AN EVALUATION OF THE POSSIBILITY OF USING MINIMUM TILLAGE IN A CANE/PEANUT ROTATION FARMING SYSTEM: A GROWER GROUP PERSPECTIVE

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KEYWORDS: Peanut Rotations, Reduced Tillage,
Trash Blanket, Inoculation.

Abstract

ROTATION cropping has been identified by the Sugar Yield Decline Joint Venture (SYDJV) as a critical tool in addressing yield decline in the Australian sugar industry. Previous research demonstrates that when break crops are combined with correct row spacing, GPS guidance and minimal cultivation they can be powerful tools in addressing yield decline. Producers on poorer sandy soil have found that the nematode controlling effects of growing peanuts as a break crop is more beneficial than other legumes. The industry standard for peanut production in cane based farming systems involves a number of cultivations. There is ample evidence demonstrating that cultivation is detrimental to soil biology and structure. The Sustainable Sugar and Peanut Agriculture (SSPag) grower group investigated the commercial potential of growing peanuts as a rotation crop under reduced/zero tillage regimes. The findings from the first project led to the development of a prototype planter for the second project. This paper highlights the difficulties in implementing all components of the new farming system and identifies the need for more research to raise the productivity of a reduced/zero tillage system to conventional levels.

Introduction

Sugarcane monoculture has led to the development of the yield decline (YD) phenomenon which Garside *et al*. (1997) describe as the loss in the productive capacity of soils under long term sugarcane production. The Sugar Yield Decline Joint Venture (SYDJV) was established in an attempt to develop an understanding of the causal agents of the YD phenomena. The SYDJV program has developed a new sugarcane farming system based on legume rotations, reduced tillage and controlled traffic (SRDC 2004/5) to improve the productivity and sustainability of the Australian sugar industry.

Background

In 2004, a group of like-minded farmers in the Calavos region of Bundaberg became the entity Sustainable Sugar and Peanut agriculture (SSPag) Pty Ltd. This group consists of four family farmers that pool resources to commercialise the SYDJV recommendations. Their current sugarcane farming system is comprised of sugarcane grown on 1.83 m rows (controlled traffic), using green cane trash blanket (GCTB) culture, with the monoculture being broken with grain legume peanuts. Peanuts offer greater profit (Bell *et al.,* 1998), however current peanut culture necessitates aggressive cultivation to: incorporate the 10–12 t/ha GCTB, destroy the cane stool, and provide adequate tilth to facilitate the planting and mechanical harvesting of the peanut crop.

There have been a number of studies assessing the productivity of zero/reduced-till peanuts with varying results. Hartzog and Adams (1989) concluded that reduced tillage peanut production had no measurable impact on yield. Thiagalingam *et al.* (1991) demonstrated comparable crop yields for zero-till and conventional tillage systems in Northern Territory, Australia. However, Oyer and Touchton (1988) demonstrated that in two of the three years, no-tillage peanut production reduced yields in comparison to conventional tillage. In contrast, in the last year, zero-tillage peanut yielded more than conventional practice. Grichar and Boswell (1987) reported an average 33% reduction in productivity through the implementation of zero-tillage production techniques. Inadequate weed control and compacted soil reduced productivity and impeded mechanical harvest. Regardless of these studies there is little evidence in the literature evaluating the productivity of reduced tillage peanuts in a sugarcane farming system. There is, however, evidence that reduced tillage peanut systems have the potential to be as productive as conventional tillage systems, provided weed control is adequate and sub-soil compaction is addressed.

The incorporation of a GCTB and the quick turn-around between sugarcane harvest and peanut planting allows little time for trash decomposition. Microbial use of any plant available nitrogen in the soil to decompose the trash results in nitrogen tie-up. In an effort to hasten residue break down some producers are applying 100 kgN/ha to the residue at the time of incorporation. There is little evidence in the literature of assessing the economic and productive effects on peanuts of fertiliser addition to GCTB at the time of stool destruction/ trash incorporation. This is particularly important given the proximity of the Great Barrier Reef to the sugarcane farming system. There is considerable evidence that the implementation of stubble retention and reduced tillage greatly reduce soil erosion in dry-land farming systems (Clarke and Wylie 1997), however implementation of these techniques in intensive sugarcane/peanut rotations has yet to be validated.

In 2006 SSPag applied to the Sugar Research and Development Corporation (SRDC) for funding through the Grower Group Innovation Program and this paper describes the use of a replicated trial and strip trials to evaluate the role of reduced tillage peanut production in the sugarcane farming system.

Materials and methods

Experiment 1

The trial design was a factorial (randomised complete block) comprising three tillage regimes (conventional, reduced and zero) by two pre-plant nitrogen applications (nil and 100 kgN/ha as urea) with four replicates. Each experimental unit consisted of three 1.83 m beds by 20 m row length on a yellow dermosol (Donnollan *et al.*, 1998). The trial was implemented in a third ratoon paddock (GPS Co-ordinates 24^{o}. 58’08’ S, 152^{o}.21’ 51’E) of Cv. Q188$^{(|)}$ that had been grown on 1.83 m beds with a dual row configuration with 500 mm between the duals under a GCTB culture. The cane was harvested on 5 August 2006.

Tillage in the conventional tilled plots consisted of coulter/rip followed by two rotary hoe operations and bed former on 30 September 2006. The only tillage in the reduced till plots was a coulter/ripper on the peanut plant line, approx. 37 cm either side of the cane bed and cane re-growth was controlled via Glyphosate (2.16 kg ai/ha) post cane harvest pre peanut plant and via Verdict® in crop. The zero tillage plots had no mechanical cultivation and cane re-growth was controlled only by the herbicides as mentioned for the reduced tillage plots.

Soil pH was ameliorated by the application of 3 t/ha of lime and 1 t/ha of dolomite post cane harvest. For the peanut crop, potassium sulfate (120 kg K /ha) was drilled via a ‘Barton’ single disc opener in bands 5 cm beside and 5 cm below the peanut plant line ten days pre-plant. The pre-plant N was applied before tillage operations. An inclined plate seed meter and ‘Day Break’ single disc opener were used to sow the peanut crop Cv. Holt$^{(|)}$ at a seeding rate of 133 000 seeds/ha on 17 October 2006. Traditional high input culture was used to grow the peanut crop which typically involves six and four fungicide applications of Bravo® and Alto®, respectively. Irrigation of approx 3 ML/ha was applied via travelling irrigator to ensure plants were not water stressed. This was a compromise between the trash section that needed less and the conventional section that could have used more.

Early season and pre-harvest peanut biomass was determined via a 0.9 m^{2} destructive sample in each plot the number of plants were recorded in the sample area to determine plant populations. Biomass was placed in dehydrator at 60 ^{o}C until constant dry weight was achieved.

Peanut yield was determined via threshing 10 m of the centre row of each plot using a KEW small plot harvester. The samples were dried, weighed and graded using commercial practice by the Peanut Company of Australia (PCA).

Cane (Cv. Q151) was planted (20 September 2007) using a conventional billet planter without the addition of any fertiliser. The conventional tilled plots were tilled pre cane plant via a rotary hoe whereas the reduced and zero tillage plots were centre ripped only to alleviate the compaction caused by the peanut harvester.

Post cane planting, conventional hilling-up and cane culture were implemented. Cane yield and CCS were determined by hand harvesting 10 m of the centre row of each plot as described by Liu and Kingston (1993), Muchow *et al.*

(1993) and Thomas *et al*. (1993). Briefly this involved weighing total biomass from the 18.3 m^2 area, partitioning a sub-sample into millable stalk (determined as the nodes below the node bearing the 5th dewlap) and trash. A record was kept of total number of stalks, total biomass, sub-sample total weight, weight of millable stalk in sub-sample and a six stalk sub-sample used to determine CCS content (small mill).

All data was analysed with GenStat® package release 9.2. Analysis of variance (ANOVA) was used on all data with the model tillage × nitrogen and replicates as block in general analysis of variance. Significant difference determined via pairwise test between means using the LSD procedure to rank means.

Experiment 2

The second experiment was a farmer strip evaluation consisting of 1 ha strip of direct drill and 1 ha of conventional tillage but replicated on different farms (Halpin and Pippia). These strip evaluations were implemented one year after experiment 1.

The Halpin trial site was a third ratoon Q205$^{\phi}$ on a yellow kandosol (Donnollan *et al*., 1998). Fertiliser in the form of 150 kg of DAP/ha and 290 kg of sulfate of potash/ha was applied pre-plant via a 750 mm coulter placing the fertiliser at approximately 75 mm depth and 10 mm from the peanut plant line. Peanuts were established using a prototype direct drill peanut planter that consisted of a ‘John Deere Maximerge’ vacuum plate seed meter on ‘Norton’ parallelogram double disc opener preceded by a 750 mm coulter and ripper leg; the objective being to cut through the trash and alleviate compaction in the peanut plant line. Both the conventional and direct drill strips were planted on 18 October 2007 with the same planter.

Traditional peanut culture was used to grow the peanut crop as outlined in experiment 1 and irrigated with a travelling irrigator but augmented with trickle irrigation on the conventional area as this area had a higher water demand.

Total peanut dry matter was determined from five 0.9 m^2 quadrats from each tillage treatment one week prior to commercial harvest. Peanuts were harvested with a commercial peanut thresher and yields were determined from weighbridge weights and quality determined using commercial standards as with experiment 1.

Cane (Cv. Q232$^{\phi}$) was planted on 20 September 2008 and grown as outlined in experiment 1 and yields were determined via commercial harvest on 18 July 2009 with bin weights and CCS attained from the Isis Central Sugar Mill. As with experiment 1, no fertiliser was applied to the plant cane crop.

The Pippia trial site was third ratoon Q170$^{\phi}$ on a yellow dermosol (Donnollan *et al*., 1998) but the site was abandoned due to very late peanut planting and heavy rain post planting.

Results and learnings

Experiment 1

When attempting to evaluate complex farming systems, access to machinery capable of establishing a crop in the heavy trash layer left by sugarcane grown under

GCTB culture is essential. Peanut productivity, rhyzobium survival and subsequent sugarcane productivity were affected by the inability of the single disc opener planter to establish the peanut test crop. This led to the development of a prototype planter for the second experiment in the following season.

Early peanut growth

Peanut biomass in the conventional tillage treatment was 84% and 95% greater than the reduced and zero tillage treatments, respectively, at 60 days after sowing (Figure 1). Crop establishment was significantly effected by reduction in tillage (Table 1) due to the single coulter's inability to cut cleanly through the trash resulting in trash enveloping the seed in the soil.

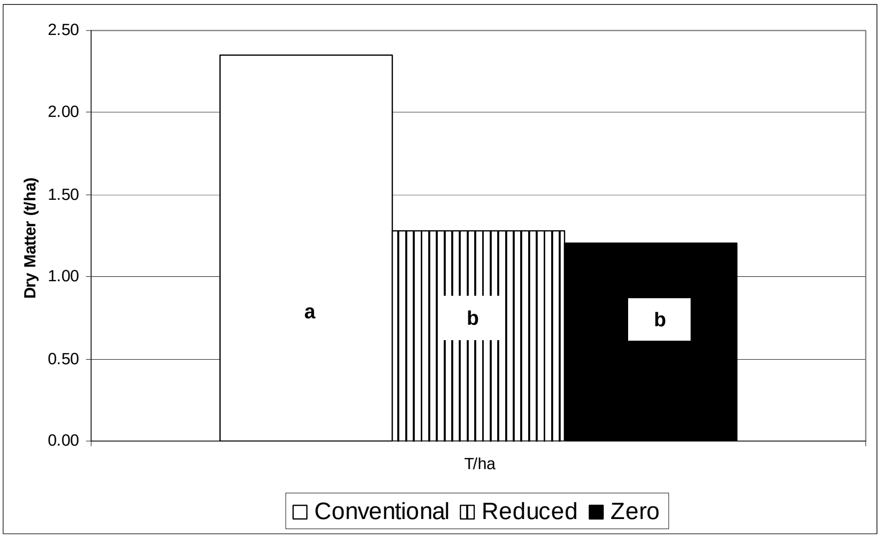

Fig. 1—Tillage effect on peanut biomass 60 days after sowing. (Values with the same letters are not significantly different p = 0.05).

Table 1—The effect of tillage on peanut establishment.

Treatment	Plant population (plants/ha)
Conventional	131 943
Reduced	99 999
Zero	106 943
lsd (5%)	14 689

There was a 130% improvement in early peanut biomass production from the pre-plant application of 100 kgN/ha (Figure 2).

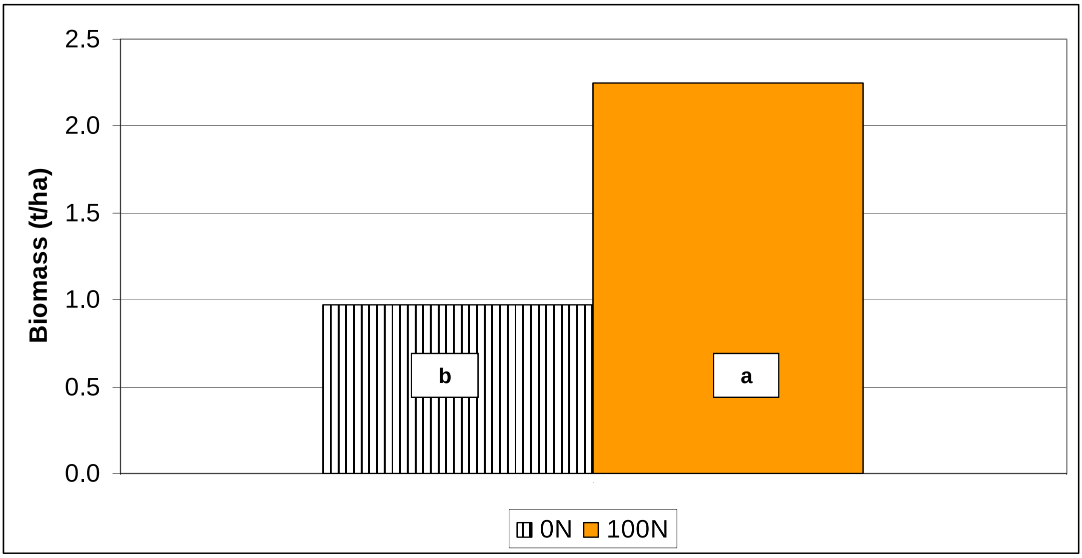

Fig. 2—Effect of pre-plant nitrogen application at 60 days. Values with the same letters are not significantly different p = 0.05).

Peanut yield

Tillage had a significant effect on peanut yield (t/ha), crop value ($/t), gross crop value ($/ha) and grades (%jumbos, %1s, %2s and %oil) (Table 2).

Table 2—Summary of peanut yields. (Values with the same letters are not significantly different p = 0.05.

P-Value							
	t/ha	$/t	$/ha	%Jumbo	%1s	%2s	% Oil
Tillage	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002
Nitrogen	0.111	0.002	0.083	0.002	0.075	<0.001	<0.001
Till x N	0.881	0.248	0.912	0.393	0.725	0.289	0.196
Tillage	t/ha	$/t	$/ha	%Jumbo	%1s	%2s	% Oil
Conventional	5.45^a	812^a	$4\ 443^a$	51.25^a	9.26^b	5.51^b	5.41^b
Reduced	3.07^b	762^b	$2\ 356^b$	43.14^b	13.3^a	8.08^a	7.41^a
Zero	2.39^b	747^b	$1\ 801^b$	39.05^b	15.19^a	9.62^a	7.59^a
Nitrogen	t/ha	$/t	$/ha	%Jumbo	%1s	%2s	% Oil
0N	3.31	754.8^b	2 556	41.14^b	13.39	9.12^a	7.84^a
100N	3.97	792.8^a	3 177	47.82^a	11.77	6.35^b	5.77^b

Pre-plant application of 100 kgN/ha significantly affected peanut grades which in-turn impacted on crop values ($/t). While there wasn’t a significant interaction between tillage and nitrogen, there was a trend for the pre-plant nitrogen application to have a greater effect in the reduced and zero tillage treatments. Peanuts are an indeterminate crop and crop value ($/t) is determined via grades with ‘Jumbos’ being the highest value and 'Oils' the lowest. Pre-plant nitrogen application improved the % Jumbos by 6.3%, 19.2% and 27% for the conventional, reduced and zero tillage treatments, respectively (Figure 3).

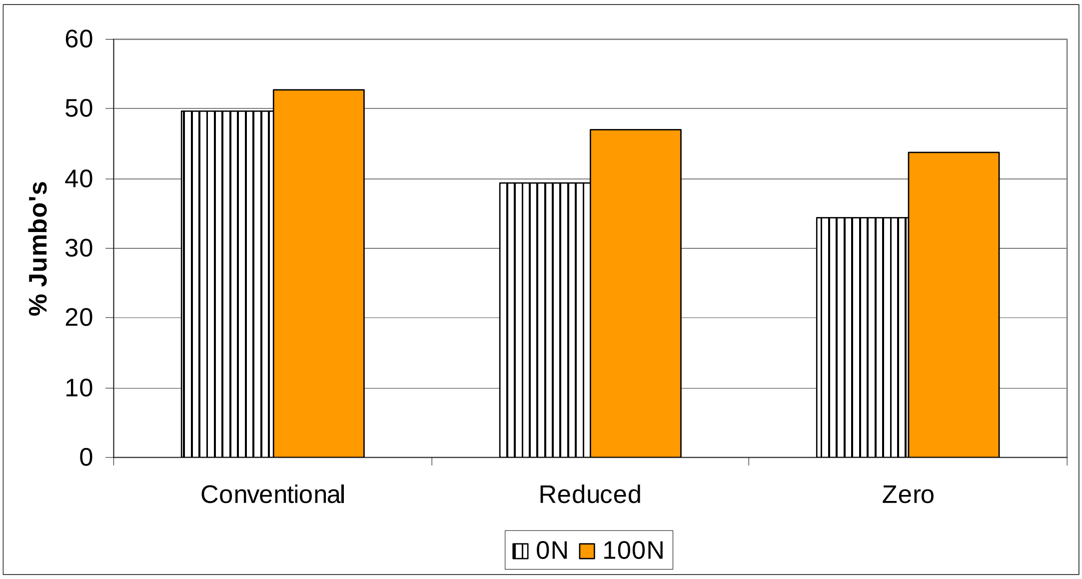

Fig. 3—Effect of pre-plant nitrogen application on % 'Jumbos' in the differing tillage treatments.

Subsequent sugarcane productivity.

While tillage and pre-peanut plant nitrogen application did not have a statistically significant effect on sugarcane total biomass, millable stalk yield, number of stalks, individual stalk weight (ISW) or CCS (data not shown), there was a trend (not significant, $p=0.055$) for sugar productivity to be higher in conventionally tilled plots.

This was due to trends to lower millable stalk yield and lower CCS content in the reduced/zero tillage treatments that, when combined, resulted in a lower sugar yield.

Sugar productivity was significantly correlated ($p = <0.001$) with the total biomass production of the previous peanut crop (Figure 4). However, only 32% of the variation in sugar yield was explained by the previous peanut crop.

Experiment 2

Results from the second experiment (season following experiment 1) high-lighted the need for better replication, either through replicated strips in selected paddocks and/or through more sites.

While the later was implemented, abandoning the 'Pippia' site only allowed interpretation of a single strip of zero and conventional tillage from the 'Halpin' site, albeit a 1 ha strip.

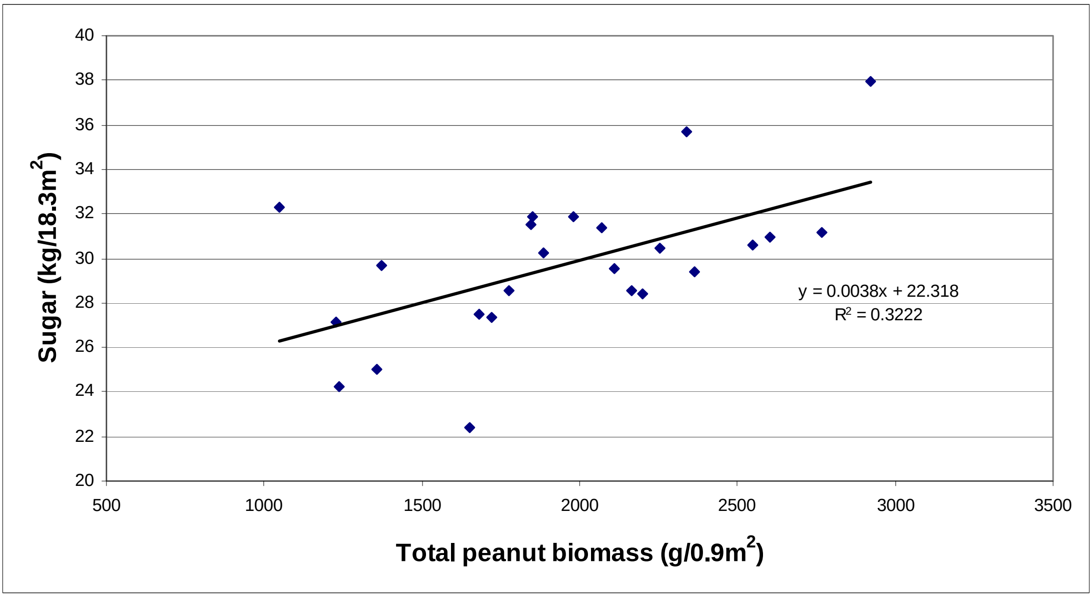

Fig. 4—Correlation between previous peanut crop total biomass production and subsequent sugar yield.

Peanut productivity

The five random samples taken one week prior to commercial harvest demonstrated the prototype planter had successfully planted the crop through the trash blanket with 12.2 and 12.0 plants/m^2 for the zero and conventional tillage strips respectively. Commercial yield of the zero tillage plot was only 76% of the conventional practice. The gross crop value of the zero tillage plot was $1 483/ha less than conventional. This is due to the combination of lower productivity (t/ha) and lower crop value ($/t) (Table 3).

Table 3—Commercial peanut yield, crop value and gross crop value from the ‘Halpin’ tillage strip evaluation area.

	Conventional tillage	Zero tillage
Yield (t/ha)	6.74	5.10
Crop value ($/t)	861	847
Gross crop value ($/ha)	5803	4320
% Jumbos	59.2	54.6
% 1s	6.8	10.1
% 2s	3.1	5.3
% Oil	3.4	4.1

Subsequent sugar productivity

Productivity from the zero tillage treatment in 2009 was 91.3% of the conventional tillage standard (Table 4). Sugar yield was 11.3 and 10.31t/ha for the conventional and zero tillage strips respectively.

Table 4—Commercial cane, CCS and sugar yield from the tillage strip evaluation area.

	Conventional tillage	Zero tillage
Yield (t/ha)	83.8	76.5
CCS	13.48	13.48
Sugar yield	11.30	10.31

Discussion

Peanut

Peanut productivity in experiment 1 was severely impeded by poor crop establishment and associated inoculation failure. Conventional tillage treatment had 24% and 32% more plants/ha compared to reduced and zero tillage treatments respectively. The poor productivity of the reduced tillage treatments measured at 60 days was reflected in the final yields with the conventional tillage plots yielding 77.5% and 128% more than the reduced and zero tillage plots respectively. This is in contrast to other farming systems in other countries where reduced tillage systems had little impact on productivity (Hartzog and Adams, 1989; Thiagalingam *et al.*,1991; Oyer and Touchton, 1988). However, Khan (1984) did demonstrate similar yield reductions in India.

The limited data from experiment 2 demonstrated conventional tillage yield was 32% greater than zero tillage (Table 4), highlighting the effectiveness of the prototype planter at ‘closing the yield gap’ between the different tillage regimes. This was the ‘learning’ from experiment 1; that a planter with the capacity to handle large levels of trash was essential to evaluate tillage treatments.

In experiment 1 there was no attempt to quantify the difference in nodulation between the tillage treatments; it was obvious from visual assessment that the reduced and zero tillage treatments had poor nodulation. This is thought to have occurred due to ‘hair pinning’ at planting. ‘Hair pinning’ is caused when the coulter doesn’t cut the trash, rather trash is pushed into the soil and envelopes the seed. The poor seed-soil contact reduced germination and inoculant survival. This is reflected in the percentage of jumbo grade peanuts where pre-plant nitrogen application had a greater effect on the reduced and zero tillage plots when compared to the conventional standard (Figure 3).

The smaller difference in grades in Experiment 2, where the percentage of kernels in the Jumbo and 1 grades differed between conventional and zero till strips, may have been due to the cooler soil temperatures under the GCTB slowing crop development and kernel maturation. If harvest was delayed for the zero till plot then the yield and grade could have been improved but this is an area for further work.

The effect of tillage on peanut productivity differs from soybean productivity evaluated in similar farming systems. Bell *et al.* (2003) reported soybean grain yields of 2.28 t/ha for conventional tillage and 2.31 t/ha for direct drill in trials conducted at Bundaberg. This could be due in-part to high soil strength in the zero tillage plots despite the prototype planter being equipped with a sub-soil ripper. While Oyer and Touchton (1988) demonstrated an advantage in ripping at time of peanut planting there is the potential for soil moisture levels at planting to be too high to provide ideal soil fracturing. At high soil moisture levels the soil preferentially passes around the tyne rather than lifting and fracturing the soil, effectively creating ‘slots’ rather than compaction amelioration.

Sugarcane

The conventional tillage standard (experiment 1) produced a non-significant (p=0.124) 8.2% and 9.4% more cane than the reduced and zero tillage systems respectively. Similarly the reduced tillage treatment had 0.30 units less ccs and the zero tillage treatment was 0.41 units less than the conventional standard (p=0.158). When combined to produce sugar yield, reduced and zero tillage treatments produced 1.6 and 1.9 t/ha less sugar than the conventional standard respectively (p=0.055). While this result is not significant at 95% level the growers see this as commercially significant. The implementation of these techniques would see a reduction of $720 and $855/ha in gross crop value based on a world sugar price of $450/t. The limited data of experiment 2 showed a 0.99 t sugar/ha reduction from implementing zero tillage. These data are in contrast with Braunack *et al.* (1999) and Bell *et al*. (2003) where no difference in sugar productivity was reported.

Given that the cane grown post peanuts was not fertilised with nitrogen, the tillage effect on sugar productivity was potentially a surrogate for nitrogen availability for the cane crop. Both the reduced and zero tillage plots produced significantly less peanut biomass , thereby supplying different amounts of nitrogen to the subsequent cane crop (assuming that there was no difference in the nitrogen concentration of the tops). There is also the potential that there was a ‘dilution’ of the break effect in the reduced/zero tillage plots with lower peanut biomass and greater weed populations. Effectively the tillage regime became a test of good legume break crop compared to a sub-optimal break crop; however this would need to be investigated in further experimentation. Whereas with Braunack *et al.* (1999) all plots had a bare fallow and Bell *et al*. (2003) had comparable legume break crop yields and their tillage trials demonstrated no yield impact of tillage.

While these trials were implemented in a controlled traffic farming system there was no GPS auto-steer guidance on any of the in-field traffic which resulted in some trafficking of the beds. Gardside *et al.* (2008) demonstrated an 86% improvement in sugarcane productivity when compaction was alleviated. While there was a centre ripping operation in the zero tillage treatment between the peanut and cane crop, soil tilth was visually more blocky and cloddy in the zero tillage plots. This condition is further exacerbated by the commercial peanut harvester trafficking directly on-top-of the peanut beds.

Conclusion

These trials have highlighted the difficulty of not only adapting all of the components of the new farming system into a commercial situation but also in evaluating results. The group, through its directors, designed a prototype planter to better deal with cane trash in the sugar farming system. They have developed a greater appreciation of how to conduct detailed trials and evaluation of tillage treatments. The lack of replication in the second experiment made it difficult to definitively demonstrate the reduction in productivity of a zero tillage system.

The group feels that more detailed studies need to be conducted to identify the key productivity constraints in a minimum/zero tillage peanut-sugarcane rotation. Issues requiring study include (i) the effect of differing soil temperatures and mineral nitrogen release patterns from decomposing trash blankets under differing tillage regimes on peanut yields and quality; (ii) the effectiveness of a deep ripping operation conducted in moist soil at planting in alleviating compaction; (iii) the impact of introducing GPS auto-steer guidance into the farming system on soil strength and peanut/cane productivity; and (iv) the impact of modified weed control strategies and machinery modifications (especially to the peanut harvester) such that every vehicle that enters the paddock is on the same wheel width.

Different levels of government have a duty of care to invest resources into farming systems research that minimise adverse effects on the environment and at the same time maintain productivity and profitability of the sugar industry to improve water quality outcomes of farming close to the Great Barrier Reef Marine Park,

Acknowledgements

The conduct of these trials would not have been possible without SRDC support in funding the projects; DPI and F Kingaroy for access to the KEW small plot header; PCA assisting with peanut grade data; Isis ‘Target 100’ initiative for assisting with the promotion of the trial and including the site in field days; Joe Muscat from Growers Services Group for assistance during the conduct of the projects.

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