainfed	14.9	9.3	104.5	12.4	13.0
lsd (0.05)	3.1	n.s.	16.4	n.s.	2.3

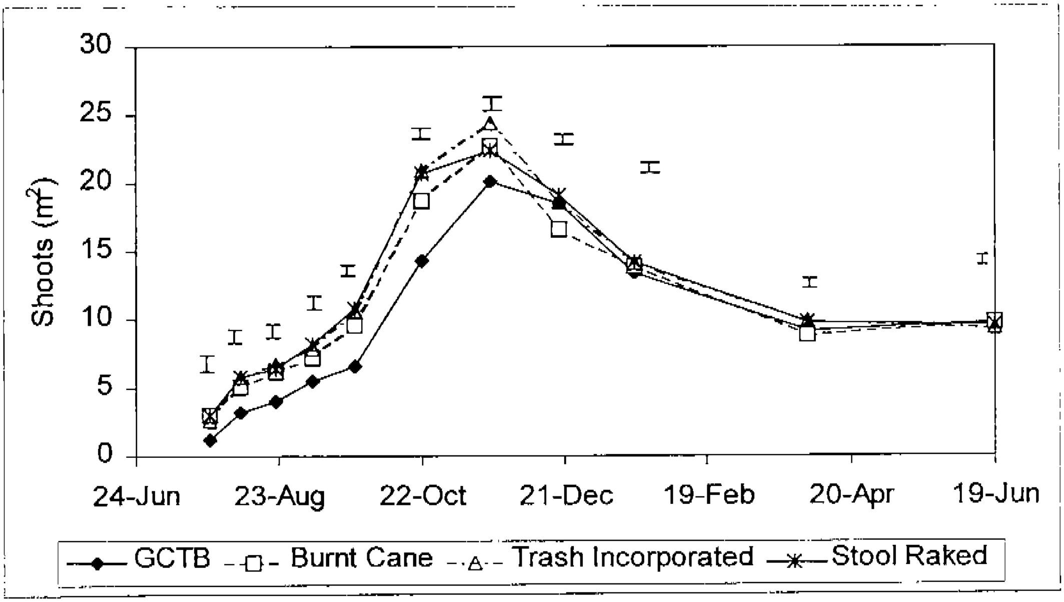

Fig. 5—Shoot numbers during the full growing season in the first ratoon cane crop at Bundaberg. Vertical bars represent average standard errors at each sample date (n=12).

yields in the second ratoon (Table 4), with higher millable stalk and sugar yields recorded in the wetter ratoon period treatments (waterlogged and field capacity).

The reasons for these yield differences in Q150 are unclear. All treatments were fertilised after the ratoon treatment period, and then irrigated uniformly through to maturity. It is possible that either subsequent irrigations may have been insufficient to fully re-wet the profile and remove earlier residual moisture differentials, or that these early moisture differentials may have differentially affected N release from trash to the second ratoon crop. While incomplete eradication of moisture differentials may have occurred in the drier second ratoon crop, the relatively low moisture holding capacity of the soil at this site suggests any residual effects would be relatively small in terms of extra soil water. The possible impact of soil moisture on trash decomposition and crop N uptake is currently being examined.

During the third ratoon, soil moisture is being closely monitored during the post-ratooning period, which will identify any differences in moisture status or root activity down the soil profile once the crops are returned to a common irrigation schedule.

Conclusions

Trash management and soil moisture status during ratoon establishment significantly affected shoot numbers and crop growth in early harvested sugarcane crops at Bundaberg and in northern NSW. However, no evidence was seen of any interaction between soil moisture status and trash management on ratoon establishment, despite some effects on final yields of millable stalk.

Variations in shoot numbers at all sites were a result of differences in the rate of accumulation of heat units (thermal time) and also the rate of shoot addition per unit of thermal time. Trash blanketing resulted in the least accumulated heat units of all trash managements, and also the slowest rate of shoot addition.

These data suggest that in areas like Bundaberg, adoption of GCTB management practices in early harvested crops is unlikely to result in ratoon failure—even during a wet ratooning period. Poor drainage can affect ratoon establishment, but this effect can occur under all trash management systems. Early ratooning is not a common practice in NSW, but if combined with GCTB, it may result in very slow establishment and significant losses in productivity.

Acknowledgments

The study at Bundaberg was conducted as part of the work program of the Sugar Yield Decline Joint Venture, with partial funding support from Sugar Industry Reference Panel. NSW experiments were part of the work program of the CRC for Sustainable Sugar

Production and were partly funded by the Sugar Research and Development Corporation. The contributions of Don Halpin, Stuart McSwan and Tony O'Connor, who provided land for the establishment of these studies, and the field assistance of Luca Pippia, Rod Davis, Peter Nielsen, Fraser Chapman, Don Parsons and Monika Anink are acknowledged.

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