EVALUATING COMBINATIONS OF FALLOW MANAGEMENT, CONTROLLED TRAFFIC AND TILLAGE OPTIONS IN PROTOTYPE SUGARCANE FARMING SYSTEMS AT BUNDABERG

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Abstract

Research conducted by the Yield Decline Joint Venture has shown that breaking the sugarcane monoculture using grain or green manure legume species, reducing compaction, and minimising the amount of fallow and in-crop tillage can individually increase the productivity of the subsequent sugarcane crop, improve soil health and rainfall capture and reduce production costs. This paper reports results of an experiment designed to evaluate the feasibility of integrating fallow legumes and reduced tillage with a crop row spacing that would minimise soil compaction into a new sugarcane farming system. Treatments had significant effects on various indices of soil health, soil N status, the rate of mineralisation of organic nitrogen reserves, and on the ability of soil to allow rainfall and irrigation water to infiltrate. The latter effect seemed to be associated with effects of treatments on the prevalence and activity of soil macrofauna (especially earthworms), and was the most important factor affecting the crop yield response. There were significant interactions between tillage and fallow management in cane yield, CCS and sugar yield, and there was a negative effect of fertiliser nitrogen on CCS. There were no significant differences in cane yield between bare fallows or soybean crops under conventional tillage, but cane yields were significantly higher after soybeans (either grain or green manure) under direct drill. Fallow management had no significant effects on CCS under direct drill, but both bare fallows and green manure soybeans produced significantly lower CCS under conventional tillage than direct drill. Collectively, there were no significant differences in sugar yields under conventional tillage, and tillage had no effect on sugar yields after a bare fallow. Sugar yields increased after direct drill soybeans, with highest yields after a green manure. Nitrogen fertiliser reduced sugar yields after a bare fallow, but had no significant effects after either soybean system. Results highlight the potential for combining legume fallows with minimum tillage or direct drill systems for the improvement of soil health, crop productivity and water and nutrient use efficiency in future sugarcane farming systems.

Introduction

Recent reports have shown that the productive capacity of Australian sugarcane soils has declined under both historical and current cropping systems, and that this decline is comprised of a number of significant components. These include detrimental soil biota that affect the health of the cane root system (Magarey 1994, 1996; Blair *et al*., 1999 a,b; Stirling and Blair, 2001), declining quantity and quality of soil organic matter and chemical fertility (Wood, 1985; Bramley *et al.*, 1996) and soil physical constraints associated with excessive tillage during fallows and soil compaction during the crop cycle (McGarry and Bristow, 2001; Bell *et al*., 2001b).

In response to these challenges to soil productive capacity, management options have been evaluated in terms of their effect on the soil property in question, and the resultant impact on productivity of the following sugarcane crop. For example, breaking the cane monoculture for even short periods (e.g. 6–9 months) with alternate crops or bare fallows has been shown to increase cane yields, reduce cane-specific pathogens and, in the case of the alternate crop treatments, produce a better balanced soil biology (Garside *et al.,* 1999, 2000; Bell *et al.,* 2001a; Pankhurst *et al.* 2002; Stirling *et al*., 2002). Similarly, short breaks that include a legume crop (either harvested for grain or grown as a green manure) can also substantially improve soil nitrogen (N) status such that fertiliser N is not required for at least the subsequent sugarcane plant crop (Garside and Bell, 2001), provided residue management systems do not encourage rapid N mineralisation and subsequent leaching losses.

Braunack *et al*. (1999) showed that similar cane yields can be produced under minimum or zero tillage systems with substantial savings in terms of crop production costs, while Bell *et al.* (2001b) showed that minimising compaction by better matching crop row spacings to wheel spacings of harvesting equipment (e.g. 1.8 m) would result in improved capture of rainfall and irrigation and hence improve crop water use efficiency.

In order to develop a more sustainable sugar industry, important components of these individual management options need to be integrated into practical farming systems. During the design of such a farming system, there was an implicit acceptance that cane grown after a short fallow would yield significantly higher than cane grown under plough-out/replant. This finding has been widely reported (e.g. Garside *et al*., 1997, 1998, 1999; Garside and Bell, 2001) so, as a result, no plough-out/replant treatments were included in the experimental program. This report details the impact of combinations of fallow management (bare fallow, grain soybeans or green manure soybeans), tillage (full conventional tillage, or direct drill) and nitrogen fertiliser application strategies (basal N only, versus full N application) on sugarcane growth on a long-term cane block (>20 years of cane monoculture) near Bundaberg.

Materials and methods

The site was established on a commercial cane block at South Kalkie, near Bundaberg, on a yellow podsolic soil with a fine loamy A horizon. The block had been sown to Q124 in 1.8 m dual rows in the spring of 1999, with the plant crop harvested green late in the 2000 crushing season. After harvest, the entire block received a broadcast gypsum application of 1 t/ha, after which individual plots (30 m long and 8, 1.8 m dual cane rows wide) were delineated. The experiment comprised factorial combinations of the 3 fallow management treatments (bare fallow, grain or green manure soybeans) and 2 tillage systems (Conventional till, CT and Direct Drill, DD) in a randomised complete block design with three replications. All main plots were split with '+' or '–' N fertiliser side-dressing during the subsequent cane plant crop.

Cultural practices during the sugarcane fallow

The developing 1st ratoon crop was killed by either cultivation (conventional till, CT) or herbicide (direct drill, DD), beds were reformed by removing soil from the inter-rows and throwing it onto the bed tops (making the tops effectively 90 cm wide), and one of three fallow management strategies (grain soybean, green manure soybean or bare fallow) was imposed.

Soybean crops were established on 19 and 20 December 2000, using a row crop planter with disc openers to establish plant densities of 350 000 plants/ha. Two varieties of soybean were chosen on the basis of fallow management strategy, with cv A6785 grown for grain production (SOYGRAIN) and cv Leichhardt sown for green manuring (SOYMANURE). Three rows were sown on each bed, with one row in between the relic dual cane rows and one on either side, so that the distance between the outermost soybean rows was *ca*. 85 cm. Basal fertiliser (30 kg N, 34 kg P and 100 kg K/ha) was applied on the basis of soil test recommendations, weeds were controlled using post-plant herbicides, and supplementary irrigation was applied when necessary using flood or trickle irrigation systems, to avoid severe drought stress. The third fallow management treatment was a bare fallow (BAREFALL), maintained by either occasional tillage (CT) or herbicides (DD).

Total soybean biomass production, grain yields and nitrogen concentrations were assessed from destructive samples collected during the season and at maturity. Destructive plant samples taken to determine total biomass were taken from quadrats measuring 3 m * 2 (1.8 m) rows (2 samples per plot), while soybean grain yields were determined from the centre two 1.8 m beds over the full 30 m plot length using a mechanical harvester. The grain was harvested from the A6785 soybeans in early May 2001, at which time the green manure Leichhardt soybeans were mulched and left on the surface of the beds (DD) or incorporated (CT). Weeds were controlled during winter using herbicides, and then beds were again tilled in the CT plots prior to planting sugarcane in the spring.

Cultural practices during the sugarcane plant crop

A sugarcane crop of cv Q188[A] was established on the site in early October 2001. All plots (each 30 m x 8, 1.8 m dual rows) were sown using a whole stick planter with double disc openers, resulting in minimal soil disturbance in the DD plots. All treatments received basal fertiliser applications of 24 kg N and 26 kg P/ha banded at planting as DAP; 100 kg K/ha broadcast immediately post planting; and 18 kg P, 50 kg K and 22 kg S/ha in a side dressing at 2.5 months after planting. Plots were split for additional N fertiliser at the time of the side dressings, with '+N' treatments receiving an additional 115 kg N/ha side dressed as urea and the '-N' treatments receiving no additional N fertiliser. The 'Nitrogen' subplots measured 30m x 4, 1.8 m dual rows. Weeds were controlled using recommended herbicides.

Infiltration of rain and irrigation and crop water use were monitored throughout the plant crop in the 'CT,BAREFALL' and 'DD,SOYMANURE treatments using an Enviroscan[R] soil moisture monitoring system, as part of the Rural Water Use Efficiency Initiative. Access tubes (three tubes per treatment) were located in the middle of the dual rows, on the shoulder of the dual row mound and in the middle of the interspace, with sensors located at 10 cm, 30 cm, 60 cm and

100 cm depths. Data were logged at 30 min intervals. The tubes in the middle of the interspace indicated relatively limited infiltration and crop water extraction, compared to those on the mounds, and so have not been included in data presented in this paper.

Destructive plant samples were collected before side dressing (2.5 months after planting), mid-season (6 months after planting) and at maturity. Destructive plant samples to determine total biomass in the first two samplings were taken from quadrats measuring 1 m * 2 (1.8 m) dual rows. When the crop was harvested in mid-October 2002, biomass, cane yields and components were determined from quadrats measuring 5 m * 2 (1.8 m) rows, using methods outlined in Garside *et al*. (1999), while CCS was measured on sub-samples of 6 whole stalks following juice extraction using a small mill. The remaining bulk crop was harvested using a commercial harvester fitted with an elevator extension to allow the wheel traffic of the haulouts to match that of the harvester. This resulted in approximately 55–60% of the ground surface area having no wheel traffic during harvest.

Soil sampling methods

Soil bulk densities were determined in 10 cm increments to 80 cm from the planted bed immediately prior to sugarcane establishment, using 10 cm diameter thin-walled push tubes. Soil samples for chemical analyses were collected from all plots immediately prior to planting, and from the BAREFALL and SOYMANURE treatments at the time of the mid-season biomass sampling and immediately after final harvest. Soil profiles were broken into increments corresponding to the top 10 cm, and then in 20 cm increments to 90 cm. Soils were either chilled to *ca.* 3^{o}C in a cold room prior to analysis of mineral N (nitrate and ammonium), or rapidly dried at 40^{o}C if used for other determinations. At least 6 soil cores were taken in each plot and bulked.

Soil microbial biomass and pathogen assessments were undertaken on soil samples (depth 0–20 cm) collected on 7 June 2001 (about 2 weeks after conventionally tilled plots had been cultivated), on 19 September 2001 (about 2 weeks prior to planting sugarcane) and on 21 March 2002 (about 5 months after planting). About 25 soil cores were collected from each plot at the first sampling time, and 15 cores at the second and third sampling times. Nematodes were extracted from 200 mL soil samples using standard methods (Stirling *et al*., 2001) and counted.

There were marked differences in soil moisture between treatments on 7 June 2001, and these differences may have affected the number of nematodes recovered. A 1 litre sample from each plot was therefore bioassayed for lesion nematode by placing the soil in a pot and planting a single-eye sett of Q188[A]. Nematodes were recovered from roots of the bioassay plant after one month.

The FDA technique was used to assess microbial activity in samples collected on 19 September 2001 and soil microbial biomass was determined on samples collected on 21 March 2002 using methods described in Pankhurst *et al*. (1999).

Soil macro-fauna were determined from samples collected during June 2002, approximately 2 months prior to sugarcane harvest. At this time, 10 square spadefuls (approx. 15 cm by 15 cm) of soil, from which aboveground vegetation had been removed, were collected in each plot to a depth of 20 cm. Soil was sorted in the field, and the recovered faunal specimens were subsequently collated and identified in the laboratory. Only the SOYMANURE and BAREFALL treatments were assessed at this time for both DD and CT tillage systems.

Soil and plant chemical analyses

Soil samples for chemical analyses were collected from the field, oven dried (40°C) and ground to < 2 mm for chemical analyses. Standard analytical procedures were used to determine the soil fertility status (Rayment and Higginson, 1992), with mineral nitrogen (ammonium plus nitrate) determined on 1:10 soil:2M KCl extracts.

Plant material was dried (70°C) and ground before analysis of total plant nutrient concentrations.

Statistical analyses

Standard analysis of variance techniques were used to compare effects of treatments on soil mineral N status, biomass production, nutrient concentrations, total nutrient uptake and crop yields.

Results and discussion

Despite relatively dry conditions and limited supplementary irrigation, the fallow soybean crops produced reasonable biomass yields (6.5 t/ha), with no significant differences between tillage systems or soybean varieties (Table 1). Grain yields were similar to those recorded in nearby commercial fields. Net returns of N to the cropping system differed significantly between SOYGRAIN and SOYMANURE treatments due to the removal of ca. 75% of the aboveground N in harvested grain. However, actual N returns to the system are likely to exceed those shown in Table 1 due to the contribution of belowground (roots, nodules etc.) not measured in this system. Bell *et al*. (1998) reviewed a number of reports that suggested aboveground N represents only 70% of total crop N, so applying this assumption to these data, net returns of N to the farming system would be some 55–60 kg N/ha higher than the figures in Table 1.

Table 1—Biomass and grain yields, crop N concentrations and N balance of the soybean crops grown during the fallow period. Total crop N and N balance figures are based solely on aboveground biomass.

	Total biomass	**Grain yield**	**Total crop N**	**Net N balance**
Factor	**t/ha**		**kg/ha**	
Tillage				
CT	6.16	2.28	180.8	108.4
DD	6.67	2.31	194.9	121.8
LSD (P = 0.05)	n.s.	n.s.	n.s.	n.s.
Rotation				
Soygrain	6.31	2.29	202.0	56.4
Soymanure	6.52	–	173.7	173.7
LSD (P = 0.05)	n.s.		n.s.	34.2

Fallow management and tillage system produced significant differences in soil biological and chemical fertility, crop growth and water balance in the following cane crop. Immediately after the incorporation of the soybean residues in June, populations of lesion nematodes were significantly lower in all plots in which soybeans had been grown during the fallow period (Table 2). This depression was still evident in the SOYMANURE treatments in mid-September, just before cane planting, but not in the SOYGRAIN treatments. There was also a trend for a reduction in lesion nematodes under CT, but this did not become statistically significant ($P < 0.05$) until the time of cane planting.

Numbers of lesion nematodes increased rapidly in all treatments during growth of the plant crop (e.g. from *ca*. 40 nematodes/200 mL soil at planting to >1000 nematodes/200 mL soil in mid March, less than 6 months after planting), as has been reported in other studies (e.g. Stirling *et al*., 2001). There were no consistent trends for the persistence of treatment differences in lesion nematode numbers recorded at planting to later stages of the plant crop (Table 2).

Table 2—Populations of lesion nematodes in the soil in response to fallow management and tillage. Data are from samplings during the fallow, just before cane planting and in a mid-season sampling 5.5 months after planting. Microbial activity was also determined just before cane planting.

	Log (no. lesion nematodes/200 mL soil +1)			**Microbial activity**
Factor	**Mid-fallow (post soybean)**	**Cane planting**	**Mid-season**	**(µg FDA/g/h**
Tillage				
CT	1.80	1.44	3.08	39.1
DD	2.00	1.86	2.98	43.2
LSD (P = 0.05)	n.s.	0.27	n.s.	3.47
Rotation				
Bare Fallow	2.29	1.74	3.08	35.0
Soygrain	1.82	1.85	2.83	46.4
Soymanure	1.56	1.36	3.18	41.9
LSD (P = 0.05)	0.36	0.33	0.26	4.2

Microbial activity (Table 2), the prevalence of free living nematodes (FLN, grouped into bacterial and fungal feeding nematodes and omnivore predators) and the ratio of plant parasitic nematodes (PPN) to free living nematodes (proposed as an indicator of soil health by Stirling *et al*., 2002) were affected to varying extents by tillage and fallow management at the time of cane planting (Table 3).

Bacterial feeding nematodes increased after soybean fallows, with the greatest increase being in the SOYMANURE treatments. On the other hand, fungal feeding nematodes and total FLN were unaffected by fallow cropping in DD, but increased with soybeans under CT. In contrast to the data for lesion nematode (Table 2), total PPN increased after soybeans–primarily due to increases in spiral nematodes. Total PPN were lowest in the CT, Fallow treatment and there was no significant difference between other tillage and fallow crop combinations.

Table 3—Populations of free living and plant parasitic nematodes in the soil prior to cane planting. Plant parasitic nematodes represent a composite of lesion (*Pratylenchus zeae*), reniform (*Rotylenchulus parvus*), stunt (*Tylenchorhynchus spp*.), spiral (*Helicotylenchus dihystera*) and stubby root (*Paratrichodorus minor*) nematodes.

	Log (nematodes/200 mL soil +1)					
Factor	**Bacterial feeding nematodes**	**Fungal feeding nematodes**	**Omnivore predators**	**Total free living nematodes (FLN)**	**Total plant parasitic nematodes (PPN)**	**FLN:PPN**
			Tillage x rotation			
Barefall, CT	2.468	2.746	1.28	2.947	1.575	26.1
Soygrain, CT	3.386	3.336	1.61	3.681	2.377	22.4
Soymanure, CT	3.888	3.102	1.34	3.956	2.078	89.7
Barefall, DD	2.843	3.287	1.32	3.426	2.142	25.0
Soygrain, DD	3.511	2.871	1.25	3.611	2.279	24.0
Soymanure, DD	3.835	2.863	1.13	3.882	2.277	54.9
LSD (P = 0.05)	ns	0.461	n.s.	0.362	0.345	ns
			Tillage			
CT	3.248	3.061	1.41	3.528	2.01	46.0
DD	3.396	3.007	1.23	3.64	2.233	34.6
LSD (P = 0.05)	ns	ns	ns	ns	0.199	ns
			Rotation			
Barefall	2.655	3.017	1.30	3.187	1.859	25.6
Soygrain	3.448	3.103	1.43	3.646	2.328	23.2
Soymanure	3.861	2.982	1.23	3.919	2.177	72.3
LSD (P = 0.05)	0.275	ns	ns	0.256	0.244	37.3

The ratio of FLN:PPN was relatively high in all treatments, compared to values typical of sugarcane monocultures (trial mean = 40:1, compared to 2–5:1 for sugarcane monocultures; Stirling *et al*., 2002), primarily reflecting the positive benefits of the short breaks on survival of PPN. However the reported values of 20–40:1 after short term, conventionally tilled soybean fallows in sugarcane fields from north Queensland (Stirling *et al*., 2002) were very similar to those recorded after SOYGRAIN and BAREFALL treatments. There was a significant increase in the ratio of FLN:PPN in the SOYMANURE treatment–primarily due to the strong increase in bacterial feeding nematodes in those treatments.

Soil macrofauna (particularly earthworms) responded positively to both DD and the inclusion of soybeans in the fallow. Earthworm densities increased from 1.0^{-2} in the CT, BAREFALL treatment to 40.0/m^2 in the DD, SOYMANURE treatment, with the DD, BAREFALL (5.3/m^2) and CT, SOYMANURE (7.7/m^2) not significantly different to the CT, BAREFALL treatment. This earthworm response was mirrored by increases in the frequency and diversity of other macrofauna (data not shown), and is consistent with responses to reduced tillage and improved soil organic matter status in other cropping systems (e.g. Bell *et al*., 1997).

The increase in soil macrofauna, and in particular earthworms, under the DD, SOYMANURE treatment was expected to have a positive impact on soil macroporosity and resultant infiltration of rainfall and irrigation. These trends were observed in the soil water data monitored using the Enviroscan^{R} system (Figure 1), with large increases in infiltrated water in the DD, SOYMANURE treatment after most rainfall or irrigation events. Differences tended to become smaller later in the season, but by then large differences in crop yield potential were already established.

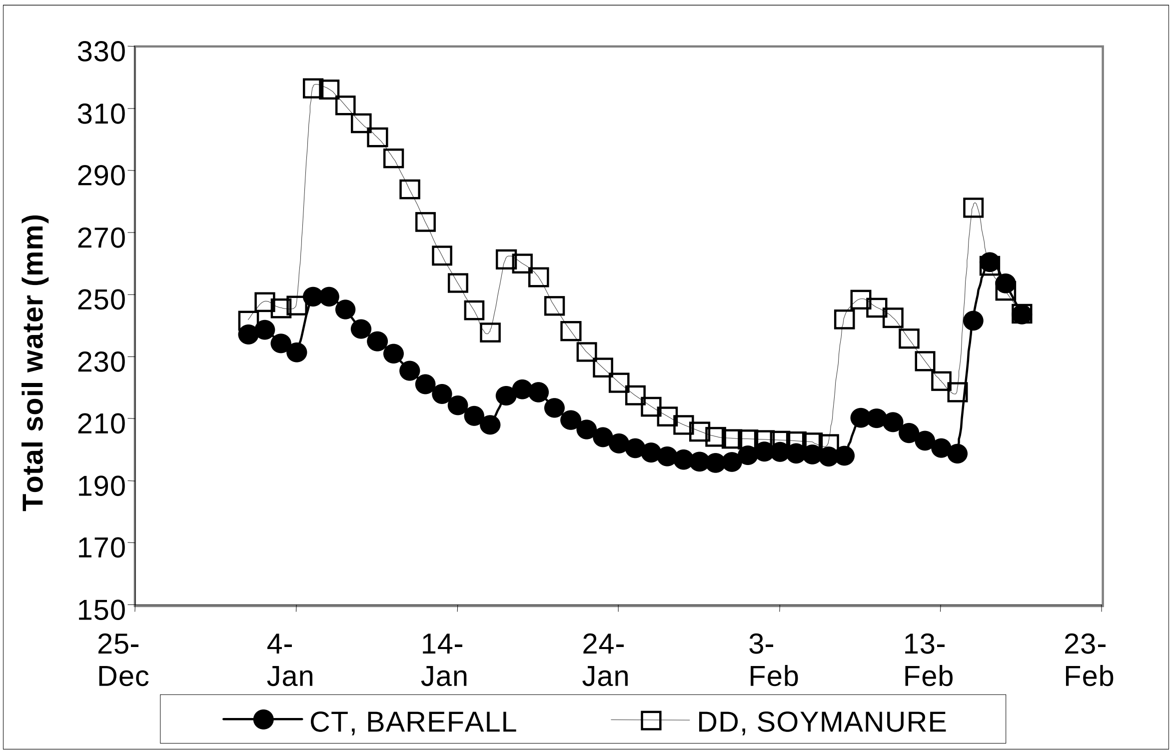

Fig. 1—Daily profile soil water (0–100 cm) under Q188[A] sugarcane grown in 1.8 m, dual row hills after contrasting tillage and fallow management histories. Both treatments received similar amounts of supplementary trickle irrigation and incident rainfall. Values are means of sensors from between the dual rows and on the shoulder of the sugarcane hill.

Treatments had a significant impact on soil mineral N at planting and at a subsequent sampling mid-season - taken to coincide with a destructive sampling for plant biomass (Figure 2). In each system, CT during the fallow significantly increased total profile mineral N at the time of sugarcane planting, with significant differences confined to the top 30 cm of the soil profile. Under DD, choice of fallow activity (bare fallow, grain or green manure soybean) had no impact on profile mineral N. However, fallow activity had a large effect on the subsequent mineralisation of N under CT, with an additional 208 kg N/ha mineralised in the SOYMANURE, compared to 53 and 56 kg N/ha mineralised in the BAREFALL and SOYGRAIN treatments, respectively. This extra mineralisation of N occurred during the relatively dry and cool winter (a 4-month period from the time of incorporation of the soybean residues in mid May), and the confinement of this mineral N to the top 30 cm was indicative of the relatively dry weather during that time. As Noble and Garside (2000) showed, conventional tillage of soybean residues under conditions of higher temperatures and rainfall in the wet tropics can accelerate both the rate of mineralisation and the depth of leaching such that poor recovery of N by the following sugarcane crop could occur.

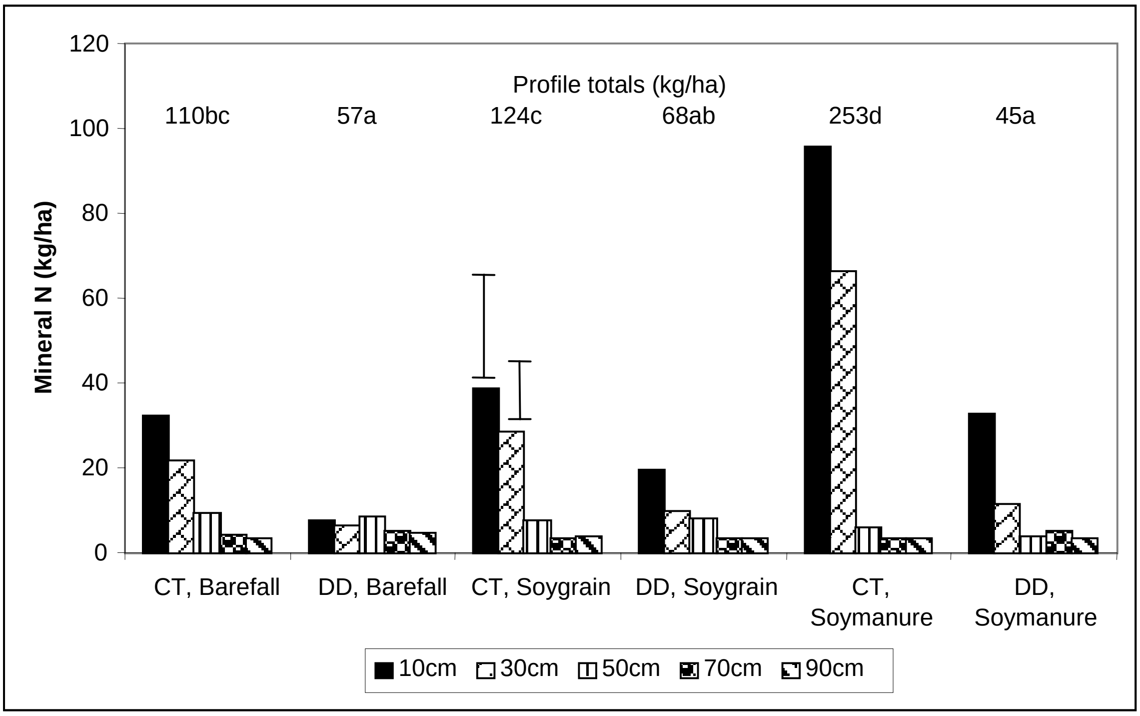

Fig. 2—Profile mineral nitrogen at planting of the sugarcane test crop in early October. Vertical bars indicate lsd values (P <0.05) for individual profile depths. Profile totals (kg/ha to 90 cm) are shown for each treatment, with significant differences (P <0.05) indicated by different letters.

A mid-season soil sampling in March (Figure 3) coincided with a destructive plant sampling for assessment of biomass and crop N uptake (Table 4). The soil N data showed reduced profile mineral N in all treatments except DD, SOYMANURE, and also a more uniform distribution of mineral N throughout the profile in all treatments. There was evidence of possible leaching of mineral N below the depth of sampling (90 cm) in only the CT, SOYMANURE–the treatment in which N mineralisation had occurred well in advance of crop demand (Figure 2). The estimates of soil N that had mineralised during the period between soil samplings (Table 4) highlighted the differences in soil N dynamics between tillage systems. Conventional tillage resulted in more rapid mineralisation of organic N and high mineral N levels at planting, well in advance of crop requirements, while mineralisation was much slower under DD. The lack of biomass response to applied N (data not shown) indicated that both systems were capable of supplying adequate N to meet crop demands.

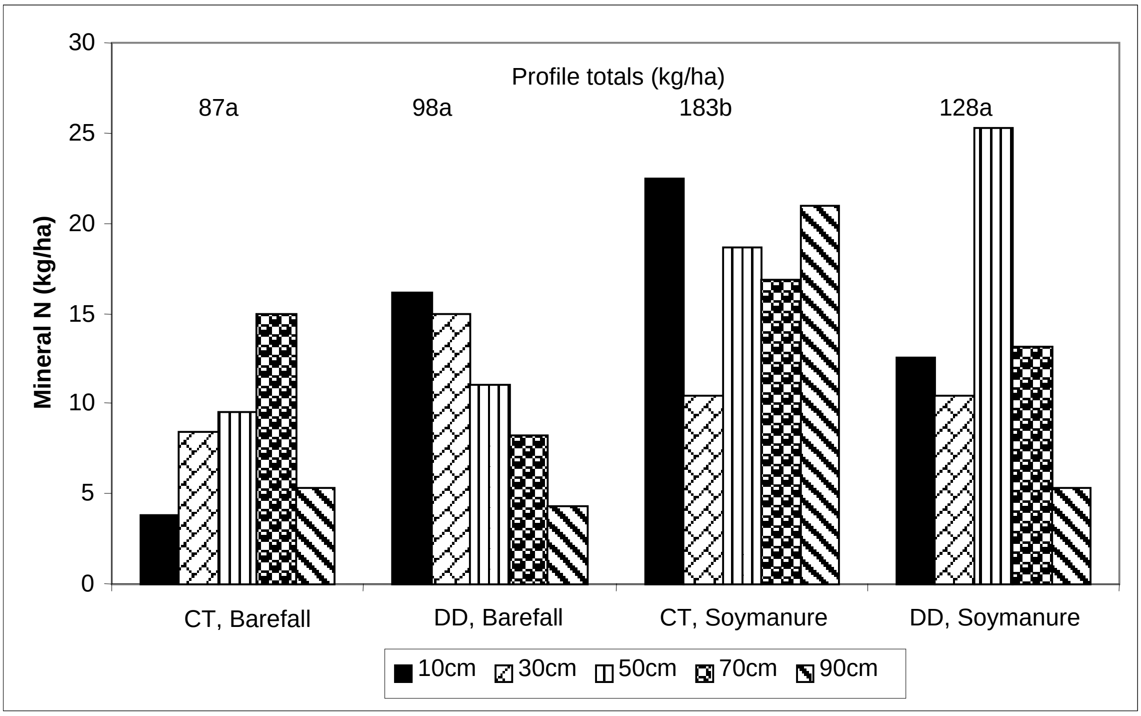

Fig. 3—Profile mineral nitrogen in a mid-season sampling of the sugarcane test crop in mid-March. Profile totals (kg/ha to 90 cm) are shown for each treatment, with significant differences (P <0.05) indicated by different letters.

Table 4—Biomass production, N concentration and crop N uptake by sugarcane (cv. Q188[A]) in mid-season destructive samples in March.

	Total biomass	**N concentration**	**Total crop N**	**N mineralised after planting[1]**
Factor	**kg/ha**	**%**	**kg/ha**	
Barefall, CT	10130	1.22	135.1	90
Soygrain, CT	8520	1.25	109.2	NA
Soymanure, CT	8530	1.08	91.6	0
Barefall, DD	11630	1.27	155.8	153
Soygrain, DD	14540	1.03	159	NA
Soymanure, DD	17110	1.06	198.9	194
LSD (P = 0.05)	3420	ns	62.7	

[1] Estimates of N mineralised since planting were derived from calculation

$N_{mineralised} = [(SoilN_{plant} – SoilN_{midseason}] + \text{crop N} – \text{N fertiliser}]$.

This calculation assumes no leaching losses of profile mineral N below the depth of sampling, which may have been breached in the DD,SOYMANURE treatment.

Crop yields were generally below expectations, primarily due to the very dry seasonal conditions and the limited supplementary irrigation available to the crop–especially during the first half of the growing season. However, cane and sugar yields and CCS (Table 5) all showed yield and quality advantages of DD treatments over CT, particularly when DD was combined with a soybean fallow crop. There was a consistent trend for a reduction in CCS and sugar yields with the application of N fertiliser to these fallow-plant systems–especially where the combinations of fallow management and tillage resulted in excessively high profile mineral N status (e.g. CT, SOYMANURE).

Table 5—Cane yield, CCS and sugar production from variety Q188[A] grown after varying combinations of fallow management, tillage and fertiliser nitrogen.

	Cane yield		**CCS**		**Sugar yield**	
	t/ha		**%**		**t/ha**	
Treatment	**Nil N**	**N applied**	**Nil N**	**N applied**	**Nil N**	**N applied**
Tillage						
CT	61.5	59.2	15.5	14.9	9.5	8.8
DD	76.4	75.0	16.0	15.9	12.2	12.0
LSD (P = 0.05)	ns		0.4		Ns	
Rotation						
Barefall	65.9	56.6	15.7	15.2	10.3	8.7
Soygrain	64.2	69.9	16.0	15.7	10.3	11.0
Soymanure	76.8	74.9	15.7	15.3	12.0	11.5
LSD (P = 0.05)	9.3		ns		1.5	

Conclusions

Our studies have shown clear advantages in the combination of legume fallow crops with DD tillage systems for future sugarcane farming systems. The similarity in crop performance between short fallows with CT (either bare fallow, or with soybean) in this study is consistent with other reported work in the Sugar Yield Decline Joint Venture (e.g. Garside *et al.*, 1999, 2000). However, despite all treatments having a short fallow, crop yields increased significantly in response to DD–most likely due to improved capture of rainfall and irrigation for crop use in a dry growing season. While both crop and bare fallow breaks from the sugarcane monoculture have been shown to reduce sugarcane-specific pathogens relative to ploughout/replant in other studies, the clear benefits in the soil macrofauna in response to DD soybean fallows have added another dimension to this issue.

In addition, the clearly demonstrated N returns to the farming system from legume fallows, combined with the improved N dynamics under DD, illustrate the potential for both reduced artificial fertiliser inputs and environmental benefits from reduced N losses to groundwater. The duration of N and soil biota benefits and crop productivity gains will be followed through subsequent ratoons.

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