# FARMING SYSTEMS AND THEIR EFFECT ON THE RESPONSE OF SUGARCANE TO NITROGEN

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## Abstract

THE AUSTRALIAN sugarcane industry is under increasing pressure to minimise losses of nutrients from the field. Inputs need to be precisely matched to crop requirements. A trial was established at Mackay to determine whether nitrogen (N) rates could be reduced following long-term green-cane trash blanketing (GCTB) and to test whether current recommendations for new farming systems were robust. Four farming system treatments were established: (B) Long-term burnt trash, 1.5 m single rows, bare fallow, conventional cultivation; (GC) Long-term GCTB, 1.5 m single rows, bare fallow, conventional cultivation; (NFSS) 1.8 m single rows, soybean fallow, pre-formed beds, GCTB; (NFSD) 1.8 m dual rows, soybean fallow, pre-formed beds, GCTB. B and GC were possible as the trial was located on a site that was set-up in 1992 to investigate GCTB and the trash treatments had been maintained. Within each farming system treatment four N rates were applied (0, 75, 150 and 225 kg N/ha). Response to N was similar for the B and GC systems. This suggests that, at this stage, N rates cannot be reduced following long-term GCTB. It is possible that soil carbon and N may not be accumulating as predicted under the GCTB system. A 4 t/ha soybean fallow crop appeared to contribute little N to the following plant cane crop as the NFSS and NFSD systems responded in a similar manner to N as the B and GC systems. The soybean fallow crop was defoliated by an insect pest which may have impacted on the amount of N returned to the soil. Current recommendations for N to be applied to plant cane following poor soybean crops appear justified. Similar yields were achieved with all farming systems. Relatively high rainfall during the study period may have negated the soil moisture conservation benefit from a GCTB system. At this stage, the benefit of new farming systems appears to be a lower cost of production. Improvements to soil health reported elsewhere will hopefully also result in increased production in the future.

## Introduction

The Australian sugar industry is under increasing pressure to minimise losses of nutrients from the field. Gaseous losses of nitrogen (N) increase greenhouse gases in the atmosphere. Losses in run-off and via leaching potentially affect environmentally sensitive ecosystems such as the Great Barrier Reef. To reduce losses of N, inputs need to be precisely matched to the crop needs. The 'SIX EASY STEPS' (Schroeder *et al.*, 2005) approach to nutrient management does this by using a regional yield potential, taking into account the soils ability to mineralise N and reducing application rates when other sources of N are present (mill by-products, legume crops and N in irrigation water). The 'SIX EASY STEPS' approach is open to the inclusion of new information in order to refine recommendations.

Green-cane trash blanketing (GCTB) is a widely adopted practice in the sugar industry. It has been shown to improve productivity (Chapman *et al.,* 2001) and is a more sustainable production system than the previous system that included burning cane prior to harvest. The change from harvesting burnt cane to harvesting green cane commenced in the late 1970s (Leslie and Wilson, 1996). Currently in Queensland approximately 72 % of the sugarcane crop is harvested green with most mill areas in excess of 85 % (Schroeder *et al.*, 2009a). Many regions have been trash blanketing for a long period of time (> 15 years). With long-term retention of trash, nutrients and organic matter may be accumulating in the soil. This improved fertility could potentially allow for fertiliser rates to be reduced. Robertson and Thorburn (2000) indicated that once long term equilibrium was reached increased mineralisation of N would equal annual trash N returns. Depending on crop size this could be 40–100 kg N/ha/year. This amount is a substantial proportion of total annual N fertiliser applications.

More recently, the industry has started to adopt the recommendations from the Sugar Yield Decline Joint Venture (Garside, 2002). Fallow legume crops, reduced tillage and controlled traffic are increasing in all mill areas. Legume fallow cropping in particular could have a large impact on fertiliser N recommendations. At this stage, indicated plant crop N rates within the SIX EASY STEPS program are reduced following a legume fallow crop, but recommendations for the first ratoon crop are not (Schroeder *et al.*, 2005).

The objective of this work was to assess whether N fertiliser rates could be reduced following long-term trash blanketing, to see whether current recommendations for new farming practices were robust and to assess whether there was any change in production when new farming practices were adopted.

## Materials and methods

### Trial site

The trial was established on a site at BSES Mackay that was previously set up to investigate GCTB (Chapman *et al.*, 2001). The original trial was planted in 1992 and consisted of four sections of a block, two sections were harvested early and two sections were harvested late. Within each section, two replicates (main plots 8 rows wide) were trash blanketed and two replicates were burnt after harvest. In 1999 Q124 was planted in the two late-harvest sections of the block and these were planted again in 2003 with Q196[Φ]. The trash treatments (burnt versus GCTB) in these sections were maintained throughout this period. From 1999 to 2005 the two early harvest sections of the block were used for various experimental purposes. The trash treatments were not maintained. These two sections of the block were available again in 2005.

**Establishment of farming system treatments**

At the end of 2005 all four sections of the block were fallowed. Four farming system treatments were established:

B and GC: On the two sections of the block originally harvested late the two main treatments of burnt trash (B) and GCTB (GC) were continued. These treatments had a history of either long-term (1992–present) burning or long-term trash blanketing. In both farming system treatments the old cane stool was sprayed out and prepared for planting in 2006 after a period of bare fallow. Tillage operations consisted of 2 offset discings (29 March 2005 and 1 June 2006) and a deep ripping (19 May 2006) operation.

NFSS and NFSD: New farming system principles were established on the two original early harvest sections of the block. Tillage was required to remove compaction and change from a 1.5 m row spacing system to a 1.8 m row spacing system. This included: 2 offset discings, 1 ripping and 1 rotary hoeing between 18 October 2005 and 21 November 2005. 1.8 m beds were formed on 23 November 2005. Soybeans (cv. Leichhardt) were planted, two rows per bed, on 30 November 2005 and were sprayed out on 29 March 2006. Single rows of cane were established on the beds as one main treatment (NFSS) and dual rows as the other (NFSD). Main plots were 6 rows wide.

Q208[Φ] was planted in all four sections of the block between 31 July 2006 and 3 August 2006. A mouldboard planter was used on B and GC to establish 1.5m single rows. These treatments were later hilled up on 9 December 2006. Double-disc opener planters were used on the beds in NFSS and NFSD. One pass of a crumble roller immediately after planting was used to reshape beds in these treatments. Overall, four farming system treatments were established with 4 replicates:

- B Long term burnt trash, 1.5 m single rows, bare fallow, conventional cultivation
- GC Long term GCTB, 1.5 m single rows, bare fallow, conventional cultivation
- NFSS 1.8 m single rows, soybean fallow, pre-formed beds, GCTB
- NFSD 1.8 m dual rows, soybean fallow, pre-formed beds, GCTB

These treatments represent a transition in sugarcane farming systems that has occurred over the last 20–30 years.

**N rates**

Sub-plots for nitrogen rates were established in each farming system treatment using a split-plot design. Sub-plots were 8 rows by 25 m in farming system treatments

B and GC and 6 rows by 25 m in farming system treatments NFSS and NFSD. Four N rates were applied: 0, 75, 150 and 225 kg N/ha. Nitrogen, as urea, was applied on 16 November 2006, 1 October 2007 and 9 October 2008 to the plant (P), first (1R) and second-ratoon (2R) crops, respectively. In the P crop and 2R crop, the N treatments were applied with a stool splitter. N was applied to the 1R crop by hand into a slot cut by a stool splitter. The slot was covered in by hand with a chip hoe.

**Other management**

Phosphorus was not applied on the trial area as soil tests showed that it was not required (BSES P > 50 mg/kg). Potassium was applied at 100 kg/ha to all crops and sulphur was applied at 45 kg/ha on the 2R crop (as potassium sulphate). Herbicides were used to control weed growth as per standard practices. The trial was conducted under rain-fed conditions apart from one irrigation event after planting in order to ensure good establishment.

**Sampling**

Soybean above ground biomass was measured on 22 February 2006. Six 1 $m^2$ quadrats were placed in the crop, three in the northern (reps 1 and 2) and three in the southern sections (reps 3 and 4) of NFSS and NFSD. Quadrats were placed in regions least affected by a soybean moth (*Aproaerema simplexella*) infestation. This was done to estimate biomass prior to the infestation. The quadrats were placed directly over the 1.8 m beds. Plants within the quadrat were cut at ground level and placed in a large paper bag. Fresh weight was measured and dry weight measured after bags had reached a constant weight after drying in an oven set at 60$^o$C. Biomass was calculated using a quadrat area of 1.8 $m^2$ to take the interrow space into account.

Leaf samples were collected from the P, 1R and 2R crops on 14 March 2007, 24 March 2008 and 7 April 2009, respectively, according to standard practice (Wood *et al.*, 2003).

The P, 1R and 2R crops were mechanically harvested on 14 September 2007, 18 September 2008 and 22 September 2009, respectively. The middle two rows of each sub-plot were weighed in a bin mounted on load cells and yield calculated. CCS was determined using near infrared spectroscopy (Berding *et al.*, 2003).

**Statistical analysis**

Data collected from the three crops (P, 1R, 2R) were analysed using repeated measures analysis of variance with a split-plot design within GenStat 10.1. Fischer's protected least significant difference was used for comparison of individual means.

**Results and discussion**

Analysis of sugar and cane yield produced similar results and conclusions. In the interest of brevity only cane yield data are presented.

**Response to N following long term trash blanketing**

There was no indication that the treatment that had been GCTB since 1992 had greater nitrogen availability compared to the burnt treatment. This was supported by three pieces of evidence. Firstly the lack of any difference in response of the B and GC systems to N, particularly at the lower N rates (Table 1). Secondly, with each successive crop, yield declined more at the lower N rates (Table 2), but this decline was not more pronounced on the B system compared to the GC system (Figure 1, P>0.05). Thirdly, there was no difference in leaf N concentration between the B and GC systems (Table 3).

**Table 1**—Effects of farming system and N rate on sugarcane yield (t/ha). Data are the average of the plant, first-ratoon and second-ratoon crops. Farming system abbreviations are explained in the text.

| Farming system | N (kg/ha) | | | | Average |
|---|---|---|---|---|---|
| | 0 | 75 | 150 | 225 | |
| B | 64.7 | 93.2 | 103.6 | 109.0 | 92.6 |
| GC | 59.4 | 91.4 | 105.6 | 109.4 | 91.5 |
| NFSS | 66.0 | 90.9 | 107.8 | 114.7 | 94.8 |
| NFSD | 64.1 | 95.1 | 109.1 | 119.9 | 97.1 |
| Average | 63.6 | 92.7 | 106.5 | 113.3 | |

*N: $LSD^{0.05}$ = 4.5 (P < 0.001)*
*Farming system: P > 0.05*
*Farming system x N: P > 0.05*

Initial modelling of the impact of long-term trash blanketing on sugarcane soils predicted that fertiliser N use could potentially be reduced by an amount equal to the amount of nitrogen returned in the trash blanket (Robertson and Thorburn, 2000, 2007).

**Table 2**—Effect of farming system, N and crop class on sugarcane yield (t/ha). Farming system abbreviations are explained in the text.

| Effect | Crop | | |
|---|---|---|---|
| | P | 1R | 2R |
| Farming system | | | |
| B | 117.2 | 88.2 | 72.5 |
| GC | 107.4 | 88.7 | 78.4 |
| NFSS | 112.2 | 97.9 | 74.5 |
| NFSD | 124.2 | 90.4 | 76.7 |
| N (kg/ha) | | | |
| 0 | 99.6 | 52.2 | 39.0 |
| 75 | 112.2 | 91.3 | 74.6 |
| 150 | 122.1 | 106.9 | 90.5 |
| 225 | 127.0 | 114.8 | 98.0 |
| Crop average | 115.2 | 91.3 | 75.5 |

*Farming system x crop class: $LSD^{0.05}$ = 12.2 (P < 0.001)*
*N x crop class: $LSD^{0.05}$ = 6.5 (P < 0.001)*
*Crop class: $LSD^{0.05}$ = 2.8 (P < 0.001)*

Robertson and Thorburn (2000) indicated this would only be possible once the system had reached a new equilibrium where the amount of N immobilised equalled the extra amount mineralised due to improved soil carbon (C) and N conditions.

They predicted that it would take 20–30 years following the adoption of trash blanketing for soils to approach this new equilibrium (Robertson and Thorburn, 2007) and that small reductions (15–40 kg/ha) in N applications may have been possible in the medium to long term (15–25 years).

Our data suggest that this equilibrium has yet to be reached at this site, 15 years after the treatments were established.

Either more time is required for soil C and N to reach equilibrium or other processes are limiting the soils ability to accumulate C and N. Blair (2000) showed that tillage (at this experimental site) during the crop cycle reduced the concentration of all C fractions compared to a no tillage treatment.

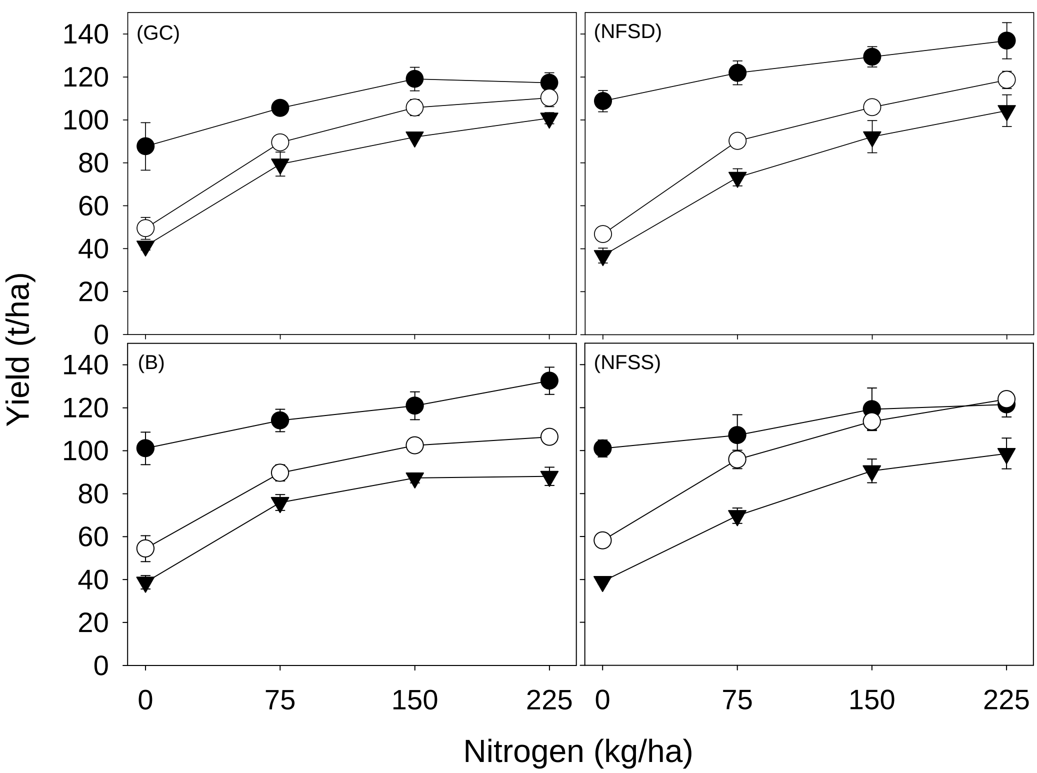


Fig. 1—Effect of N on yield of plant (●), first-ratoon (O) and second-ratoon (▼) *cane grown in four farming systems. Farming system abbreviations are explained in* the text. Error bars represent SEM.

Although tillage within the crop cycle is no longer a common practice in many regions, tillage at the end of the crop cycle is still widely used, and was used between crop cycles at the experimental site.

Numerous passes of offset discs, rippers and rotary hoes may have reduced the accumulation of soil C and N in the GC treatment (soil C and N were not measured), thus explaining the lack of any difference in response to applied N. A tillage effect was shown by Bell *et al.* (2001) who found that total C and labile C in a burnt cane system were no different to that of a GCTB system after plough-out, even though total C and labile C were significantly higher in the GCTB system prior to plough-out. N losses to the environment may also have increased in our GCTB system.

Wang *et al.* (2008) showed that denitrification losses were greater under GCTB, most likely due to the presence of a carbon source and a wetter soil profile. Increased N losses are likely to extend the time required to reach equilibrium.

**Table 3**—Leaf N concentrations (%) for the plant, first- and second-ratoon crops. Farming system abbreviations are explained in the text.

| Crop | Farming system (FS) | N (kg/ha) | | | | FS average |
|---|---|---|---|---|---|---|
| | | 0 | 75 | 150 | 225 | |
| Plant | B | 1.76 | 1.90 | 1.97 | 2.09 | 1.93 |
| | GC | 1.77 | 1.94 | 2.06 | 2.22 | 2.00 |
| | NFSS | 1.84 | 2.05 | 2.19 | 2.19 | 2.07 |
| | NFSD | 1.80 | 2.08 | 2.17 | 2.26 | 2.08 |
| | N average | 1.79 | 1.99 | 2.10 | 2.19 | |
| 1st ratoon | B | 1.57 | 1.82 | 1.97 | 2.08 | 1.86 |
| | GC | 1.72 | 1.77 | 1.90 | 2.01 | 1.84 |
| | NFSS | 1.68 | 1.71 | 1.88 | 1.88 | 1.79 |
| | NFSD | 1.61 | 1.62 | 1.80 | 1.99 | 1.75 |
| | N average | 1.64 | 1.73 | 1.89 | 1.99 | |
| 2nd ratoon | B | 1.47 | 1.62 | 1.78 | 1.84 | 1.68 |
| | GC | 1.53 | 1.67 | 1.84 | 1.91 | 1.74 |
| | NFSS | 1.66 | 1.66 | 1.74 | 1.79 | 1.71 |
| | NFSD | 1.55 | 1.64 | 1.68 | 1.82 | 1.67 |
| | N average | 1.55 | 1.65 | 1.76 | 1.84 | |
| | Overall N average | 1.66 | 1.79 | 1.91 | 2.01 | |

*N: $LSD^{0.05}$ = 0.04 (P < 0.001)*
*Farming system x Crop $LSD^{0.05}$ = 0.1 (P < 0.001)*

Given these results, it is difficult to suggest that reductions in N recommendations could be made due to long-term trash blanketing at this stage.

**Comparison of all farming systems**

Sugarcane was grown following a soybean fallow crop in NFSS and NFSD and a bare fallow in B and GC. Soybean above ground biomass averaged 4.0 t/ha. Assuming an N concentration of 3.5 %, an estimated 180 kg N/ha would have been returned to the soil (Schroeder *et al.*, 2005). While the legume crop potentially fixed/trapped large amounts of N, a heavy infestation of soybean moths (*Aproaerema simplexella*) defoliated the entire crop by the end of March 2006 (Figure 2).

(a) (b)

Fig. 2—(a) Soybean crop January 2006 (b) Soybean crop defoliated following an infestation of soybean moth (*Aproaerema simplexella*) March 2006.

Despite the soybean fallow crop, sugarcane grown in systems NFSS and NFSD responded to N in a similar manner as systems B and GC (Table 1, Figure 1). The significant response to N, was present in all three crops (P, 1R and 2R) in all four farming systems. However, the N response was more pronounced as the N stress increased with each crop (Figure 1).

A response to N by a sugarcane plant crop following a good soybean fallow is not expected given the potentially large nitrogen contribution (Garside *et al.*, 1997; Garside and Bell, 2001). However, they have been reported previously (Garside *et al.*, 2006). Our results suggest that the soybean crop did not contribute significant amounts of N to the following cane crop, most likely due to the soybean crop being completely defoliated by an insect pest.

Current recommendations suggest fertiliser N should be applied if the soybean fallow crop is classified as poor (less than 4 t/ha soybean biomass). In this situation it appears that the legume crop was so poor that no discounting of its N content should have taken place.

Leaf analysis also showed no overall difference in leaf N concentration among farming systems. However, the average third-leaf N value associated with B was significantly lower than those associated with NFSS and NFSD in the plant crop (Table 3).

Leaf N concentration values for the plant crops of all farming systems were above the accepted critical value (N = 1.8 %). This may explain why there were no differences in crop response by the different farming systems (Figure 1).

Overall, there was no difference in cane yield among all four farming systems (Table 1). GC was significantly lower than NFSD in the plant crop but this difference was lost in the 1R and 2R crops (Table 2). This result is comparable to that indicated by Garside *et al.* (2009) where a dual-row sugarcane system produced a large plant crop, but similar ratoon yields.

This may be due to stool damage caused by the use of harvesters that were not specifically set up to harvest dual rows. The dual-row system responded to N in a similar manner as the single-row systems on 1.5 m and 1.8 m spacings. This shows that N recommendations based on trial work conducted on 1.5 m single-row systems are appropriate and robust enough to also cover dual-row systems.

Chapman *et al.* (2001) showed that trash blanketing improved cane yields at this site compared to the burnt trash treatment. The increased yield was mainly attributed to increased soil moisture conservation in the GCTB system.

Rainfall (calculated from 1 July–30 June) was 1162, 1265, 990, 1188, 1651 and 1203 mm for the crops harvested by Chapman *et al.* (2001) from 1993–1998, respectively. Rainfall for the crops harvested from 2007–2009 was 1762, 2230 and 1804 mm, respectively.

Clearly, our trial was during a period of greater rainfall than that of Chapman *et al.* (2001). It appears likely that in our study rainfall was sufficient for the B system to overcome the advantage the GC system has in terms of moisture retention.

Crop yield did not increase when new farming system principles were used. However, recent improvements to sugarcane farming systems lower the cost of production (Schroeder *et al.* 2009b).

Potentially, production may increase in the future or input costs could be reduced even further once the soils condition has had sufficient time to recover from excessive tillage and compaction. This site will be monitored into the future to examine whether this is the case.

## Conclusions

- The response to N was similar for cane grown following long term (15 years) burning of trash and long term GCTB. This suggests that soil C and N conditions have yet to improve sufficiently for N rates to be reduced in the long-term GCTB treatment.
- The lack of any difference in response between burnt and GCTB systems may have been due to insufficient time, a loss of C following tillage between crop cycles, increased denitrification under GCTB, or other unknowns.
- A significant response to N following a legume fallow crop appears to be due to damage to the legume crop by an insect pest. This validates the recommendation that N should be applied following poor legume crops.
- Improved farming systems did not result in increased crop yield however the improvements to soil condition, the aim of improved farming systems, are likely to occur over the long term.

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