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Reduced tillage planting and the long-term effect on soil-borne disease and yield of sugarcane (*Saccharum* inter-specific hybrid) in Queensland, Australia.

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Sugar Yield Decline Joint Venture

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Abstract

Land preparation for planting sugarcane (*Saccharum* inter-specific hybrid) generally consists of multiple tillage passes to remove the old stool and the compacted inter-rows. The next crop is usually planted in the old inter-row area to minimise the effect of *Pachymetra chaunorhiza*, a soil borne disease which builds-up under the old crop row. However, in order to adopt reduced tillage and not be adversely affected by soil compaction in the old inter-row it is necessary to re-plant into the old crop row. The hypothesis tested was: would reduced tillage and planting back in the old crop row in conjunction with rotation of resistant and susceptible cultivars minimise the effect of this soil borne disease on crop yield ? Field experiments were undertaken on Alfisol soils, near Tully in north Queensland and Bundaberg, south Queensland, Australia to compare

reduced tillage with conventional cultivation for planting sugarcane on soil known to have the soil borne disease *Pachymetra chaunorhiza*. Conventional cultivation involved intensive land preparation with a 6-10 month bare fallow and this was compared with three different types of reduced tillage. With the reduced tillage treatments only the old row area was treated not the inter-row. The reduced tillage treatments included (1) mechanical stool removal with a 6-10 month bare fallow, (2) chemical spraying to kill the stool with a 6–10 month fallow period followed by cultivating the row area prior to planting and (3) mechanical stool removal and replanting with no fallow period. The crop was planted directly back into the previous crop row in the reduced tillage treatments and as close as possible in the conventional treatment by planting from the same edge of the field as the original crop and using the same row spacing. Two cultivars were grown at each site, one resistant and one susceptible to the known fungal root pathogen *Pachymetra chaunorhiza*.

Results showed that, providing Pachymetra resistant cultivars were used, there was no yield reduction with reduced tillage and in most situations reduced tillage enhanced cane and sugar yields. Further, with the Pachymetra resistant cultivar there was no adverse effect from planting directly into the old cane row from the previous cycle. Levels of Pachymetra remained low under the resistant cultivar but increased under the susceptible cultivar as the crop cycle progressed. When a resistant cultivar was planted after a susceptible cultivar yields were not compromised while a susceptible cultivar following a resistant cultivar did not produce a significantly lower yield in the following plant crop but there were indications that yields would be reduced later in the crop cycle. Over a crop cycle of a plant and three ratoon crops in the Bundaberg experiment the average

yields of the susceptible and resistant cultivars were 114 and 89 t/ha, respectively, an increase of 28% with the resistant cultivar.

Earthworm numbers recovered more rapidly after reduced tillage compared with maximum soil disturbance at planting suggesting that in the medium to long-term soil health will benefit by the adoption of reduced tillage for planting sugarcane. Reduced tillage did not enhance the population of pathogenic nematodes.

It is concluded that cultivars are available to allow the adoption of reduced tillage in Pachymetra susceptible areas without compromising crop yield. Reduced tillage will result in substantial cost savings.

Keywords: *Ratoons, Earthworms, Nematodes, Cultivar, Luvisols, Chromosol*.

1. Introduction

In times of low commodity prices and economic downturn, growers look for ways to reduce the cost of production. When the time comes to plant a crop, reduced tillage is a means by which the cost of land preparation for planting can be reduced. (Braunack et al., 1999; McGarry et al., 2001). Previous studies on reduced tillage for sugarcane planting were undertaken to reduce erosion on sloping land (Holmes and Verri, 1988), conserve soil moisture and reduce costs through minimising the number of tillage operations (Trouse, 1982). In most instances the crop was replanted as near as possible to the old inter-row (McIntyre and Barbie, 1989) and on occasion back into the old row (Burgess,

1986) with little consideration of the impact of row location on soil-borne pests and insects.

However, many growers have expressed concern that planting back into the old row is likely to result in a build-up of the soil-borne fungal disease *Pachymetra chaunorhiza* and increase soil pests, resulting in yield loss. *Pachymetra chaunorhiza* is unique to the Australian sugar industry (Magarey et al., 2008). This study was undertaken as a component of a project comparing reduced tillage with conventional land preparation to determine the effect of reduced tillage and cultivar rotation on *Pachymetra chaunorhiza* and the long-term yield of sugarcane. In addition advantage was taken of the different tillage treatments to assess their impact on earthworm numbers as it was expected that reduced tillage was likely to promote earthworm numbers.

2. Materials and methods

Field experiments were conducted at Feluga, near Tully (17º55'S, 140º54'E, mean annual rainfall 4300 mm) and Bundaberg (24º 50'S, 153º 30'E, mean annual rainfall 1100mm) at sites where *Pachymetra chaunhoriza* (Pachymetra root rot) was known to be prevalent. The soils at both sites are classified as yellow earths (Yellow Chromosol at Tully and Yellow Kandosol at Bundaberg - Isbell, 1996) or Alfisols (Soil Survey Staff, 1990) or Luvisols (FAO-UNESCO, 1974). At both sites the experiments were established on fields that had grown sugarcane for 10 – 15 years. The experiments were planted to pachymetra susceptible and resistant cultivars of sugarcane over three years 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. Plots at Tully were not planted in 1998 due to very wet seasonal conditions. The experiments were continued until 2000, providing from one to three years data after each planting date. In 2002 the second planted plots at Tully (1997 planting) were re-planted on the same plots with the cultivars swapped to assess the effect on Pachymetra inoculum of resistant cultivars planted on plots that previously had grown a susceptible cultivar and vice versa. The 1997 planting had grown a plant and two ratoon crops when this planting and cultivar swapping took place. Replanting of the trial at Bundaberg and swapping the cultivars was not undertaken. Plot size at Bundaberg was 7 rows by 15 m and at Tully 6 rows by 20 m. Row spacing was 1.5 m, which was the existing spacing at both sites. The trials were a randomized-block design with three replicates per treatment. The experimental detail and treatments are provided in Braunack and McGarry (2006) and Table 1. The two sugarcane cultivars grown at each site were Q115 and Q117 at Tully and Q138 and Q155 at Bundaberg. The cultivars Q117 and Q138 are rated as resistant (rating 4 and 2, respectively) and Q115 and Q155 as susceptible (rating 6 and 9, respectively) to the soil-borne disease Pachymetra root rot (Croft et al., 1998). These cultivars were selected to test effectiveness of cultivar rotation on Pachymetra root rot, since the crop was planted directly into the old row in treatments T2 to T4 (reduced tillage treatments) and as close as possible to the old row in T1 (conventional tillage). Cultivars previously grown at Tully were Q115 and Q117 while CP5121 and Q144 (rating 6 and 9, respectively for Pachymetra) had been grown at Bundaberg.

Pachymetra spore counts were made prior to establishing the experiments and post-harvest of the plant and each ratoon crop and after the cultivars were swapped on replanting on bulked soil samples (0-45 cm depth). The technique of Magarey (1989) was used for these counts. It involves the wet blending (kitchen blender) and sieving of soil through a nest of sieves of different aperture (250, 125, 63, and 38μ) followed by the collection of the deposits on the 38μ sieve. Soil deposits are then decolorized, the spores stained blue and counted at 63x under a microscope. Spore identity is determined on color of the stained spore, the appearance of the projections on the oogonial wall and spore size. Counts are expressed in spores per kg (dry weight) soil. Samples for Pachymetra assessment were collected within the row, near to the row and in the inter-row. This allowed assessment of the distribution of Pachymetra with respect to tillage treatment.

Earthworm counts were made on soil collected from five spade holes (0.2 x 0.2 x 0.2 m) per plot under one cultivar for each trial site, a modification of the Robertson et al. (1994) technique. Samples were collected on 29 July 1997, 2 July 1998, 28 July 1999 and 4 July 2000 at Tully and on 27 July 1997, 22 April 1998, 24 August 1999 and 26 June 2000 at Bundaberg. Samples were placed on a white sheet and carefully hand sorted to determine earthworm and earthworm egg numbers, which were counted as earthworms while other fauna, were counted separately. Nematode counts were performed for the Bundaberg site only, using the standard technique of Whitehead and Hemming (1965). Samples for earthworm and nematode assessment were collected from within the row.

Shoot and stalk numbers were monitored in 10 m sections of the central two rows from emergence to prior to harvest. Yield was determined at Tully by weighing stalks from the four central rows of each plot harvested with a Toft 7000 mechanical harvester. At

Bundaberg 5 m lengths from the two central rows of each plot were weighed after being cut at ground level by hand with a cane knife and leaves and tops removed. Plots were harvested 12 months after planting. Commercial cane sugar (ccs, %) was measured on six stalk sub-samples using the small mill technique (BSES 1984). CCS in conjunction with cane yield was used to calculate sugar yield (tonnes sugar ha^{-1}) for each treatment.

Data were analysed by standard Analysis of Variance at the 5% significance level using the Genstat13 statistical package (VSN International, 2010).

3. Results

Data are presented for the first (1996), second (1997) and third (1999) and the replant (2002) at Tully; and for the first (1996), second (1997) and third (1998) Bundaberg plantings to provide an indication of long-term response to tillage treatment. There were few significant differences between treatments indicating that there are no adverse effects of reduced tillage on cane and sugar yield.

The only time the soil was disturbed was at the initial planting of the experiment and re-planting when the cultivars were swapped at Tully in 2002. There was no soil disturbance during the crop cycle of first, second or third ratoon.

3.1 Pachymetra status

Results from both Tully and Bundaberg show that Pachymetra levels were significantly lower under the resistant cultivars Q117 and Q138 compared with the susceptible cultivars Q115 and Q155 (Table 2). Also there was a significant tillage by cultivar interaction where spore numbers with the susceptible cultivar increased with less soil disturbance. Further, there was a cultivar by crop class interaction, where spore numbers with the susceptible cultivar built up the longer the crop was in the ground (Table 2).

Data for the distribution Pachymetra spores across rows and inter-rows indicated that the number of Pachymetra spores decreased with distance from the cane row (Table 3).

When plots went back into Q117 after Q115, sampling at the end of the plant crop showed that Pachymetra spore counts were significantly lower in the crop row, near the row and in the inter-row compared with immediately prior to planting (Table 3) . There was a significant cultivar by position by year interaction with significantly lower spore numbers under the resistant cultivar, and further away from the crop row after the cultivars were swapped (Table 3).

3.2 Crop yield

The yield of the susceptible cultivars (Q115, Q155) was significantly lower compared with the resistant cultivars (Q117, Q138) for year one and year three planting at Tully and all three plantings at Bundaberg (Table 4). It was only for the year two planting at Tully, where seasonal conditions forced an 18 month fallow prior to planting that the resistant cultivar did not out-yield the susceptible cultivar. Further, there was an interaction between tillage treatment and cultivar for the year three planting at Tully and year one planting at Bundaberg with yield of the susceptible cultivar decreasing with less soil disturbance at both sites and the resistant cultivar increasing at Bundaberg (Table 4). This effect carried through all ratoons at Bundaberg and coincides with an increase of Pachymetra spores under the susceptible cultivar at both sites and only a small variation in spores under the resistant cultivar. As the third planting at Tully was only grown for a plant crop it is not possible to gauge whether this tillage effect would carry through to the ratoons at Tully.

3.2.1 Stalk development and yield after swapping cultivars (Tully)

Mean stalk development was significantly superior under conventional cultivation on day 99. However, differences became non-significant and relatively small as the season progressed Figure 1). The stool spray-out treatment (T3) seemed to lag behind the other treatments for most of the sampling period; this was due largely to Q115 growing poorly under the stool spray-out system (data not shown) consistent with its susceptibility to Pachymetra root rot.

An early biomass sampling (60 days after planting) showed no significant effect of tillage (T1:5.7, T2:6, T3:5.7 and T4:5.1 t/ha) or cultivar (Q115:5.3 and Q117:5.9 t/ha) on biomass at this early stage. This confirms the results from the year one planting and further indicates that crop yields were not compromised by reducing tillage for planting. The final yield for the tillage treatments after swapping the cultivars is shown in Table 5. There was no significant difference in yield (tonnes/ha) between tillage treatments. However, there was a strong trend for cultivar differences (p=0.065) with Q117 out yielding Q115, which has been consistent throughout the experiment and confirms the Pachymetra rating for the two cultivars. Higher ccs with Q117 combined with the cane yield trends resulted in significantly more sugar/ha with Q117 than for Q115.

3.3 Earthworms

In both experiments, earthworm numbers began to recover by the second ratoon with greater numbers under reduced tillage than under conventional tillage (Figure 2, 3). Numbers of earthworms at Tully were higher than those at Bundaberg which may be a consequence of sampling time and/or associated with the variable nature of biological populations (Figure 2, 3).

3.4 Nematodes

Counts for the two most prevalent nematodes in the Bundaberg experiment, *Pratylenchus zeae* and *Rotylenchus* are shown in Figure 4. There was no significant difference in the numbers of *P. zeae* between any of the tillage treatments, but there were significantly greater numbers of *Rotylenchus* than *Pratylenchus* under all treatments while T3 had significantly more *Rotylenchus* than the other tillage treatments (Figure 4). There was no correlation between nematode numbers and Pachymetra spore counts (data not shown).

4. Discussion

Previous studies on the soil borne fungal disease *Pachymetra chaunorhiza* have concentrated on soil suppressiveness and resistant cultivars (Magarey et al. 2004) while studies on nematodes have examined the effect of break crops/rotations on reducing populations (Stirling et al. 2002). This is one of the first studies to examine the effect of tillage on the known sugarcane soil borne fungal disease *Pachymetra chaunorhiza* when planting back into the old crop row on crop response. In addition some preliminary observations were made in relation to the effect of tillage on earthworms and nematodes in sugarcane fields. These studies provide useful information for growers contemplating adopting a controlled traffic, minimum tillage framing system.

4.1 Pachymetra

At both sites the resistant cultivars were effective in reducing the build-up of Pachymetra throughout the duration of the crop cycle compared with susceptible cultivars. Magarey and Mewing (1994) also found lower Pachymetra inoculum levels under resistant cultivars.

The effect of tillage was less clear as Pachymetra spores are robust and not destroyed by tillage *per se*... Tillage had a variable effect on Pachymetra spore numbers with fewer spores under T1 (conventional cultivation) compared with the other treatments, which may be due to a dilution effect associated with more soil disturbance compared with the other tillage treatments. Further there was a trend for Pachymetra spore counts to be greater under the stool spray-out treatment for the resistant cultivar at Tully. This may reflect the minimal soil disturbance of the initial treatment resulting in less dilution and a slower rate of decline as a result. Also there was an interaction between tillage and cultivar and between cultivar and crop class. Spore numbers built up under the susceptible cultivar and as the amount of soil disturbance decreased. However, under the resistant cultivar spore numbers did not increase to the same extent, which agrees with the results of Magarey and Mewing (1994). The variation in spore numbers with crop class probably reflects seasonal conditions (Magarey and Mewing, 1994).

The planting in May 2002 where the tillage treatments were maintained but with the cultivars being swapped provided information on management strategies. Basically, this re-set the system and provided the opportunity to assess the effect of the previous tillage treatments (levels of soil disturbance) and cultivar on crop performance with the cultivars swapped. Such a strategy may provide a means to manage the levels and distribution of Pachymetra spores in the soil. Croft and Saunders (1996) recorded higher numbers of Pachymetra spores closer to the row than in the inter-row and on the basis of this suggested that re-planting should be done in the old inter-row. However, this strategy gives little consideration to the large amount of energy required to generate a seedbed in the compacted inter-row area (Braunack et al., 1999). Reduced tillage for planting sugarcane is being adopted by the industry to reduce the cost of planting and to implement a controlled traffic farming system (Braunack et al. 2003, Braunack and McGarry, 2006, Garside et al. 2004). Such a strategy is at odds with that proposed by Croft and Saunders (1996) for Pachymetra management. Thus it is important that there is no adverse effect of adopting a strategy that re-plants cane into the old row area from the previous cycle. The results of these experiments indicate that such a strategy can be developed by using Pachymetra resistant cultivars.

In the Tully experiment the resistant cultivar had the effect of moderating the spore numbers that had built up under the susceptible cultivar. However, when plots were planted with Q115 following Q117 there was a significant decrease in Pachymetra levels in the row for T3 and T4 but not for T1 and T2 (Table 5). This result further indicates that rotation of resistant and susceptible cultivars in conjunction with reduced tillage may be a feasible strategy to manipulate Pachymetra levels to maintain yields in areas where high Pachymetra spore counts may otherwise limit yield. However, long-term information over a full-term second crop cycle is required to confirm the longevity or sustainability of this strategy.

The number of Pachymetra spores that can result in economic loss is in the order of forty thousand per kilogram of soil (Magarey et al., 2006). It can be seen from Table 5 that, after re-planting, levels of Pachymetra were lower than 40,000/kg, with the exception of T2, T3 and T4 in the row (ex Q115),. Where levels are greater this corresponds to the row position in plots that were previously under Q115. The reverse is observed in the plots now under Q115 following re-planting since these plots were previously under Q117 a resistant cultivar. By swapping the cultivars Pachymetra levels remained below the threshold value of 40,000, however, it remains to be seen whether this can be maintained for the crop cycle. The potential economic loss due to Pachymetra has been estimated at $914,000 for the Tully mill area (Magarey et al., 2006). This will vary depending on soil type, environmental conditions and previous cropping history. Cultivar rotation provides a strategy to minimise such losses within mill areas and to manage Pachymetra disease levels in the soil. To derive the greatest benefit Magarey et al. (2006) suggest that a regular soil sampling strategy be instigated to identify areas where Pachymetra was above the threshold spore number. This would enable growers to manage those areas by either planting resistant cultivars or growing a break crop.

The results here show that planting a resistant cultivar into the old row can reduce the impact of Pachymetra on productivity. Such a strategy is suited to a controlled traffic minimum tillage system as proposed by Braunack and McGarry (2006).

4.2 Crop yield

The response in crop yield was not consistent between the resistant and susceptible cultivars at Tully while there was a more consistent response at Bundaberg. Also the inter-action between tillage and cultivars was not consistent at both sites. This probably reflects differences in seasonal conditions and the level of soil disturbance at planting between the two sites. Crop yield differed significantly for the year one planting at Tully and there was a non significant trend for the resistant cultivar to produce higher yields with the year 2 planting and there was a significant difference in yield between cultivars with the year 3 planting. There was a significant difference in yield for year one, two and three plantings at Bundaberg. This is consistent with Pachymetra spore build-up under susceptible cultivars with time under a sugarcane monoculture (Magarey et al., 2008). However, it is not known how many spores of the total number are viable which may influence the observed response.

The results presented here demonstrate that reducing the number of tillage operations has not compromised yield, but the benefit of reduced cost in land preparation has been gained (Braunack et al. 1999). The effect of swapping the cultivars may not be evident in the plant crop since Pachymetra spore levels were generally below the economic threshold under each cultivar at planting. However, differences may become more evident with time as the crop cycle progresses and this should be monitored.

4.3 Earthworms

This is one of the few instances where the effect of different tillage strategies on earthworm populations under sugarcane has been assessed. Earthworm numbers only started to recover after the second ratoon crop and on the reduced tillage treatments compared with the conventional treatment (Fig 2, 3). Similar results have been observed under semi-arid (Wilson-Rummenic et al., 1999) and temperate (Douglas, 1987) cropping systems. It has been shown that conventional tillage reduces the number of earthworms and numbers had not recovered after one crop (Röhrig et al., 1998).

As earthworms are generally considered an indicator of soil health (vanVliet and Hendrix, 2007), there is some indication that soil health has started to improve under the reduced tillage system. Earthworms are also considered to be beneficial soil fauna because they create pathways for water and air movement and for root growth.

Earthworms also incorporate organic materials and contribute to soil aggregate stability. Studies have also shown that the presence of earthworms can substantially reduce the fungal diseases of take-all and Rhizoctonia of wheat (Doube et al., 1994). It is thought that the build-up of earthworms is a positive indicator that less soil disturbance may enhance other beneficial soil organisms and microbiology. Although these experiments only continued for a short period the number of earthworms increased under the reduced tillage systems compared with the conventional system at both sites. However, this did not consistently translate into significantly better yield. This needs to be monitored further to confirm whether the trend continues and can be related to crop response over time.

4.4 Nematodes

Nematode populations were assessed for the Bundaberg site only. It has been demonstrated that nematodes can limit the productivity of sugarcane (Stirling et al., 1996). The effect of tillage on nematode numbers under sugarcane in Australia is largely unknown. The difference in populations of the two nematodes may be due to the fact that different nematodes respond differently to tillage operations (Whalen and Sampedro, 2010). Also it is possible that an ineffective kill of the crop was not achieved by spraying; enabling nematode numbers to build up on/in the surviving roots. Stirling (no date) has shown that tillage initially reduces the population of nematodes and that recovery in numbers occurs rapidly. It is speculated that the higher nematode (Pratylenchus) population under T3 may be the result minimum soil disturbance in removing the old cane stool and the opportunity time for the population to increase during the fallow period. In contrast under T4 the old cane stool was removed with minimal soil disturbance and there was no fallow period hence the population may not have been reduced initially to the same extent. However, the differences observed may also be due to the time of sampling (90 days after planting) and not reflect the effect of tillage strategy. Similar observations were made under soybean comparing conventional and reduced tillage strategies with greater nematode numbers in the row with zero and ridge tillage compared with reduced or conventional tillage (Gavassoni et al. 2001). The nematode counts tend to contrast with the Pachymetra counts, which were greater under T4, but generally not significantly so from T3. A similar result was observed under semi-arid conditions where greater nematode populations occurred in no-till soil compared with conventionally tilled soil (Lopez-Fando and Bello, 1995). Seasonal and soil conditions may be a greater influence on the build-up of soil-borne diseases and pests over-and -above that of cultural operations. Soil tillage will have an immediate effect on soil conditions which may favour one organism at the expense of others. This requires further investigation.

5. Conclusions

There is no detrimental effect on cane yield by planting directly back into the old row provided a Pachymetra resistant cultivar is used. Rotation of cultivars provides a means to minimise the effect of Pachymetra root rot on productivity, along with the practice of good crop hygiene of controlling volunteers.

Earthworms recovered more rapidly after minimal soil disturbance compared with massive soil disturbance under conventional cultivation. This has implications for soil health improvement and disease and insect control.

Reduced tillage needs to be considered as a viable alternative to conventional cultivation for planting and to protect the soil resource of the sugar industry.

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Table 1 Sequence of tillage operations for each treatment at the Tully and Bundaberg sites

Treatment	Tully	Bundaberg
Conventional (T1) (6-10 month fallow)	1 x rotary hoe (10 cm)	1 x rotary hoe (10 cm)
	4 x disc (20 cm)	2 x tine rip (40 cm)
	1 x rotary hoe (10 cm)	5 x disc (20 cm)
	Plant	1 x rotary hoe (10 cm)
		Plant
Stool ploughout (T2) (6-10 month fallow)	1 x rotary hoe skim (5cm)	1 x rotary hoe skim (5 cm)
	2 x tine (30 cm)	1 x tine (35 cm)
	Plant	4 x herbicide (8 l ha^{-1} glyphosate 180 g l^{-1} ai)
		1 x tine (30 cm)
		Plant
Stool sprayout (T3) (6-10 month fallow)	2 x herbicide (8 l ha^{-1} glyphosate 360 g l^{-1} ai)	3 x herbicide (8 l ha^{-1} glyphosate 360 g l^{-1} ai)
	1 x rotary hoe (5 cm)	Plant
	1 x tine (30 cm)	
	Plant	
Ploughout-replant (T4) (no fallow)	1 x rotary hoe skim (5 cm)	1 x rotary hoe skim (5 cm)
	2 x tine (30 cm)	2 x tine (30 cm)
	Plant	Plant

Numbers in parentheses are depths of tillage operations

Table 2 Pachymetra spore counts (spores/kg soil) under each treatment and cultivar for each crop class at the Tully and Bundaberg sites

([a] Treatments as in Table 1, 2)

	Year 1								Year 2						Year 3	
	Q115				Q117				Q115			Q117			Q115	Q117
Tully	P	1R	2R	3R	P	1R	2R	3R	P	1R	2R	P	1R	2R	P	P
T1[a]	139321	8401	214225	253791	133068	61582	76154	35279	38802	65552	101111	44382	45756	29787	47622	26045
T2	139488	179228	192709	252965	82865	46538	53685	27127	81351	110012	129012	52159	49496	33913	60613	23782
T3	303365	83053	249590	197426	189085	62418	121272	67800	42761	53765	82781	64591	70812	42821	87598	59598
T4	166556	89558	239998	193687	128442	63677	111239	57237	117732	136250	151470	62855	26032	26853	41489	33627
lsd (P<0.05) trt									22786							
lsd (P<0.05) cult	26701								16112						25447	
lsd (P<0.05) trt*cult.	37761								32225							
lsd (P<0.05) cult*crop class.	53402								27907							
Bundaberg	Q155				Q138				Q155			Q138			Q155	Q138
	P	1R	2R	3R	P	1R	2R	3R	P	1R	2R	P	1R	2R	P	P
T1	23909	29618		14198	9137	3360		2376	9271	20785	12445	1204	24859	4724	73476	33598
T2	26305	49345		40926	36912	18172		6245	14334	10544	2154	12043	9606	1770	80450	53178
T3	56358	46720		29229	33799	32446		8619	1587	66509	3678	8238	9153	4379	172874	12787
T4	116592	98234		29606	46428	44383		21544	29213	7551	21453	29149	14153	17718	98301	17690
lsd (P<0.05) trt.	26229															
lsd (P<0.05) cult.	18546															
lsd (P<0.05) trt*cult.																
lsd (P<0.052) trt*class									22519						55987	

Table 3 Pachymetra levels under each treatment and cultivar prior to and after swapping cultivars at Tully (lsd's ($P<0.05$) only given where significant differences occurred) ([a]Treatments as in Table 1)

Year 2 (2R)	Q115			Q117		
Treatment	Row	Near row	Inter row	Row	Near row	Inter row
T1[a]	253791	40227	17452	35279	18512	14388
T2	252965	56103	13738	27127	12570	17240
T3	197426	41125	18885	67800	26187	33005
T4	193687	34248	24609	57237	26333	23287
Year 2 replant (P)	Q117 (ex Q115)			Q115 (ex Q117)		
T1	33570	22288	18527	14239	6985	7023
T2	47132	27936	14305	20891	6759	5512
T3	52923	23498	3812	20530	8413	5423
T4	70937	30675	16205	10079	7120	5717
lsd ($P<0.05$)						
cultivar	9064*					
position	11103*					
year	9064*					
cult*posn	156999*					
cult*year	12818*					
posn*year	15699*					
cult*posn*yr	22202*					

Table 4 Cane yield (tonnes/ha) for each treatment, variety and crop class at each experimental site

(a Treatments as in Table 1, P = Plant crop, 1R = first ratoon, 2R = second ratoon, 3R = third ratoon, lsd only given where significance occurred between treatments (trt), cultivars (cult.) or interaction (trt*cult) at the 5% level Year 1 planted 1996, Year 2 planted 1997, Year 3 planted 1999 (Tully), 1998 (Bundaberg))

	Year 1								Year 2						Year 3	
	Q115				Q117				Q115			Q117			Q115	Q117
Tully	P	1R	2R	3R	P	1R	2R	3R	P	1R	2R	P	1R	2R	P	P
T1a	79	90	76	46	84	90	80	55	52	82	51	49	91	64	65	62
T2	71	90	77	39	81	92	78	51	60	94	56	51	96	67	57	53
T3	71	79	72	44	82	87	81	55	53	94	60	55	104	74	51	62
T4	65	90	74	42	77	87	70	49	48	95	58	45	91	62	53	52
lsd (P<0.05) trt	5.9															
lsd (P<0.05) cult.	4.2		5.4	3.7											3.8	
lsd (P<0.05) trt*cult.															7.7	
Bundaberg	Q155				Q138				Q155			Q138			Q155	Q138
	P	1R	2R	3R	P	1R	2R	3R	P	1R	2R	P	1R	2R	P	P
T1	107	97	81	84	103	117	101	112	98	91	108	118	116	125	41	56
T2	96	96	89	96	106	131	105	115	92	91	104	121	110	124	32	57
T3	99	97	85	85	119	123	108	115	93	96	109	119	115	118	36	56
T4	85	82	69	70	110	132	111	120	75	81	108	109	105	116	32	52
lsd (P<0.05) trt.										8.8						
lsd (P<0.05) cult.	6.7	8.9	7.6	8.0					8.9	6.2	8.0				8.9	
lsd (P<0.05) trt*cult.	13.4															

Table 5 Yield for the plant crop of each cultivar under each tillage treatment after being swapped. (Q115 = ex Q117 & Q117 = ex Q115)

Treatment	Cultivar	Cane (tonnes/ha)	CCS	Sugar (tonnes/ha)
T1[a]	Q115	60	10.4	6
	Q117	89	12.0	11
T2	Q115	79	10.3	8
	Q117	83	11.8	10
T3	Q115	78	10.0	8
	Q117	82	11.5	9
T4	Q115	79	9.9	8
	Q117	81	11.6	9
lsd(P<0.05) trt		18.4ns	1.1ns	2.1ns
lsd (P<0.05) cult		13.0ns	0.76*	1.4*
lsd (P<0.05) trt*cult		26.1ns	1.5ns	2.9ns

([a]Treatments as in Table 1)

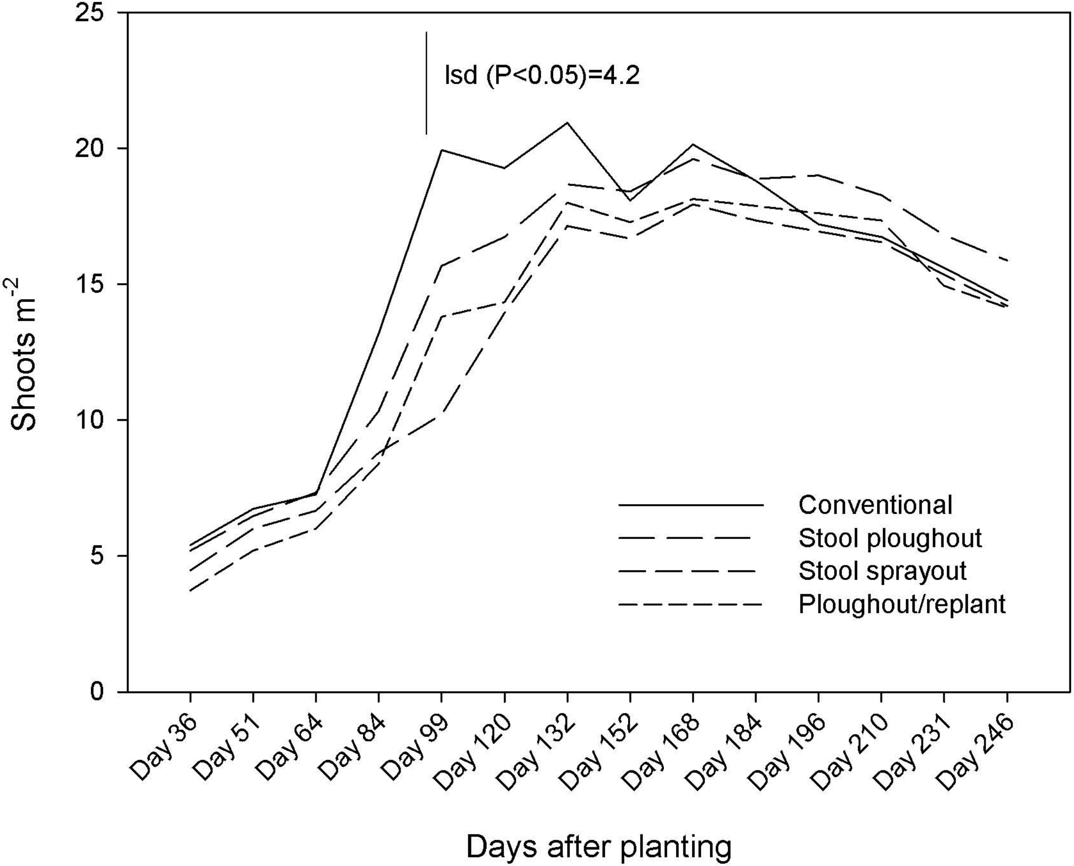
Figure Captions

Figure 1 Stalk development (mean of Q115 & Q117) for each tillage treatment after swapping cultivars.

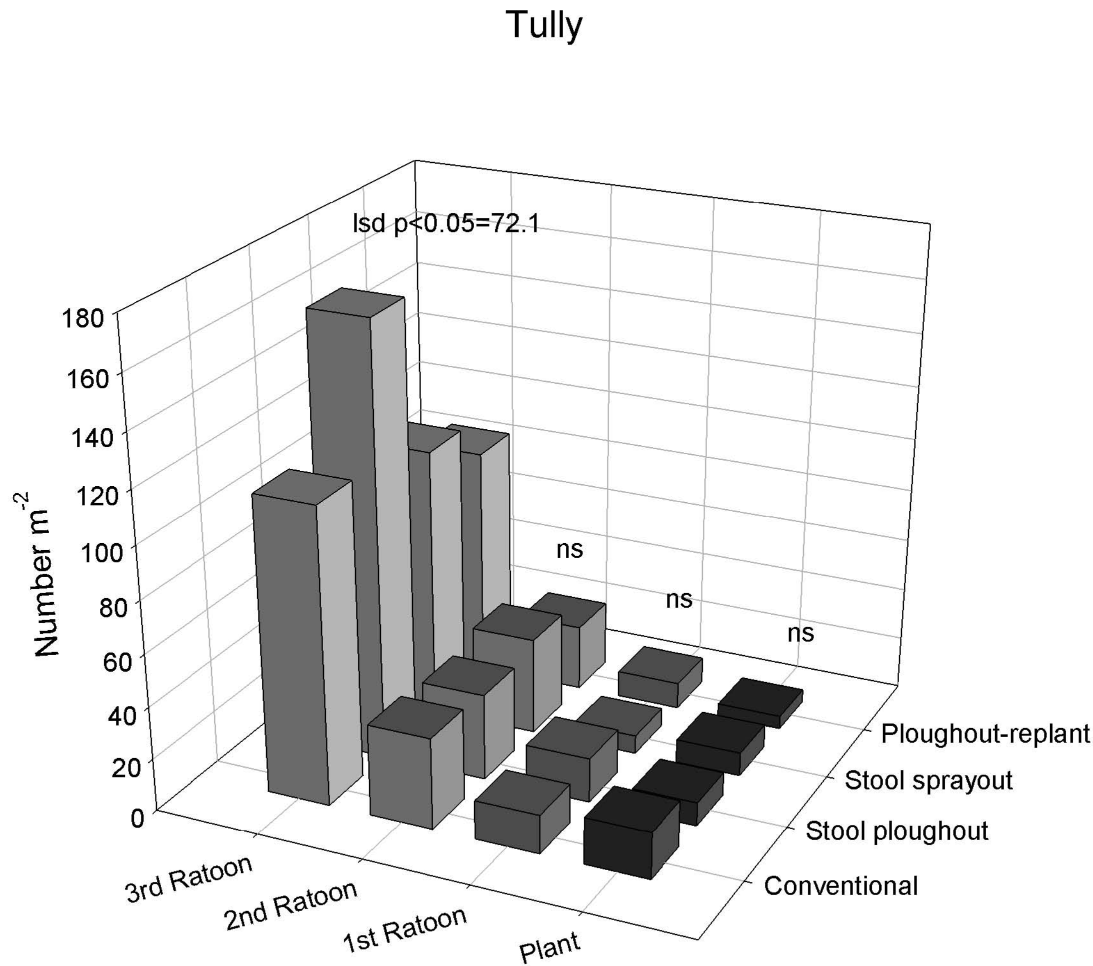
Figure 2 Earthworm numbers/square metre under tillage treatments at Tully

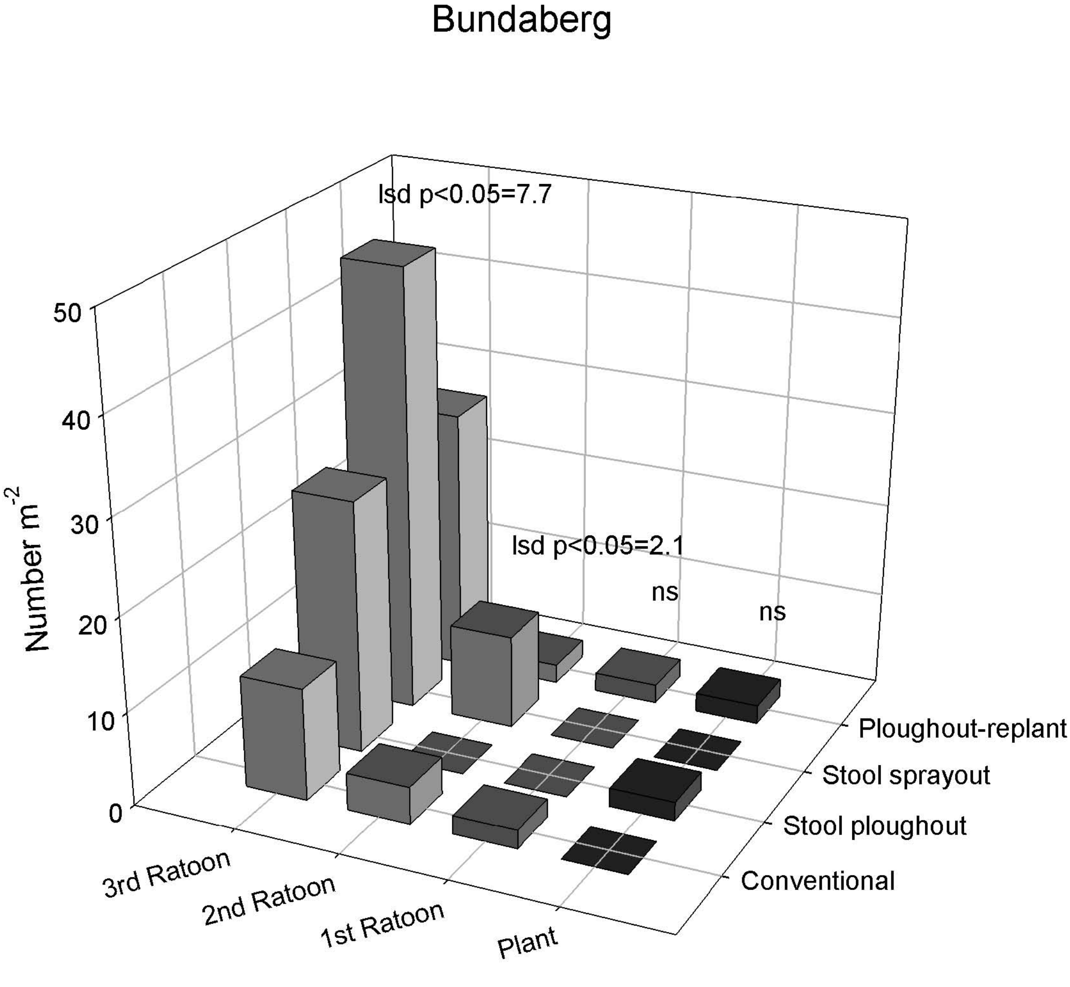
Figure 3 Earthworm numbers/square metre under each tillage treatment at Bundaberg

Figure 4 Nematode counts under each tillage treatment at Bundaberg (3rd Ratoon, columns with the same letter are not significantly different)

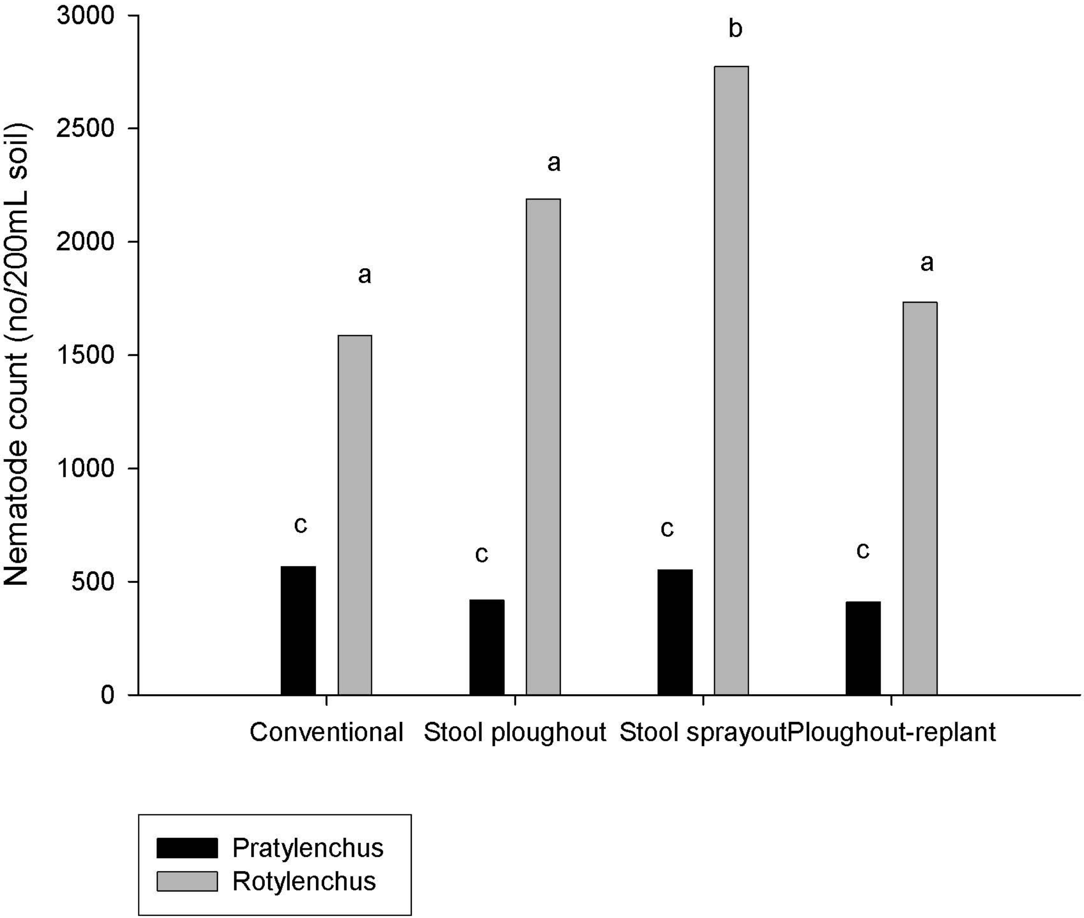


lsd (P<0.05)=4.2
Conventional
Stool ploughout
Stool sprayout
Ploughout/replant
Shoots m-2
Days after planting
0
5
10
15
20
25
Day 36
Day 51
Day 64
Day 84
Day 99
Day 120
Day 132
Day 152
Day 168
Day 184
Day 196
Day 210
Day 231
Day 246


Tully
lsd p<0.05=72.1
ns
ns
ns
Number m-2
0
20
40
60
80
100
120
140
160
180
3rd Ratoon
2nd Ratoon
1st Ratoon
Plant
Ploughout-replant
Stool sprayout
Stool ploughout
Conventional



Bundaberg
lsd p<0.05=7.7
lsd p<0.05=2.1
ns
ns
Number m-2
0
10
20
30
40
50
3rd Ratoon
2nd Ratoon
1st Ratoon
Plant
Ploughout-replant
Stool sprayout
Stool ploughout
Conventional


3000
2500
2000
1500
1000
500
0
Nematode count (no/200mL soil)
b
a
a
a
c
c
c
c
Conventional
Stool ploughout
Stool sprayout
Ploughout-replant
Pratylenchus
Rotylenchus