

**BUREAU OF SUGAR EXPERIMENT STATIONS
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**FINAL REPORT - SRDC PROJECT BSS143
STRATEGIC TILLAGE TO REDUCE SOIL STRUCTURAL
DEGRADATION AND IMPROVE PRODUCTIVITY**

by

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	The ideal soil moisture for cultivation; and
	Strategic tillage saves dollars

SUMMARY

Focus groups of growers were convened to discuss industry attitude and reasons for non-adoption of reduced tillage planting. It was largely agreed that compared with ten to fifteen years ago the industry had moved to reduced tillage practices. The question the groups focused on was, why was it necessary to cultivate the whole block, why not just cultivate the old row? Opinion was expressed that land preparation was undertaken the way it was, generally because that is how it had always been done. Other reasons recorded were difficult soil types relating to soil moisture at the time of tillage; run-off and erosion; cultivation was one factor that could be controlled; risk of crop failure (poor emergence, but this could also be due to poor planting material); soil-borne diseases and insect pests; and the technique had not been thought about before. Benefits that were perceived included soil structure preservation, and saving of time and energy. During the discussions it was learnt that innovative growers were practising a version of strategic tillage, unknown to neighbouring growers.

Interest in the concept of strategic tillage was generated through these groups, to the extent that the strategy is being trialed by several growers.

Field trials were conducted at Tully and Bundaberg to compare conventional land preparation, where the whole area was cultivated, with strategic tillage where only the row was disturbed. Results demonstrated that reducing the number of cultivations did not compromise seedbed conditions at either site. This means that fewer tillage operations can be undertaken for the same end result. The inference is that time and energy can be conserved and that soil degradation can be minimised. Yield was not affected by a reduction in tillage for land preparation. With savings in time and energy, the costs of planting can be reduced.

Monitoring of the known soil-borne disease, *Pachymetra chaunorhiza*, showed greater levels under the susceptible variety compared with resistant variety grown at each site. The yield of the susceptible variety was lower than that of the resistant variety. Varietal rotation is suggested to limit or minimise the effect of *Pachymetra* under strategic tillage. The BSES plant breeding program is providing varieties of greater resistance for the northern areas. Caution in variety selection is required in the central and southern districts to minimise the effect of *Pachymetra*. New varieties being released have resistance to *Pachymetra*. Thus varietal rotation by growers (good hygienic practice) will minimise the effect of the soil-borne disease on productivity and allay concerns about planting directly back into the old row.

There was a trend for the number of earthworms to recover more rapidly under less soil disturbance. This is seen as a positive benefit in that earthworms create macroporosity which enhances water movement and aeration.

It is recommended that, for the sugar industry to derive the maximum benefit of strategic tillage, a system be developed using controlled traffic principles with direct drilling of cane, and a legume crop or green manure be included in the fallow period. Such a system will improve soil health over time, resulting in a more sustainable sugar industry with less dependence on chemicals for soil pest and soil-borne disease control. This will enhance the industry's environmental image.

1.0 BACKGROUND

Cultivation enhances soil degradation if conducted too often or when the soil is too wet (causing smearing and compaction), or when the soil is too dry (causing structural pulverisation). Soil degradation results in reduced productivity and off-site pollution due to erosion losses. Reduced tillage protects the soil resource by minimising structural degradation.

The establishment of a plant crop, although only occurring every fourth or fifth year, costs the industry between \$1,300 and \$1,500 per hectare. Land preparation for planting is a large component and is estimated to cost between \$250 and \$600 per hectare. If the number of tillage operations was reduced, savings of between 20% to 50% may be achieved in land preparation costs.

There is a need to reassess whether frequent cultivations are required and whether it is necessary to cultivate the whole area in preparation for planting. Harvesting during the previous crop cycle results in compaction of the inter-rows, and cultivation of this area results in cloddy conditions that require further tillage. This instigates a cycle of recompaction of loose material and decompaction that requires further tillage operations.

If strategic tillage was utilised to destroy the old stool without cultivating the inter-row area, a smaller percentage of the area would be cultivated and fewer passes would be required. This should result in considerable time and energy savings, and produce zones suitable for plant growth (the cultivated row) and zones suitable for machinery traffic (the undisturbed inter-rows). Reduced run-off and erosion will improve the image of the industry as an environmentally responsible steward of agricultural land.

The project was undertaken to assess the benefits of zonal tillage, where only the crop row is cultivated, leaving the compacted inter-row as a permanent traffic zone.

2.0 OBJECTIVES

1. Assess the industry attitude to and reasons for non-adoption of reduced tillage planting to identify acceptable strategies.
2. Compare the effect of conventional and reduced tillage land preparation on soil conditions at planting and subsequent crop growth.
3. Assess the status of soil-borne diseases and insect pests under reduced tillage planting.
4. Develop simple guidelines for tillage decisions.
5. Extend results to canegrowers.

3.0 MATERIALS AND METHODS

Field trials were established at Tully and Bundaberg on yellow earths. The sites were in 6th and 5th ratoon at the Tully and Bundaberg sites, respectively. The trials were planned to enable three consecutive years of planting and to continue each planting for three ratoons.

Planting occurred on 19 August 1996, 4 November 1997 and 21 June 1999 at Tully, and 18 October 1996, 23 September 1997 and 23 September 1998 at Bundaberg. Soil moisture was 7, 9 and 12% at Tully and 5, 8 and 6% (w/w) at Bundaberg for each year of planting, respectively. The soil at each site did not exhibit any plastic behaviour. Plots at Tully were not planted in 1998 due to wet seasonal conditions. Harvesting of plots was scheduled as close as possible to 12 months, with the exception of the late planting at Tully in 1997 where the crop was harvested at 10 months. This was to provide better ratooning conditions for the crop.

Trial design was the same at both sites with two varieties and four treatments arranged in three blocks. Q115 and Q117 were grown at Tully and Q138 and Q155 were grown at Bundaberg. Q117 and Q138 are resistant to the soil-borne disease *Pachymetra chaunorhiza*, while Q115 and Q155 are susceptible. The four treatments are detailed in Table 1.

Table 1: Tillage operations to instigate treatments at the Tully and Bundaberg sites

Treatment	Tully	Bundaberg ³
Conventional (T1)	1 x rotary hoe (0.15 m) 4 x offset disc 1 x rotary hoe Plant	1 x rotary hoe 2 x tine rip (0.5 m) 5 x disc 1 x rotary hoe Plant
Stool ploughout (T2)	1 x rotary hoe skim ¹ 2 x tine (0.3 m) ² Plant	1 x rotary hoe skim 1 x tine 2 x herbicide 1 x tine Plant
Stool sprayout (T3)	2 x herbicide 1 x rotary hoe skim 1 x tine Plant	3 x herbicide Plant
Ploughout replant (T4)	1 x rotary hoe skim 2 x tine Plant	1 x rotary hoe 2 x tine Plant

¹ Rotary hoe skim - the hoe just skimmed the surface of the hill to remove the old stool, chop and incorporate leaf material.

² Three tines were spaced to disturb sufficient soil for planting - a central tine and two set at the base of the hill (30-50 cm apart).

³ Trickle tape was installed prior to planting after the last tillage operation.

Conventional land preparation involves a number of tillage operations, usually discing, ripping and finishing with a rotary hoe (Photos 1 and 2). The strategic tillage concept involves only a shallow rotary hoe (Photo 3) along the old row to chop the old stool and leave it to desiccate on the surface and then a ripper tine with two spring tines to loosen the soil to depth and provide width for planting (Photo 4). The inter-row area is not disturbed. Stool sprayout involves spraying the ratooning crop (Photo 5) and then, prior to planting, generating a seed-bed by a shallow rotary hoe pass and the three tines.



1. Conventional tillage



2. Conventional tillage



3. Strategic tillage



4. Strategic tillage



5. Stool sprayout



6. Little difference in crop growth

3.1 Measurements

Soil measurements

Soil bulk density was measured before treatment instigation and after harvest of the plant crop. Image analysis of soil structure was also undertaken (Moran *et al.*, 1989). Soil strength to a depth of 0.6 m was measured using a recording cone penetrometer. Seed-bed conditions after planting were measured (Håkansson, 1990) as was the effect of cultivation on aggregate stability. To assess the effect of tillage strategies on soil biological factors, soil fauna counts (Robertson *et al.*, 1994) and counts of *Pachymetra* spores (Magarey, 1989) were undertaken each season.

An instrumented tractor was used to determine fuel use and time taken during land preparation operations at Bundaberg. Equipment failure on the tractor at Tully resulted in the loss of similar data for that site. Results for Bundaberg are presented in Appendix 1.

Crop measurements

Stalk population was monitored during the season. Gappiness of the stand was assessed before and after each harvest. Final yield was determined by mechanically harvesting and weighing the four central rows at Tully, and hand harvesting a five-metre length from the two central rows and weighing stalks after removal of leaves and tops at Bundaberg. This enabled the effect of the various tillage strategies on tonnes cane per hectare, ccs and tonnes sugar per hectare to be determined. Plot size at Tully was 6 rows by 1.5 m spacing by 20 m long, while at Bundaberg it was 7 rows by 1.5 m spacing by 15 m long.

There were three replicates of each treatment, with data being analysed by standard analysis of variance techniques using the Statistix software package.

4.0 RESULTS

Objective 1

Assess the industry attitude to and reasons for non-adoption of reduced tillage planting to identify acceptable strategies.

To address this objective a series of focus group meetings was convened and discussions with individual growers were conducted. The questions posed to the groups and a summary of responses are provided in Appendix 2.

In summary, the general attitude was that soil conditions for planting was something that the individual had some control over. Cultivation for planting was done the way it was because that was the way it had always been done. There was the risk of not getting good crop establishment and this risk was minimised by cultivation operations.

Most growers had indeed reduced the number of tillage operations for land preparation, but had not considered the option of only cultivating the planting row. Both advantages and disadvantages, in only cultivating the row, were perceived by growers. The main advantages were that a smaller area was cultivated saving fuel, time and wear and tear on equipment, and being able to harvest under adverse seasonal conditions. Disadvantages were difficulty in cultivating blocks of variable soil types; the need to remove compacted zones; concern about potential increase in chemical use; a lack of long-term trial data; and that trials had not been undertaken in each area.

The concept of only cultivating the row was considered reasonable, notwithstanding the concerns expressed above. The techniques employed to remove the old stool and generate a seed-bed were generally agreed to be feasible, and using a rotary hoe and ripper tines was relatively easy to implement. The issue of only doing one row at a time was not favoured, but to do two rows involved trafficking the rows being cultivated. This was seen as a reasonable compromise because several growers were in fact doing this already, albeit for different reasons. It is thought that if suitable equipment was available more growers would adopt the concept of minimum tillage planting where only the row was cultivated. There are several growers currently trialing the concept of strategic tillage.

Objective one has been achieved.

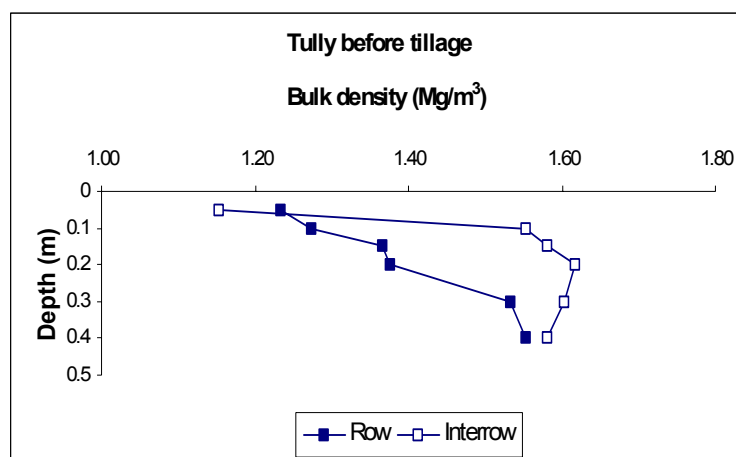
Objective 2

Compare the effect of conventional and reduced tillage land preparation on soil conditions at planting and subsequent crop growth.

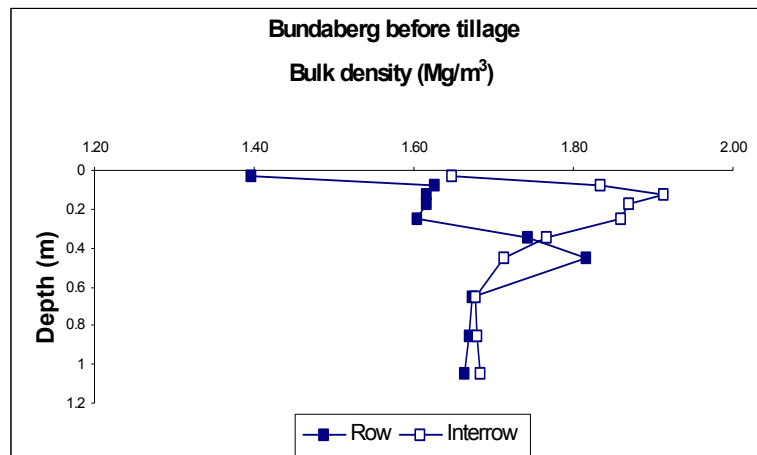
Measurements of soil bulk density were undertaken prior to and after cultivation to determine the changed effected, and the degree to which the difference between the crop row and inter-row could be maintained under strategic tillage. There were distinct differences in bulk density between the row and inter-row, which had developed during harvesting of the crop at both sites, with the row being less dense than the inter-row (Figure 1a, 1b).

Figure 1: Difference in bulk density (Mg/m^3) between the row and inter-row at (a) Tully and (b) Bundaberg

(a)



(b)



These differences can also be seen in the images of soil structure from the Tully site at "Day 1". The undisturbed tree-line soil shows the best structural condition (Image 1c), followed by the row (Image 1a) and the inter-row, the worst (Image 1b).

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Depth (cm)

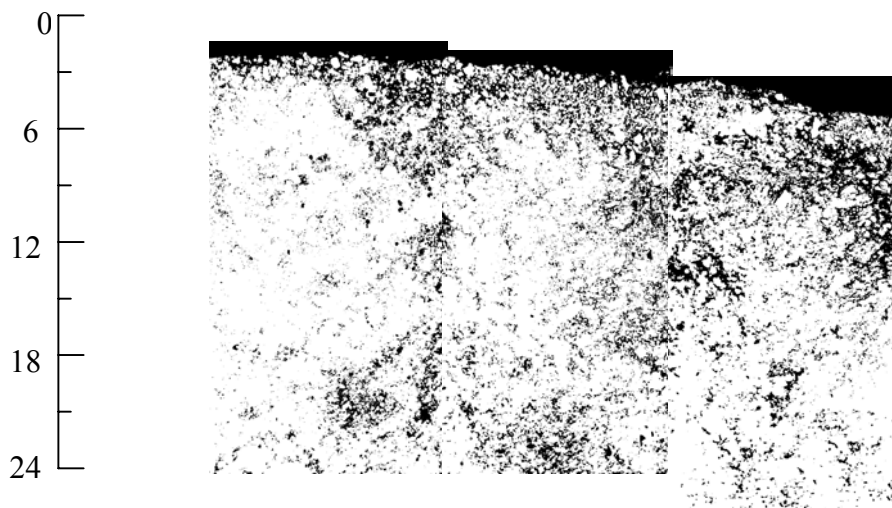


Image 1a Row soil structure

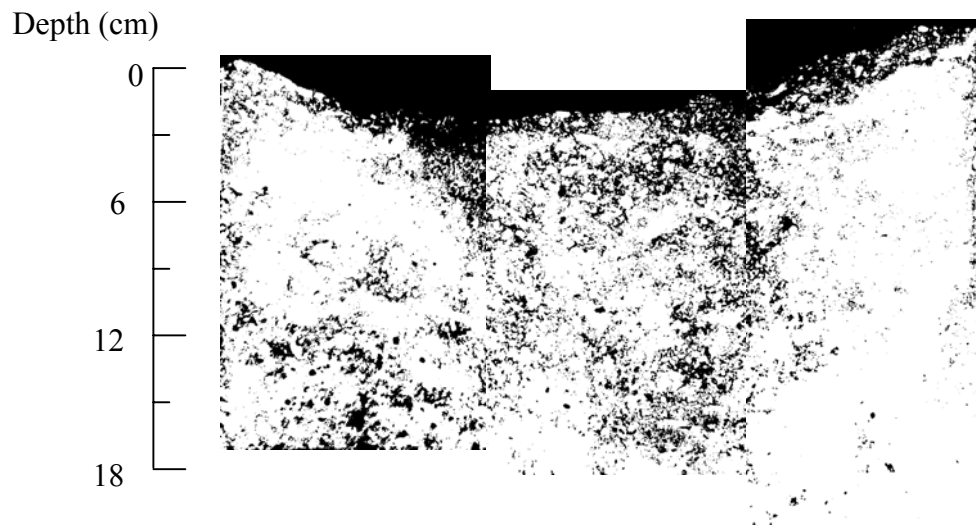


Image 1b Inter-row soil structure

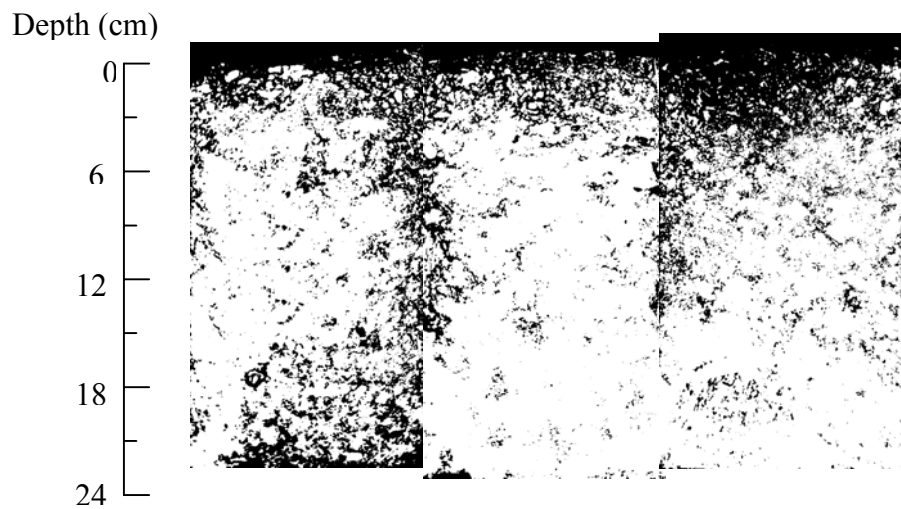
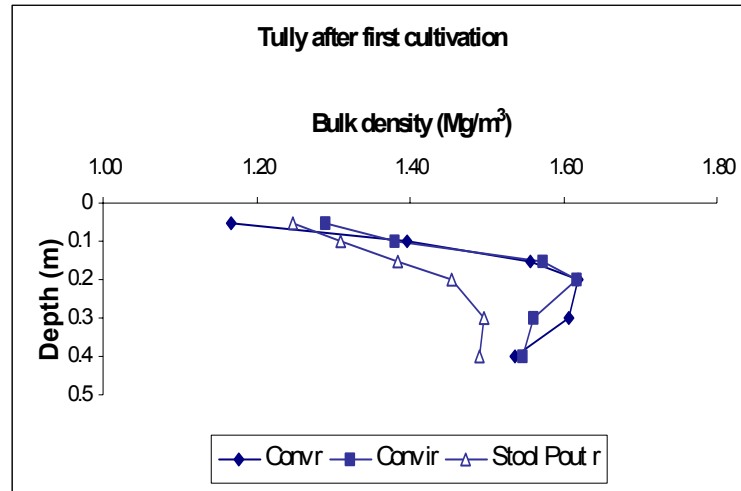


Image 1c Tree-line soil structure

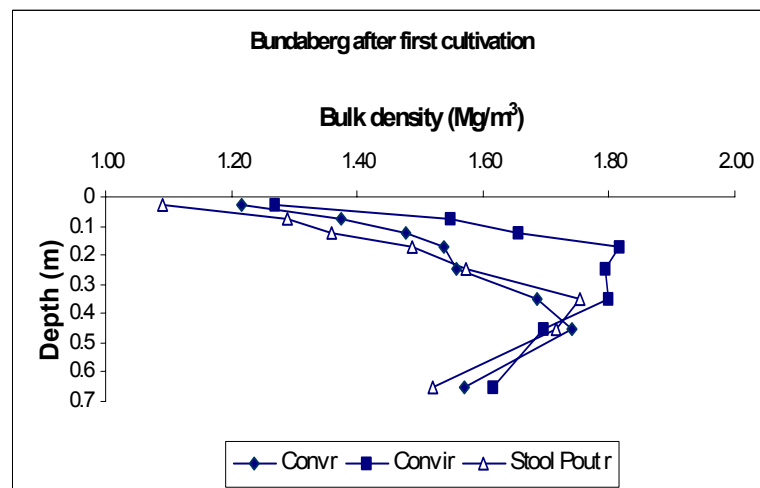
After the first cultivation operation, the surface density has decreased at both sites; however, there has been little change in the inter-row density with depth (Figure 2). In fact, the row density at Tully closely follows that of the inter-row, suggesting some recompaction has occurred during the cultivation operation (Figure 2a).

Figure 2: Changes in bulk density (Mg/m^3) after one cultivation at (a) Tully and (b) Bundaberg.

(a)



(b)



Soil strength measurements from the Tully site also indicate the difference between the row and inter-row position that exists at the end of a crop cycle (Figure 3a).

Figure 3a: Soil strength (kPa) profile of Tully trial site before tillage, indicating zones of lower strength under the row.

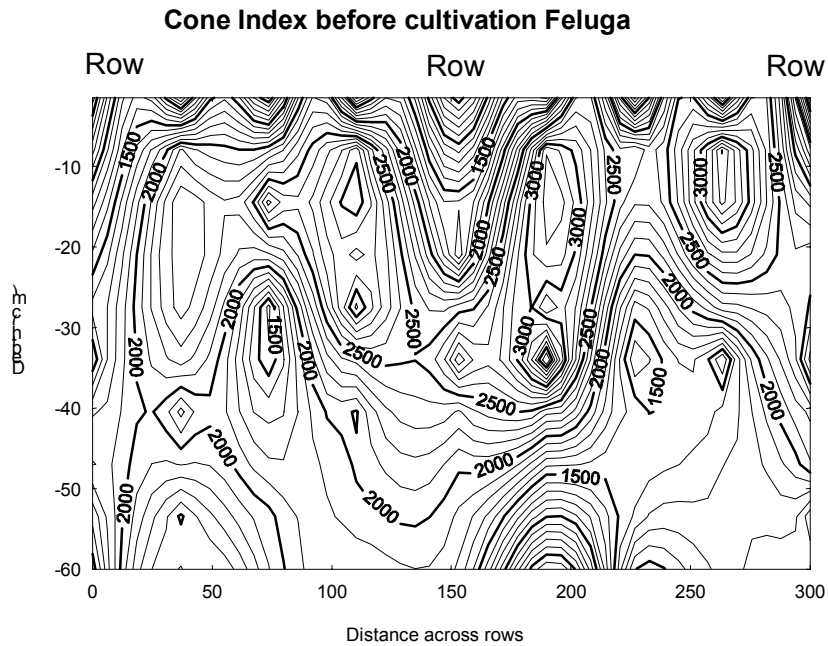


Figure 3b: Soil strength (kPa) profile after two discings at Tully, showing homogenisation of pattern (horizontal orientation) and recompaction of loose material (thumb prints).

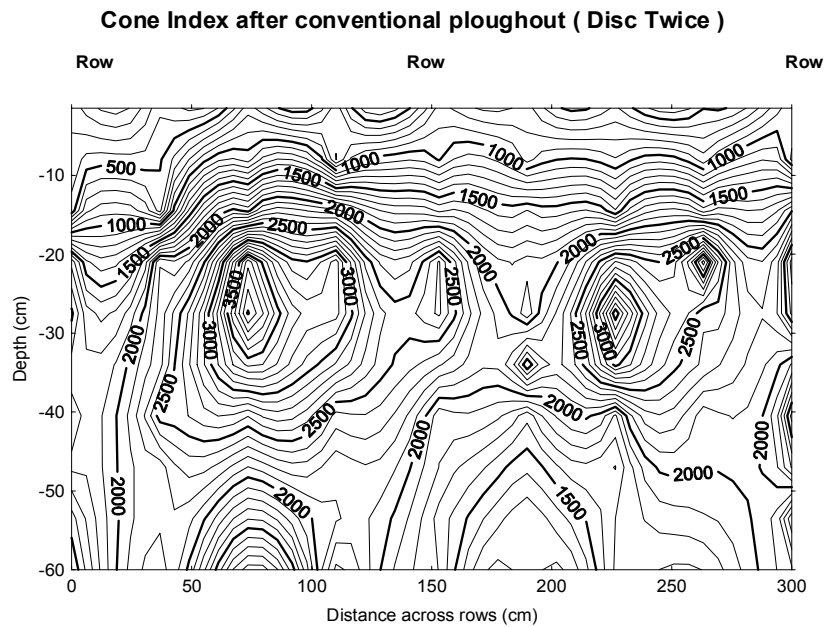
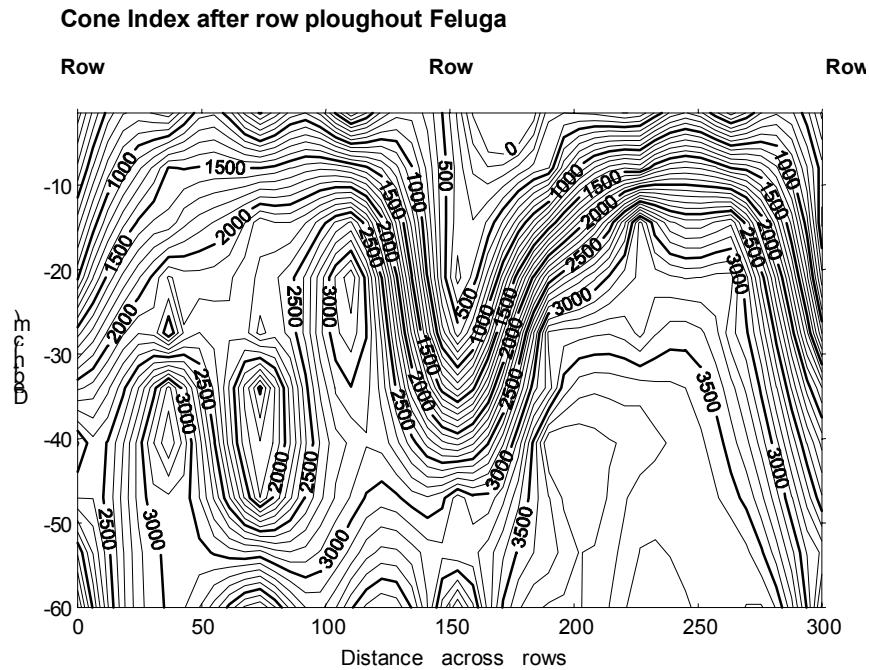


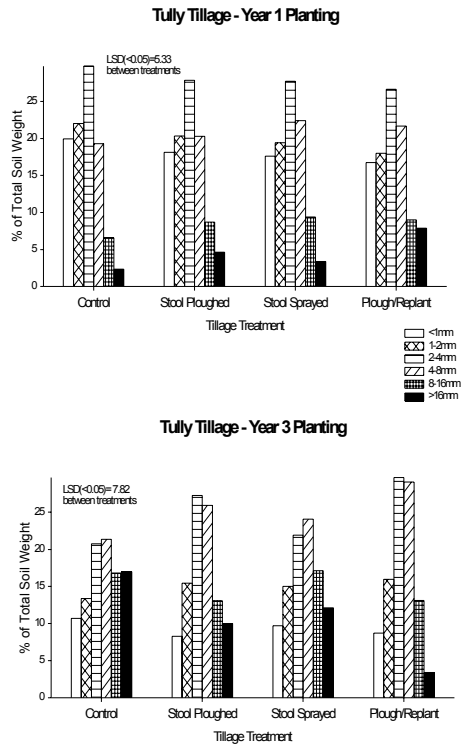
Figure 3c: Soil strength (kPa) profile after stool ploughout at Tully, showing the maintenance of low (row) and high (inter-row) strength zones. Similar pattern to before cultivation (Figure 3a).



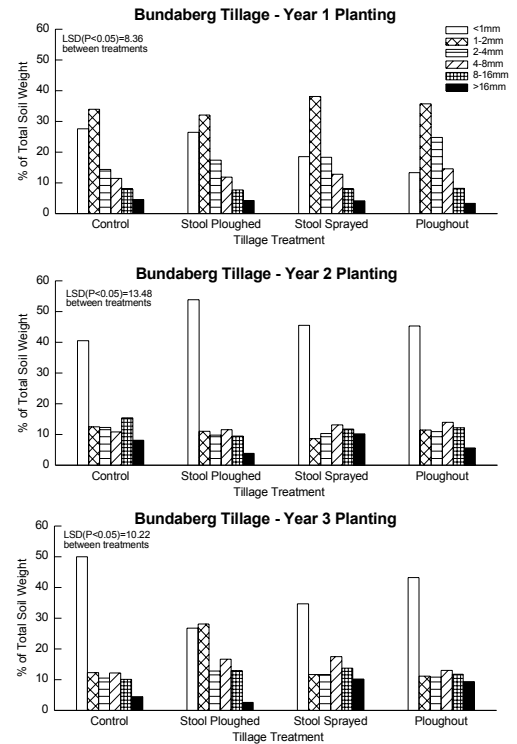
After cultivation there is some mixing and homogenisation of the row and inter-row with respect to soil strength as indicated by the horizontal pattern compared with a more vertical orientation that existed prior to cultivation. This orientation suggests that a plough pan is beginning to develop at the depth of cultivation (15-20 cm). After cultivating the row only, a similar pattern of soil strength is observed to that at the end of a crop cycle (compare Figures 3a and 3c). The main difference between the two is that after the recent tillage operation a larger volume of soil under the row is weaker compared with before cultivation. The difference between the row and inter-row has been effectively maintained. This has implications for tractor efficiency and harvesting under wet soil conditions. Assessment of seed-bed conditions after planting at both sites, by determining the aggregate size distribution, shows that similar aggregate distributions occur under all tillage strategies (Figure 4). There are differences between the two sites, which reflect differences in soil moisture at tillage and the sequence and number of operations. Generally, coarser seed-beds were generated at Tully (1-8 mm, Figure 4a) compared with Bundaberg, where finer conditions were evident (<1-4 mm, Figure 4b). Aggregate size distribution does not differ between tillage strategies, indicating that seed-beds are not compromised by reducing the number of operations. This provides potential for cost savings to be made in land preparation for planting.

Figure 4: Seed-bed aggregate size distribution in the seed-bed after planting at (a) Tully and (b) Bundaberg.

a)



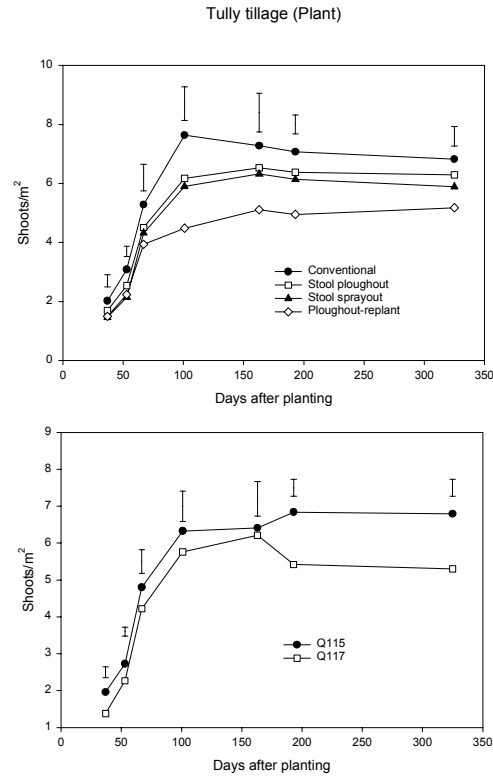
b)



The implication of the above is that under conventional cultivation, with respect to bulk density, there is potential to create a condition that is worse than that which existed before cultivation. It is also questionable as to how effective the operation was in removing soil compaction in the inter-row, which is one objective of tillage. The soil strength profiles show that it is possible to maintain the difference between the row and inter-row (one of the objectives of strategic tillage) and that under conventional tillage there is potential to create a pan at, or slightly below, the depth of tillage after two operations.

Data on stalk population for year 1 planting at Tully are provided as an indication of crop performance at each site. The stalk population response for the subsequent year 2 and year 3 planting was similar to year 1. There was no significant difference in stalk populations between the conventional, stool ploughout and stool sprayout treatments at Tully (Figure 5). At Tully, the stalk population for the ploughout-replant treatment was significantly lower than all other treatments. At Bundaberg, there was no significant difference between any of the tillage treatments (data not shown). Crop performance was not compromised by the reduction in tillage operations prior to planting.

Figure 5: Stalk populations (shoots/m²) for each tillage treatment and variety at Tully for Year 1 planting.



With respect to yield parameters, there were very few significant differences between tillage treatments at both sites (Tables 2 and 3). The general trend was that the yield of one of the strategic tillage treatments to be greater than the conventional tillage, but not significantly so. The ploughout-replant treatment tended to produce lower yields compared with the strategic tilled and conventional plots. There were, however, some exceptions. There is no reason to expect a yield increase from increasing the number of cultivations. In cereals, the same yield has been achieved from cultivated and direct drilled treatments (Holland *et al.*, 1987).

Table 2: Yield parameters for each year of planting and treatment at Tully (Treatments per Table 1)

Site	Treatment	TCPH	CCS	TSPH	
Plant Tully Planted 19/08/1996	T1	81.4	13.8	11.2	
	T2	76	13.8	10.4	
	T3	76.3	13.7	10.4	
	T4	71.4	13.9	9.9	
	lsd	9	ns	ns	
	1R	T1	90.1	14.6	13.2
		T2	90.8	14.9	13.5
		T3	82.7	15.5	12.8
		T4	88.5	15	13.2
		lsd	ns	0.8	ns
	2R	T1	77.7	15.9	12.3
		T2	77.4	15.6	12
		T3	76.5	15.9	12.1
		T4	71.8	16	11.5
		lsd	ns	ns	ns
3R	T1	50.7	13.8	7	
	T2	44.7	14.4	6.4	
	T3	49.7	13.9	6.8	
	T4	45.5	14.3	6.5	
	lsd	ns	ns	ns	
Plant Tully Planted 4/11/97	T1	50.3	15	7.5	
	T2	55.8	14.3	8	
	T3	54.2	14.4	7.8	
	T4	46.3	14.6	6.7	
	lsd	ns	0.6	ns	
	1R	T1	86.7	15.4	13.3
		T2	94.9	15.2	14.5
		T3	98.9	15.4	15.3
		T4	93	15.6	14.5
		lsd	10.6	ns	1.6
	2R	T1	57.6	14.4	8.3
		T2	61.1	14.5	8.8
		T3	67.2	13.8	9.3
		T4	59.6	14.4	8.6
		lsd	ns	ns	ns
Plant Tully Planted 21/06/1999	T1	63.9	13.4	8.6	
	T2	54.9	13.6	7.5	
	T3	56.7	13.5	7.6	
	T4	52.1	13.8	7.2	
	lsd	6.6	ns	0.9	

Table 3: Yield parameters for each year of planting and treatment at Bundaberg (Treatments per Table 1)

Site Plant	Treatment	TCPH	CCS	TSPH	
Bundaberg Planted 18/10/1996	T1	105	15.5	16.3	
	T2	101.1	15.1	15.3	
	T3	108.5	15.6	16.8	
	T4	97.5	15.5	15	
	lsd	ns	ns	1.7	
	1R	T1	107.1	14.4	15.4
		T2	113.3	14.2	16
		T3	110.1	14.8	16.2
		T4	107.4	14.7	15.7
		lsd	ns	ns	ns
	2R	T1	90.7	15.3	13.8
		T2	96.7	15.4	14.9
		T3	96.2	15.3	14.7
T4		89.9	15.4	13.8	
lsd		ns	ns	ns	
3R	T1	97.7	14	13.6	
	T2	105.3	14.4	15.1	
	T3	100.2	13.7	13.7	
	T4	95.2	14.2	13.3	
	lsd	ns	ns	ns	
Bundaberg Planted 23/09/1997	T1	107.8	14.3	15.4	
	T2	106.8	13.8	14.7	
	T3	106	14	14.8	
	T4	91.7	13.6	12.5	
	lsd	ns	ns	2.8	
	1R	T1	103	14.9	15.3
		T2	100.2	15	15
		T3	105.6	14.9	15.6
		T4	92.8	14.8	13.7
		lsd	ns	ns	1.8
	2R	T1	116.3	14.5	16.8
		T2	113.5	14.5	16.4
		T3	113.6	14	15.8
T4		111.9	14.3	16	
lsd		ns	ns	ns	
Bundaberg Planted 23/09/1998	T1	48.2	13.7	6.5	
	T2	44.7	12.5	5.5	
	T3	46.3	12.3	5.7	
	T4	42.1	13.5	5.7	
	lsd	ns	ns	ns	

Harvestability of the crop was determined by assessing the gappiness of each ratoon. The number of gaps increased as the crop aged (Table 4). The conventional cultivated plots had significantly fewer gaps than the strategic tillage plots for all crop classes. This had little effect on crop performance in that the strategic tillage plots tended to produce slightly greater yield compared with the conventional plots (see Tables 2 and 3). The fact that gaps increased throughout the ratoon cycle is consistent with harvester damage, and this is greater under the strategic tillage systems. It should be noted that the high number was largely due to one variety in each of the trials; namely, Q117 at Tully and Q155 at Bundaberg. Varietal selection may be important for planting when using strategic tillage techniques. It is not known whether this may be related to the rooting pattern of particular varieties, or whether some varieties are more susceptible to harvester damage than others.

Table 4: The number of gaps (%) for each treatment as in Table 1 to assess harvestability of tillage treatments

Site	Treatment	Year 1						Year 2						Year 3			
		1R		2R		3R		Plant		1R		2R		Plant			
		Q115	Q117	Q115	Q117	Q115	Q117	Q115	Q117	Q115	Q117	Q115	Q117	Q115	Q117	Q115	Q117
Tully	T1	7.5	5.4	8.8	7.5	10.0	6.3	17.9	10.4	11.3	7.1	12.5	8.3	8.3	10.8	7.1	4.6
	T2	11.7	17.1	10.4	20.8	15.0	20.4	11.3	18.8	6.3	13.8	5.8	17.9	13.3	6.7	9.6	8.3
	T3	7.5	17.1	10.0	22.9	8.3	26.3	10.4	22.9	7.5	21.7	12.5	20.8	10.0	10.8	12.5	16.3
	T4	12.5	19.2	14.2	24.2	21.7	23.3	20.0	24.2	17.9	19.6	19.2	29.2	12.5	10.8	7.1	9.6
	trt*var LSD (P<0.05)	11.00		8.50		10.76		13.80		12.20		12.02		9.40		7.42	
		Q155	Q138	Q155	Q138	Q155	Q138	Q155	Q138	Q155	Q138	Q155	Q138	Q155	Q138	Q155	Q138
Bundaberg	T1	13.3	7.8					12.2	1.1					7.8	7.8		
	T2	7.8	3.3					4.4	0.0					16.7	3.3		
	T3	15.6	5.6					10.0	6.7					22.2	8.9		
	T4	13.3	6.7					10.0	3.3					12.2	12.2		
	trt*var LSD (P<0.05)	9.50						7.60						12.5			

Results show that seed-bed conditions are not compromised by a reduction in the number of cultivations to generate them. Crop yield was not significantly affected by reduced cultivation. There were few significant differences between tillage treatments for any of the yield parameters measured.

Objective 2 has been achieved.

Objective 3

Assess the status of soil-borne diseases and insect pests under reduced tillage planting.

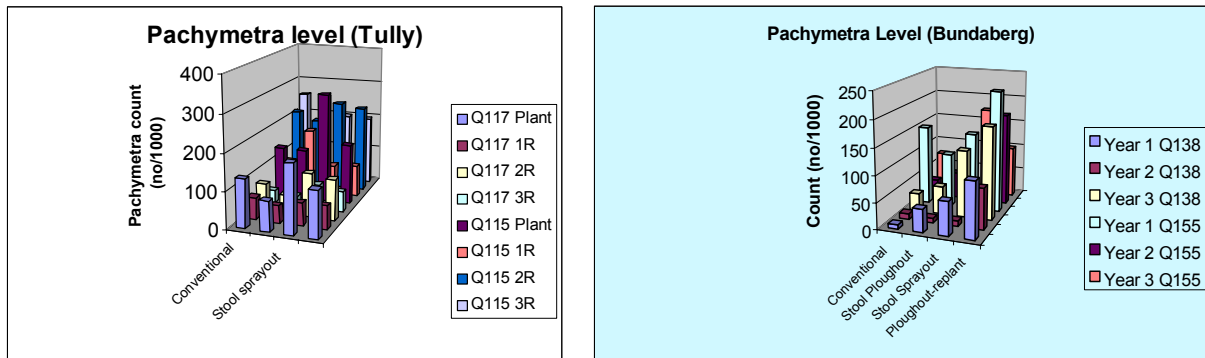
The concept of strategic tillage involves only disturbing the row, leaving the inter-row intact, and planting back into the old row position. Concern has been expressed about the buildup of soil-borne diseases by this practice and an increased risk of soil insect pests.

No soil insect pests have been detected at either site for the duration of the trial. It appears that the presence or absence of soil insects is a hit and miss situation. There is no reason to suspect that reducing the amount of tillage for land preparation predisposes an area to insect infestation or not.

Both sites were known to be infected with the soil-borne disease of *Pachymetra chaunorhiza*. To test the effect of *Pachymetra* on crop yield, two varieties were grown, one susceptible and one resistant to *Pachymetra*. At both sites, levels of *Pachymetra* were greater under the susceptible variety compared with the resistant variety (Figure 6). A similar observation has been made by Croft and Saunders (1996). This was

reflected in the yield of each variety as well (Tables 2, 3). This suggests that varietal rotation will minimise the effect of the soil-borne disease, *Pachymetra*. Also, the new varieties from the BSES breeding program for the northern areas have resistant ratings to *Pachymetra*, thus allaying fear of planting back into the old row using strategic tillage. Care needs to be exercised in the southern and central districts to select varieties with the highest *Pachymetra* resistance ratings to minimise yield losses.

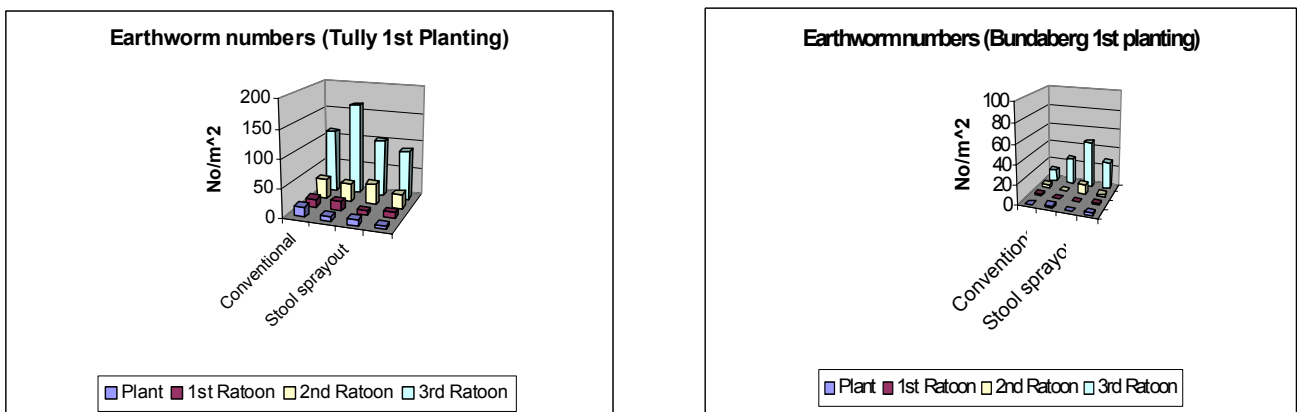
Figure 6: Levels of *Pachymetra chaunorhiza* inoculum under each tillage treatment for year 1 planting at Tully and each plant crop at Bundaberg.



A positive result from the trials is with respect to earthworm numbers. Earthworms are considered to be beneficial soil fauna in that they create pathways for water and air movement and for root growth. Earthworms also incorporate organic materials and contribute to soil aggregate stability.

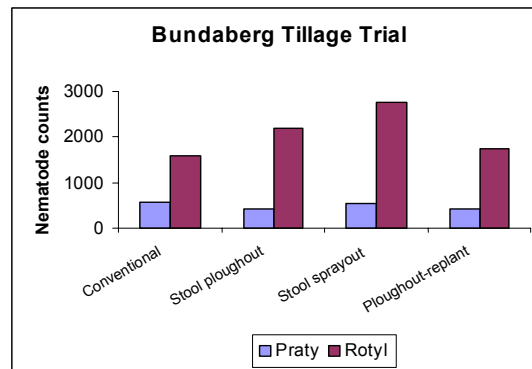
Monitoring of earthworm numbers in the first planting at Tully and Bundaberg shows that numbers build up more rapidly and to greater numbers under strategic tillage compared with conventional tillage (Figure 7). This is more evident at Bundaberg than at Tully. Data for year two and year three planting show a similar trend (data not presented).

Figure 7: Earthworm numbers under each tillage treatment for the year 1 planting at Tully and Bundaberg.



Nematode populations were assessed for the Bundaberg site only. Counts for the two most prevalent nematodes, *Pratylenchus zaei* and *Rotylenchus*, are shown in Figure 8. There was no difference in the numbers of *P. zaei* under any of the tillage treatments, but there were greater numbers of *Rotylenchus* under all treatments, especially the stool sprayout strategy. It is not known why this difference occurred. A possible explanation is that an effective kill of the crop was not achieved by spraying, enabling nematode numbers to build up on/in the surviving roots, but why one type of nematode should increase at the expense of the others is unknown. It should be remembered that the stool sprayout was a six month fallow prior to planting. This tends to contrast the *Pachymetra* counts, which were greater under the ploughout-replant treatment, but generally not significantly so from the stool-sprayout treatment. There is little indication that reducing the number of tillage operations predisposes the crop to infestation by nematodes or *Pachymetra*. Seasonal conditions may be a greater influence on the buildup of soil-borne diseases and pests over and above that of cultural operations.

Figure 8: Nematode numbers under each tillage treatment at Bundaberg.



From results to date, the use of resistant varieties offers a means of minimising yield loss due to *Pachymetra*. Long-term information is required to confirm the longevity or sustainability of this strategy. The buildup of earthworms is a positive indicator that less soil disturbance may enhance beneficial soil organisms.

Objective three has been achieved.

Objective 4

Develop simple guidelines for tillage decisions.

No specific experiments were conducted to achieve this objective. Literature sources and the collective experience of the principal researchers were utilised to establish the simple guidelines for tillage decisions, and these have been written up as an article for publication in industry publications. A copy is appended to this report.

A further publication has been produced alerting the industry to strategies to cope with or manage soil compaction for benefit. This contains information regarding tillage operations and is a further source of information. A copy is appended to this report.

Objective four has been achieved.

Objective 5

Extend results to canegrowers.

Results from this project have been widely extended to the sugar industry. Articles have been published in the BSES Bulletin, Australian Sugarcane Journal and the Australian Canegrowers magazine. Results have been presented at ASSCT Conferences and at BSES field days.

Presentations on strategic tillage have been made at information meetings conducted by the Sugar Yield Decline Joint Venture throughout the State as well as FutureProfit meetings conducted by Queensland Department of Primary Industries. Presentations have also been made at an invitation meeting of the Ingham Young Farmers Group, as well as meetings conducted by Sugar Solutions throughout the northern areas of the sugar industry.

The results from the project have been widely extended throughout the sugar industry. Feedback from extension officers and individual growers suggests that interest in strategic tillage is increasing to the extent that growers are trialing areas for themselves.

Objective five has been achieved.

5.0 DISCUSSION

The sugar industry practises intensive cultural operations in generating a seed-bed for planting. In doing so, there is some concern about the effectiveness of these operations in achieving the desired result. Generally, the first tillage operation is the most effective in loosening the soil, with the rest tending to rearrange the loosened material and recompact it. Each operation is a cost to the grower and results in accelerated soil degradation. Degradation occurs due to exposure and oxidation of organic material reducing structural stability. Also, losses of stored soil moisture, disruption of continuous macropores, disturbance of soil biology; namely, earthworms, and soil compaction can occur, the removal of which was one of the original objectives of tillage.

The project has effectively demonstrated that reducing the number of tillage operations has not compromised seed-bed conditions, and as a result crop performance has not been significantly affected. There is some misconception that reducing the number of tillage operations will result in reduced yield.

The results indicate that yield is not compromised by reducing the number of tillage operations. There were very few significant differences between tillage treatments for any yield parameter measured. There is no reason to expect a gain in yield through repeated manipulation of the soil. In fact, the reverse is quite often the case, due to soil

moisture loss and recompaction of soil. Harvestability of the crop was similar under all tillage treatments, with the number of gaps increasing as the crop class increased. There was a significant difference between varieties at Tully with fewer gaps under Q115 compared with Q117. A similar situation occurred at Bundaberg with Q155 having a greater number of gaps compared with Q138. Varietal selection may influence the harvestability under strategic tillage for planting, but this requires further testing.

A major industry concern with strategic tillage was the increased soil-borne disease and soil insect pest incidence due to planting directly back in the old row. BSES had previously advised against this practice to minimise the effect of soil-borne diseases on productivity. Results from this project show that reduced tillage and planting directly back into the old row have not compromised productivity. Two varieties were grown at each trial site to assess the effect of varietal resistance to the soil-borne disease of *Pachymetra*. The resistant variety had the greatest yield at both sites compared with the susceptible variety (Braunack *et al.*, 1999). Levels of *Pachymetra* were lower under the resistant variety. This suggests that plant breeding for *Pachymetra* resistance produced and continues to produce varieties resistant to this disease. Varietal rotation offers a solution to the concern by industry of planting directly back into the old rows. Soil insect pests were not a serious problem at either trial site. It is thought that reducing tillage will not predispose the crop to infestation, which if it happens was probably going to occur anyway.

A reduction in soil disturbance is seen as being beneficial in terms of soil invertebrates and soil biodiversity. There were greater numbers of earthworms in treatments where less soil cultivation occurred. Earthworms are seen as being beneficial because they create macroporosity, which improves water movement and aeration. These pores are destroyed during tillage. There is some evidence that less soil disturbance may be beneficial as part of the IPM strategy for canegrub suppression.

The benefits from reducing cultivation for land preparation and planting will not be immediate, but will accrue in the medium to longterm. It is speculated that as soil structure improves, soil water relations and soil biodiversity will change. This may translate into fewer irrigations, improved crop tolerance of drought periods, less reliance on chemicals for disease and pest control, less run-off and erosion, and most importantly an improved image of the industry's image as a custodian of agricultural land.

6.0 RECOMMENDATIONS

The concept of strategic tillage land preparation and planting needs to be tested for the establishment of a second crop cycle to determine the robustness of the system. It is recommended that, on the current trial site at Tully, a second crop cycle be established using strategic tillage, but with varieties being rotated. This would address industry concern about planting back into the old row, and it would enable monitoring soil-borne disease and earthworms in relation to soil disturbance.

This project was undertaken using current field conditions and row spacings employed by the industry. To maximise the benefit of strategic tillage and improve the sustainability of the sugar industry, it is recommended that work be undertaken where the crop is grown using controlled traffic and planted using minimum tillage. This effectively separates traffic from crop growth areas, which was not possible in the current project.

An issue not addressed in the current work is the timeliness of operations. Future work needs to consider possibilities of timeliness of land preparation and planting, fertiliser application and weed control, all of which could be enhanced by the adoption of controlled traffic and minimum tillage options. In areas prone to waterlogging, mounding in conjunction with minimum tillage or direct drilling planting presents an opportunity to improve early crop growth and productivity. To promote root growth, deep ripping the plant line and direct drill planting may reduce crop lodging, thereby improving ccs levels. This needs to be investigated in the northern districts of the sugar industry.

Less soil disturbance should maintain soil structure and improve soil health. Some indication of this was gained in this project, because greater earthworm numbers were evident where less soil disturbance occurred. Trials where minimum tillage planting or direct drilling is practised should be monitored for soil fauna, and soil-borne diseases and pests.

Further to this, the incorporation of a direct drilled legume crop or green manure should be investigated as a means of maintaining soil structure, protecting the soil surface during the fallow period, and providing nitrogen for the following cane crop.

The adoption of strategic tillage has potential to reduce the cost of land preparation and planting, as well as protecting and improving the soil resource of the sugar industry.

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8.0 ACKNOWLEDGMENTS

B Harte and G Borgna are thanked for their cooperation and allowing trials to be conducted on their properties at Bundaberg and Feluga, respectively. Lyn Crees and Norm King provided able field and laboratory assistance at Tully, and Neil Halpin and Luca Pippa did likewise at Bundaberg. BSES extension officers are acknowledged for facilitating grower focus groups.

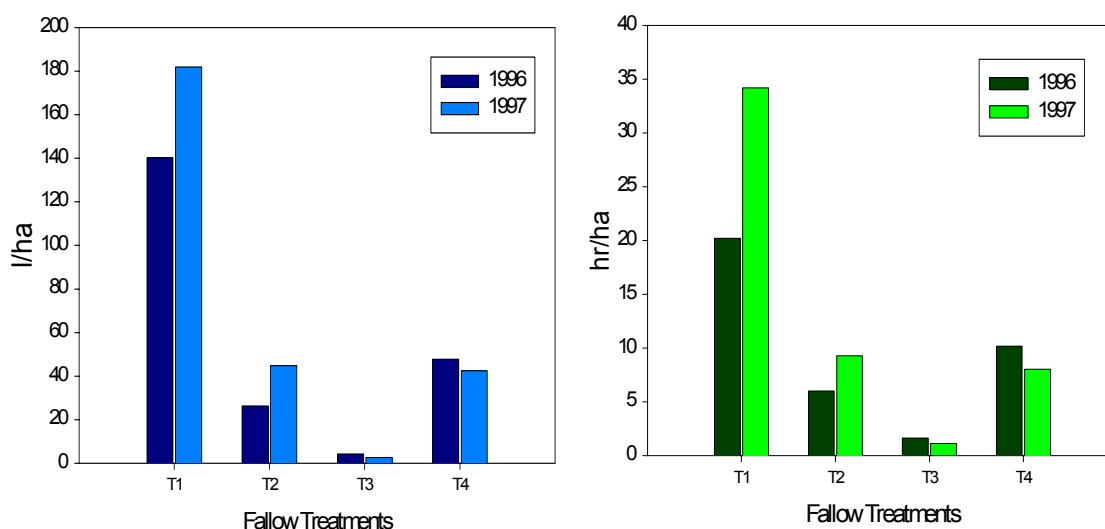
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APPENDIX 1 Tractor measurements (Bundaberg only)

During the conduct of the field trials, the opportunity was taken to instrument the tractor used for cultural operations. This enabled, for the first time in the sugar industry, energy use and the time taken for the various tillage operations to be determined. These values will vary between systems due to different tractors and implements being utilised, but the relativity between systems should be similar.

Figure 1A: Tractor efficiency data from three treatments at Bundaberg - conventional cultivation (T1), stool ploughout (T2), stool spray-out (T3) and ploughout/replant at the Bundaberg site: (i) litres/ha of fuel, (ii) hours of tractor time per hectare.



Fuel use (litres/hectare) and time taken (hours/hectare) are given for each tillage strategy for 1996 and 1997 at the Bundaberg site (Figure 1A). Equipment failure prevented the collection of similar data for the Tully site. The results show a considerable saving in fuel use and time taken in land preparation between conventional and strategic tillage practices.

Fuel savings of up to 80% were achieved by utilising strategic tillage (stool ploughout) compared with conventional cultivation. Similarly, the operation used 97% less tractor hours to achieve the same seed-bed condition.

To illustrate the economic advantage of adopting strategic tillage for planting, a simplistic gross margin calculation was performed based on plot yield of both varieties in 1997 (Table 1A).

Table 1A: Preliminary cost of land preparation operations at Bundaberg for 1997 planting

Costs^a : \$/ha						
	Fuel	Roundup	2,4-D	Labour	Total	Total less labour
Conventional	63.14			410.40	473.54	63.14
Stool ploughout	15.58	87	18.6	111.6	232.78	121.18
Stool sprayout	0.94	152.25	18.6	13.2	184.99	171.79
Ploughout-replant	14.74					
Income vs costs : per hectare Q138						
	Cane yield	Price (\$/T)^b	Gross income	Fallow costs	Difference	% difference to conventional
Conventional	117.9	23.27	2743	473.54	2270	0.0
Stool ploughout	121.2	20.93	2535	232.78	2303	+1.4
Stool sprayout	118.7	22.61	2684	184.99	2499	+10.1
Ploughout-replant	108.6	21.47	2333	111.94	2221	-2.2
Costs^a : per hectare Q155						
	Cane yield	Price (\$/T)^b	Gross income	Fallow costs	Difference	% difference to conventional
Conventional	97.4	24.26	2363	473.54	1889	0.0
Stool ploughout	92.2	24.50	2257	232.78	2025	+7.2
Stool sprayout	93.1	23.58	2196	184.99	2011	+6.5
Ploughout-replant	74.6	23.08	1721	111.94	1609	-14.8

^a Assumed cost fuel (\$/l) = 0.35; Labour (\$/hr) = 12; Roundup (\$/l) = 7.25; 2,4-D Amine (\$/l) = 6.2

^b Price (\$/tonne) is based on ccs levels

This simple analysis illustrates that savings of around 50% can be achieved in land preparation costs by using stool ploughout compared with conventional land preparation. When the crop yield and ccs levels are included, strategic tillage results in up to a 10% better gross margin compared with conventional tillage. The ploughout-replant results in a lower gross margin than conventional practice due to lower yield. All treatments except ploughout-replant were fallow planted. This large cost benefit is achieved in the year of planting, where the greatest costs are incurred.

Other benefits not considered here are less wear and tear on tractors and equipment, which may prolong the useful life of the investment. At the time of equipment renewal, the option of downsizing is real, because less power is required for cultivation, since only the row is disturbed. This would be a real cost saving. Also, the time saved on tillage can be invested in other farm operations, such as weed control or headland restoration. In the year of planting, up to 50% in land preparation costs can be saved by the adoption of strategic tillage. This has also been demonstrated by a grower who is trialing the concept, where conventional land preparation and planting cost \$190/ha compared with zonal tillage land preparation and planting, which cost \$95. Again, a considerable saving in the year of planting.

APPENDIX 2 Focus groups – questions and responses

Minimum tillage planting focus group meetings:

Ingham 9 March 1999 (I)
Mackay 12 May 1999 (M)
Tully 25 May 1999

What do you understand minimum tillage planting to be?

- I To cultivate an area as little as possible to generate a seed-bed for planting
- I Three to four cultivations are not beneficial with respect to soil structure
- I Problems could be seen with trash blanketing
- M To plant cane with the least number of cultivations and for the lowest cost
- M Perceived a need to cultivate to hold (conserve) soil moisture
- M Problems associated with different soil types - 'glue-pot' for example, need to time cultivation with soil moisture
- M Guidance seen as an issue, in not being able to traffic the same area each time

What are the benefits of minimum tillage planting?

- I Less wear and tear on machinery during land preparation
 - Able to harvest under adverse seasonal conditions
 - Save fuel, working less ground, down-size equipment
 - System likely to be soil dependent, able to implement min-till on some areas but not on others
 - Potential for some erosion control
- I Need to minimise compaction near stool, maintain compaction for traffic
- I Problems - some shallow rooting varieties may tip out, need to cultivate ground to enable water to penetrate soil
- M Only working a small area of block, resulting in time and cost savings
- M Concerns - increased chemical usage, ability of roots to grow into the inter-row area, need research in each area due to variety of soil types before results will be believed, weed control was a concern
- M Could increase the window of opportunity for tillage and planting

What are the benefits of conventional planting?

- I Growers have the tools and knowledge, feel comfortable with the system
- I It is what the growers know, tradition as knowledge passes from father to son
- I Similar attitude as that when GCTB was first suggested
- I Difficult to make valid comparisons over the long time scale involved, because only work ground at the end of each crop cycle
- M Traditional to work ground
- M Bigger tractors available to work ground quicker
- M Best min-till equipment was irrigation, where the soil could wet and dry and break down
- M Deep ripping effect was noticeable after a drainage line was put across a block, there was a noticeable improvement in growth

In your farming situation, what do you see as barriers to the adoption of minimum tillage planting?

- I Variable soil types across farm
- I Convention - to keep planting the same traditional way
- I Would like to see results before adoption - prefer other areas to adopt min-till planting over a range of soil types
- M Variable soils across farm and within blocks

Do you feel that changes are needed to current planting techniques?

- I Dual rows a consideration, but filling-in perceived to be a problem, HDP could be OK
- I Long-term data needed on changes, more trials needed on mound planting
- I At present plant in furrows, when it rains, even if block lasered the furrows fill, what is the point?
- I Changes needed to row spacing due to width of current equipment
- M Felt little or no changes were required

Would you adopt minimum tillage planting?

- I There is a need for more information and local trials, generally prepared to trial a small area to compare it with conventional planting
- I Equipment considerations, a planter needs to be built and available for hire
- I Attitude to change, similar situation to adoption of GCTB
- M Thought that seasons would affect the system, would work some years and not others, similar comment with respect to soil type where it would work well on some soils, but not on others
- M Need to remove compacted layers and loosen soil
- M Need to incorporate a green manure crop in the system
- M Most willing to try small areas in the first instance, to fine tune the system for that particular area or soil type

Do you think that min-till will make your farm more sustainable?

- I Benefit in reduced erosion to conserve soil
- I Costs can be reduced if go to controlled traffic and min-till, size of tractors can be reduced. Harvesters need to be modified before adoption (longer elevators, for example)
- I Concern about increase in chemical use, potential residue buildup in soil and health risk to growers
- M Yes, if yield is not compromised and if sugar levels are not affected
- M Seed-bed condition is the only factor that the grower can control. There also seems to be a variety influence as well, Q124 seems to respond to min-till
- M Smaller tractor can be used resulting in fuel savings. Less time would be taken for land preparation
- M The visual appearance of paddock at planting was a factor, an achievement to be proud of

Minimum tillage focus group meeting - Feluga 25 May 1999

Did not address the specific questions as circulated.

Meeting consisted of fruitful discussion on the concept of strategic tillage, since consensus was that everyone knew what was meant by minimum tillage.

Main concern in the area was surface water, especially where country was undulating and water collected in hollows. There was a need to coult-rip the interspace to improve infiltration of this surface water.

Soil types were discussed with concern about using strategic tillage on heavier soils. There was a need to open the soil and aerate the profile. Compaction removal was another consideration.

Timing of tillage operations – due to wet conditions, had to cultivate when soil could be cultivated. This was usually too wet resulting in large clods being generated, and working back to reduce clod size. This usually involved a rotary hoe operation. Potential for plough-pans to develop.

Minimum tillage:

- ratoon sprayed out then cultivate area as per usual.
- to prepare a seed-bed for planting using the minimum number of operations.

Comments:

Focus group was useful because it provided an opportunity for growers to meet and talk in a small group.

Things were done in a particular way because historically it has been done that way (fixed in ways). Problems (perceived): ploughout-replant situation, handling trash, volunteers, weed control, run-off, erosion, waterlogging in low areas.

Benefit: cutting plants under wet conditions.

Discussion centred on how rapidly interspaces recompacted after cultivation – results were shown indicating that recompaction back to the level before cultivation occurred in a 12 month period, ie after the first harvest.

The same pattern of soil strength can be maintained using strategic tillage as to that measured before any tillage operations undertaken. It was shown that after two discing operations, a plough-pan was developing and that compaction at depth (50-60 cm) was not removed; an initial objective of tillage in the first place.

Data illustrating time, energy and cost savings were shown. It was commented that the cost of herbicide should be included in the spray-out system to enable a fairer comparison to be made.

It was suggested that a fact sheet should be produced to illustrate the various strategies, outcomes and potential cost savings, because it would be timely in the current climate of low sugar prices.

Benefits of strategic tillage discussed included, conservation of OM, less disturbance to soil fauna, less dilution of inoculum (*Metarhizium* for example) and protection of soil structure.

Discussion also included the use of legumes in the systems as a source of nitrogen, to protect the soil surface and as a break crop. The ratoon could be sprayed out and the legume could be direct drilled into hills. The legume could be sprayed out, incorporated or the next cane crop direct drilled into the standing legume (several of the options discussed). Emphasis was on the development of a system by putting various components of the YDJV together.