OVERCOMING ON-FARM CONSTRAINTS TO PRODUCTIVITY AND PROFITABILITY IN A WET TROPICAL AREA

FINAL REPORT

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A statutory body controlling cane pests and diseases and promoting productivity in the Babinda area

CSIRO

Statement of Confidentiality:

No part of this report is considered confidential.

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TABLE OF CONTENTS

EXECUTIVE SUMMARY 1
BACKGROUND 2
OBJECTIVES 3
METHODOLOGY 4
Grower liaison and interaction 4
Demonstration of ‘best-bet’ trash management practices 5
Exploration of improved nitrogen fertiliser placement 6
Broad scale survey of plant nitrogen status 7
RESULTS 7
Trash management trials 7
Harvest and yield data 7
Soil water content and temperature 9
Nitrogen availability 10
Fertiliser placement trials 13
Yields at harvest 13
Soil nitrogen availability 14
Broad scale survey of plant nitrogen status 15
DISCUSSION 19
Management practice effects on cane production 19
Trash management 19
N Fertiliser placement 20
Soil and plant nitrogen status 20
Soil mineral nitrogen 20
Broad survey of plant nitrogen 21
OUTPUTS 22
EXPECTED OUTCOMES 22
FUTURE RESEARCH NEEDS 23
RECOMMENDATIONS 23
ACKNOWLEDGEMENTS 24
PUBLICATIONS ARISING FROM THIS PROJECT 24
REFERENCES 25

EXECUTIVE SUMMARY

The CCS in the wet tropics has been declining steadily for over three decades, a period in which green cane harvesting-trash blanketing (GCTB) has become standard practice among growers throughout the wet tropics. In the Babinda Mill region, where this situation is most acute, it has been hypothesised that a part of the low CCS problem is due to the effect of GCTB in increasing soil moisture and soil fertility, which aggravates lodging and suckering in the crop and restricts the opportunity for drying crops out. During the 1990's Babinda growers were assessing alternative management systems to overcome some of these perceived problems associated with trash blanketing.

This project aimed to implement best-bet initiatives to overcome problems associated with trash blanketing, and so improve productivity and profitability in a wet tropics environment. The project was directed by stakeholders and conducted using a participative approach.

There were four interrelated 'strands' of activity undertaken in this project:

1. Liaison and interaction with Babinda growers and the wider industry, achieved through establishment of a Grower Management Group, conducting all trials on farms (as opposed to research stations), distributing regular newsletters and holding regular bus tours and shed meetings to view demonstration sites and discuss trial results.
2. Demonstration of 'best-bet' trash management practices (for improved profitability). Trials were established on four farms comparing the impact of raking trash from the stool and/or incorporating it into the soil.
3. Exploration of improved nitrogen fertiliser placement (for improved profitability). Trials were established on two farms comparing different placement of N fertiliser (in the ground or on the trash blanket) and different N carriers (urea and Nitram).
4. Determination of soil and plant nitrogen status in response to different soils and/or management practices. Soil and crop N status were determined in all trials and a survey of amino-N in juice from sugarcane (a good indicator deficiency and over-supply of N to the crop) from all blocks on eight farms in the region.

The trash management trial sites consistently failed to demonstrate any advantage of either raking trash from the stool, incorporating trash into the soil, or doing both. Thus the extra cost of purchasing and operating a trash rake is not justified. At one site, in a flood prone area where trash blanketing is impractical, trash burning consistently gave higher yields than trash raking and incorporation. This result suggests that raking and incorporation of trash is economically disadvantageous, in the short term, in these areas. However, damage to the stool during raking caused the lower yields in the raked incorporated treatments at this site and improved methods of raking trash may overcome this problem.

Incorporation of urea fertiliser (to protect it from volatilisation losses) did not consistently increase yield compared to surface-applied urea or Nitram. The results suggest that either volatilisation was not significant, or N fertiliser application rates were high enough for losses to have no impact. Thus surface applications of urea will be a more cost effective method of applying N fertiliser at the current application rates (but possibly not at reduced rates) and the expense of non-volatile forms of N fertilisers (at current N application rates) cannot be justified.

The soil mineral N data from this project showed two important and consistent results: (1) that soils in the Babinda Mill region had considerable amounts of mineral N at all sites and times and (2) that the majority of mineral was in the from of NH_4^+. These results challenge conventional thinking about N in the wet tropics and may have important, practical

implications for N fertiliser management. Soils of the Babinda area are ‘N-rich’ due to the high amounts of NH_4^+ and this being a form of N that is not be subject to the major environmental loss processes of leaching and denitrification. Thus, fertiliser N inputs can (should) be tailored to more closely reflect crop requirements, and actions (such as splitting fertiliser applications or over fertilisation) to combat environmental losses of N may be unnecessary. Further work is required to understand (1) the processes causing the high amounts of NH_4^+ and (2) how widespread this phenomenon is in the wet tropics so that implications for management of N fertiliser in the wet tropics can be understood and widely communicated.

The survey of amino-N in sugarcane juice showed that the majority of sugarcane crops surveyed had an adequate supply on N, with some exhibiting ‘luxury uptake’ of N. Thus it was unlikely that N was limiting yields of these crops. These results are in general agreement with the implications of the soil N studies, that the soils of the area were not ‘N poor’.

This project has had, and will continue to have several outcomes. Firstly, the project has prevented unproductive expenditure by Babinda growers on trash rakes and raking. Secondly, the project is changing attitudes of Babinda growers and members of the research community about N cycling in soils of the Babinda region and elsewhere in the wet tropics. It became obvious as the project progressed that growers’ concepts (mental models) of soil N cycling were changing, and it is likely they will be more receptive to innovative concepts about N fertiliser management in the future. Indeed, one farmer commenced experimenting with reduced N fertiliser application rates during the project. Thirdly, there is a move towards applying urea fertiliser on the surface of trash blankets as a result of this project. While this reasoning behind this is sound, it may lead to higher losses of N via volatilisation. Growers may be as well off reducing urea application rates (and so saving input costs) and burying the urea. However, rationalisation of these concepts was beyond the scope of this project.

BACKGROUND

The CCS in the wet tropics has been declining steadily for over three decades (Leslie and Wilson, 1996). The situation is most acute in the Babinda mill area, which has the lowest CCS of any mill area in Queensland, now averaging 11.5 units of CCS a season. This low CCS, combined with low cane yield is threatening the industry’s viability in the region.

In the mid to late 1970’s farmers in the wet tropics moved towards the green cane harvesting-trash blanketing (GCTB) system (Wood 1991). Growers were encouraged by the flexibility this system gave in choosing blocks for harvesting and the elimination of losses due to burnt blocks not being harvested in wet conditions. The additional 0.5 to 0.75 of a unit of CCS gain that was originally associated with GCTB also gave an impetus. By the mid 1980’s, GCTB had become standard practice among growers throughout the wet tropics. Cost savings from zero tillage, initial reduced herbicide use and erosion control were also incentives. A significant improvement in soil nutrient status and structure from the build up of organic matter has also appeared to result. However, these benefits of GCTB have not prevented the declining trend and, in the Babinda area, CCS and cane yield has not improved to the extent that it has in other drier areas of the North (e.g., Mulgrave).

Despite the practical value of the GCTB system, there are some potential drawbacks associated with the system. Improved soil fertility resulting from retention of trash (Robertson and Thorburn 2001, Thorburn *et al*. 2000) may be aggravating lodging and suckering (Salter and Bonnett 2000, Bonnett *et al*. 2001) in the crop and, in some soils, inhibiting drying out of the crop. Technical advice on fertiliser application rates and timing has not been adjusted to reflect the improved/altered soil conditions under GCTB. It is hypothesised that a part of the low CCS problem is due to the effect of GCTB in increasing soil moisture and soil fertility, which aggravates lodging and suckering in the crop and restricts the opportunity for drying crops out. Although some growers in the wet tropics continue to burn trash (mainly in flood prone areas where trash blanketing can cause large floating 'rafts' of trash to move onto adjacent fields during floods and kill considerable areas of cane), it is desirable to maintain widespread trash blanketing because of the environmental and practical benefits associated with this trash management practice.

However, during the 1990's Babinda growers were assessing alternative management systems – experimenting to overcome some of the perceived problems associated with trash blanketing. One practice was to reduce rates of N in ratoon crops in an attempt to improve CCS. In a survey conducted by BSES in 1996, 97% of Babinda growers applied equal or less than the BSES recommended rates of N fertiliser (Greg Shannon, pers. comm.) whereas the majority of north Queensland growers were applying greater than recommended rates.

Another way to retain the advantages of the GCTB system and minimise the perceived problems associated with it would be to rake trash from stools and/or incorporate it into the ground. There was much interest amongst growers in this concept on the late 1990's – many growers had purchased or were considering purchasing trash rakes to rake trash from the stool in an attempt to assist ratooning.

Finally, in order to reduce costs and save time associated with fertiliser application, a number of growers started placing N fertiliser on the surface of the stool, as opposed to the recommended practice of burying N fertilisers in the soil in bands alongside the stool. There was also anecdotal evidence of improved growth with surface application of N fertilisers. If the nitrogen carrier is urea (as is commonly the case), there is a danger with surface application that a large proportion of the N will be lost through volatilisation (Freney *et al*. 1991). To avoid this loss, some growers have applied non-volatile forms of N fertilisers. However, these fertilisers cost more than urea and so they counter the cost reductions sought with surface N fertiliser applications.

While Babinda growers were searching for ways to improve their productivity and profitability, they felt that there was little specific information about N and carbon dynamics in soils of the Babinda mill area (and perhaps the wet tropics in general) against which to evaluate the possible benefits and disbenefits of these (and other) trash management practices (Alan Zapala, pers. comm.). This information was seen as vital for removing the uncertainty surrounding concepts of alternate management practices and so this project was proposed.

OBJECTIVES

The broad objective of this project was to implement best-bet initiatives for improved productivity and profitability in a wet tropics environment with stakeholders using a participative approach. This was achieved by focussing on the impacts of the green cane harvesting – trash blanketing management system. Specific objectives were to:

1. Define and demonstrate effective strategies for managing any detrimental post harvest and (possible) in-crop effects of GCTB practices in the Babinda area.
2. Monitor the productivity, and soil and plant nitrogen dynamics, at demonstration sites and selected blocks across the whole mill area.
3. Determine the profitability of the management practices demonstrated.
4. Actively disseminate information on the outcomes of the improved management practices to growers within the Babinda area.

5. Transfer information gained from the project to the sugar industry via the BSES extension network.

Objectives 1 to 4 have clearly been achieved, with an additional achievement constituted by investigations into the profitability of different combinations of N fertiliser placement and carriers. Objective 5 has only been achieved for information gained in Babinda that was relevant to other areas in the wet tropics. As this was a participatory action research project, the grower community in the Babinda Mill region has driven the issues investigated (and the methods of investigation) and so not all the information in the project is relevant for other areas of the wet tropics. An example of this is the broad survey of plant N status, which is specific to Babinda – the information is not relevant to other mill regions (although we do set it in the perspective of the wider industry in this report). Also, some information is not appropriate for extension messages. An example of this is the finding of most soil mineral N being in the form of NH_4. This result has immense implications for our understanding of N cycling in the wet tropics and practical implications for management of N fertiliser in that environment. However, it will need to be better understood before the practical implications are fully developed and 'translated' into extension messages. (As one step in gaining this understanding, a CRC-Sugar and SRDC funded PhD project has been established focussing, in part, on this issue.) The main issue of general relevance to other areas within the wet tropics is the results of the trash management trials. These have been communicated to BSES and CSIRO extension personnel in the wet tropics.

METHODOLOGY

There were four interrelated 'strands' of activity undertaken in this project:

1. Liaison and interaction with Babinda growers and the wider industry.
2. Demonstration of 'best-bet' trash management practices (for improved profitability).
3. Exploration of improved nitrogen fertiliser placement (for improved profitability).
4. Determination of soil and plant nitrogen status in response to different soils and/or management practices.

A more detailed description of the activities conducted in each of these strands of the project follows.

Grower liaison and interaction

Grower interaction was promoted and maintained through (1) a Grower Management Group, (2) regular newsletters and (3) bus tours and shed meetings held to view demonstration sites and discuss trial results. In addition to these actions, all trials were conducted on farms as opposed to research stations, 'embedding' this work within the grower community.

At the commencement of the project, a circular was sent to all growers in the Babinda area outlining the possible scope of the project and inviting interested participants to form a management group. A group of 10 growers were formed and identified (1) the interactions between raking and incorporation of trash and (2) N fertiliser placement, as priorities for investigation. The group met twice yearly to discuss project progress and interim results. The meetings were open to all growers in the district.

Newsletters outlining the project's progress and results were sent to all Babinda growers prior to each Management Committee meeting. The newsletters also informed growers of the forthcoming meeting and invited them to attend.

Bus tours and shed meetings were held annually (each June or July) to allow growers to view demonstration sites and discuss trial results.

Local BSES and CSIRO extension staff were also invited to the meetings and tours, and informally informed of the project's progress whenever opportunities arose.

Demonstration of 'best-bet' trash management practices

'Best-bet' trash management trials were established on four farms in spring 1999, following harvest of plant cane. Details of the sites and treatments are given in Table 1. In response to the priorities set by the Grower Management Group, treatments centred around combinations of trash raked from the stool and/or incorporated into the soil. The control treatment was generally a full trash blanket. Site 1 floods regularly, however, and so a trash blanket is impractical. The owners of that site suggested that a more appropriate control was burning trash.

A three-row trash rake was used to rake trash from the stool into the interspace in the treatments where this was necessary. Being of light construction for portability, two passes were sometimes required for satisfactory removal of the trash from the stool area. Heavy ratooning disks were used to incorporate trash where required.

As the local interest in trash raking/incorporation was based on the hypothesis that soils would be drier if trash was raked/incorporated, soil moisture was measured in some treatments with electronic data logging equipment. Three data logging systems were available with six water content sensors per system. Systems were installed at three of the demonstration sites with measurements made at three depths in both the stool and the interspace areas. Soil temperature was also measured as it may affect emergence after harvest.

Treatments were duplicated at each site, but randomisation of treatments was not possible at all sites. Cane was harvested with a commercial harvester and cane from all trial strips was sent to the mill as separate rakes. Bin weights and mill CCS was recorded for yield determination.

Table 1. Details of the on-farm demonstration trials established during the project.

Site	Soil type*	Variety	Treatments
On-farm trash management demonstration trials			
Site 1 Nucifora and Torrisi	Tully	Q174	1. Trash burnt post harvest 2. Trash raked from stool and incorporated in interspace
Site 2 Sacchetti	Malbon	Q166	1. Full trash blanket 2. Trash left on the stool and incorporated in the interspace 3. Trash raked from the stool into the interspace. 4. Trash raked from the stool and incorporated in the interspace
Site 3 Stewart	Coom	Q166	As for site 2 above
Site 4 Mangano	Coom	Rep 1, Q135 Rep 2, Q152	As for site 2 above
Nitrogen fertiliser placement trials			
Site 5 Cardillo	Innisfail	Q152	1. Nitram – surface applied (@ 170 kg/ha) 2. Urea – surface applied (@ 170 kg/ha) 3. Urea – sub-surface applied (@ 170 kg/ha)
Site 6 Mangano	Tully	Q152	1. Nitram – surface applied (@ 160 kg/ha) 2. Urea – surface applied (@ 144 kg/ha) 3. Urea – sub-surface applied (@ 144 kg/ha)

* Refer to Murtha *et al*. (1996).

At all four sites, soil samples were taken and analysed for mineral N (NO_3^- and NH_4^+) at two times during each crop; (1) post harvest but prior to fertilisation and (2) midway through the growth cycle. Samples were collected to 1.5 m depth post-harvest, and to 0.3 m depth at the mid-crop sampling. Soil samples were taken with 50 mm diameter steel 'push tubes', with six cores taken from each duplicate plot, three from the row and three from the inter-row. Samples from each core were bulked within each depth increment. Samples were stored and transported, refrigerated in plastic bags until analysis. NO_3^--N and NH_4^+-N in the soil cores were determined colorimetrically (Henzell *et al.* 1968) after extraction of the soil with 2M KCl (Catchpoole and Weier 1980).

Leaf samples were also taken from all treatments at the time of the mid season soil sampling for determination of total N concentration by dry combustion.

Exploration of improved nitrogen fertiliser placement

Trials were established at two sites demonstrating the effect of different fertiliser carriers and placements in spring of 2000. The trials were located at different sites from the trash management demonstrations (Table 1). At both sites, N was surface applied as urea and Nitram, and sub-surface applied as urea (the local recommended practice). N application rates were 140 kg/ha in all treatments at both sites, except the Nitram treatment at Site 6 where it was 170 kg/ha due to operator error. With sub-surface application, a conventional fertiliser box was used to place fertiliser into the soil in two bands behind a coulter either side of the stool. For the surface applications the coulters were still run beside the stool but the tubes were redirected to apply the fertiliser directly on the trash blanket over the stool area.

Treatments were duplicated at Site 5, as had been done in the four trash management demonstration trials, but they were not able to be duplicated at Site 6. Cane was harvested with a commercial harvester and cane from all trial strips were sent to the mill as separate rakes. Bin weights and mill CCS was recorded for yield determination. At Site 5, treatments were re-applied after harvest in 2001 and cane yields and CCS measured in 2002.

At both sites soils samples were collected to 0.3 m depth in the two urea treatments (surface applied and buried), five times during the 2000-2001 crop, and analysed for mineral N (NO_3^- and NH_4^+) using the methods described above. No soil measurements were taken in the second crop at Site 5.

Broad scale survey of plant nitrogen status

As well as monitoring soil and leaf N concentrations at the individual trial sites (i.e., within specific blocks on the farms), amino-N in sugarcane juice (Keating *et al*. 1999) was also monitored on every block of eight farms distributed across the Babinda Mill area during the project. Amino-N is a very sensitive indicator of plant N status and juice is easily obtained from the juice laboratory in sugar mills. Eight farms were chosen to represent a range of soils, climates and management practices (e.g., fertiliser applications, lime applications, etc.). The farms were selected as four pairs; i.e. farms 103 and 104, 133 and 137, 187 and 189, and 317 and 376. One farm (the first mentioned) in each pair had consistently lower CCS than the other in the 5 to 10 yr preceding the project. For the first three of the four pairs, farms were located on similar soil types. The farms of the fourth pair were from opposite ends of the Mill area and had contrasting soils: Farm 317 has predominately Malbon and Coom series soils (Murtha *et al*. 1996), and is prone to flooding and waterlogging on half the farm, while Farm 376 is on a Eubanangee series soil (a well drained red soil).

An attempt was made to collect juice from each rake of cane harvested from the eight farms. Juice was collected by staff of the juice laboratory of the Babinda Mill and keep frozen until analysis. Juice was obtained from approximately 80 % of rakes of the survey farms in 1999 and 2000, but from only ~ 20 % rakes in 2001. Amino-N was determined by the ninhydrin reactive method described by Keating *et al*. (1999). Juices from each rake in a cane block was mixed (in equal amounts) prior to analysis to give an average value for each block. Data for each cane block were then averaged to give a farm-average amino-N concentration and standard error, the standard error indicating the within-farm variability of the amino-N concentration.

RESULTS

Trash management trials

Harvest and yield data

The full harvest results for individual sites are given in Appendix 1.

Site 1 – Nucifora and Torrisi

In both years the cane yield (tcph) and sugar yield (tsph) were higher in the burnt cane treatment compared to the raked incorporated treatment (Table 2). In all cases the burnt treatment was approximately 20% larger than the raked incorporated. This trend however was not found for CCS, where there was no consistent treatment effect across years. The highest CCS in the 1R crop was recorded in the burnt cane treatment, while in the 2R crop it was in the raked incorporated treatment (Table 2). When results where averaged across years the trend for higher cane yield and sugar yield in the burnt cane treatment continued, with the burnt treatment being approximately 20 % greater (Table 2).

During raking at this site it was observed that some stool was damaged and removed from the ground. This damage is a likely explanation for the lower yield in the raked incorporated treatments. Given the results at this site, the extra expense of raking and incorporation of trash cannot be justified except where burning of trash is not a practical option.

Table 2. The harvest data for site 1 (Nucifora and Torrisi) for two harvest years and averaged across years and ratoons.

	Treatment	**CCS**	**tcph**	**tsph**
1R (2000)	Burnt	11.10	94.58	10.48
	Raked incorporated	10.95	82.0	8.99
2R (2001)	Burnt	13.40	83.22	11.16
	Raked incorporated	13.90	72.83	10.12
1R & 2R (Averaged across years)	Burnt	12.25	88.90	10.82
	Raked incorporated	12.43	77.42	9.56

Sites 2, 3 and 4 – Sacchetti, Stewart, and Mangano

The treatment effects on yield (tcph) were inconsistent between the three sites, with no trend apparent in either the mean yields across the two crops grown at each site (Table 3) or in data from individual years (Appendix 1). Yields were higher in the two raked treatments compared to the two trash treatments at Sites 2 and 4, but not at Site 3 (Table 3). Thus, the results do not demonstrate any yield benefit from either raking trash from the stool and/or incorporating it into the soil. The results were similar for CCS and sugar yield (Table 3). However, there was a consistent trend across the three sites for higher sugar yield (tsph) and CCS in the raked treatment compared to the racked incorporated (Table 3).

Table 3. The harvest data for sites 2, 3, and 4 (Sacchetti, Stewart, and Mangano) averaged across two crops (1R and 2R).

Site	**Treatment**	**CCS**	**tcph**	**tsph**
Sacchetti	Trash	13.25	73.44	9.62
	Trash incorporated	13.20	73.76	9.57
	Raked	13.09	77.89	10.07
	Raked incorporated	13.05	73.96	9.53
Stewart	Trash	14.18	56.25	7.92
	Trash incorporated	14.25	57.94	8.21
	Raked	14.48	55.44	7.97
	Raked incorporated	14.29	52.05	7.37
Mangano	Trash	11.89	75.20	8.58
	Trash incorporated	11.73	71.01	8.05
	Raked	11.94	76.03	8.67
	Raked incorporated	11.58	79.18	8.65

Soil water content and temperature

There were no consistent differences in water content between treatments. Example water content data in the trash and raked treatments at Sites 2, 3, and 4 over time periods of five to eight months are shown in Figures 1, 2 and 3. At Sites 2 and 4 (Figures 1 and 3), the soil moisture contents were higher when the trash was raked away from the cane stool. However Site 3 (Figure 2) displayed the opposite trend, with the trash treatment having consistently higher soil moisture contents compared to the raked. At all sites the moisture contents were relatively consistent between treatments once a canopy had established. Thus there was no evidence of increased soil moisture contents under the trash systems as might be expected to occur due to the suppression of soil water evaporation. A similar pattern to soil moisture was demonstrated by soil temperature (data not shown).

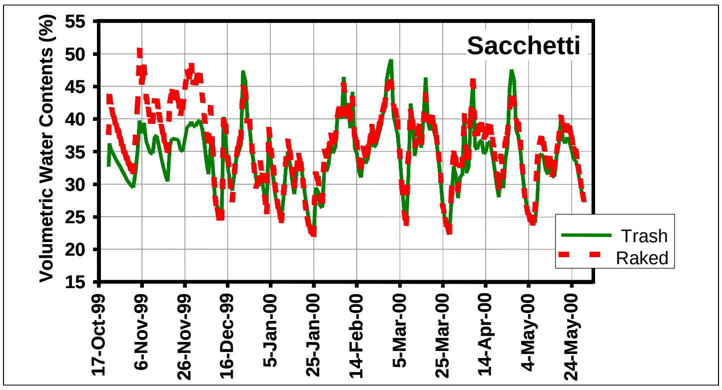


Figure 1. The volumetric water contents over a time period of approximately 8 months for the trash and raked treatments at Site 2, Sacchetti.

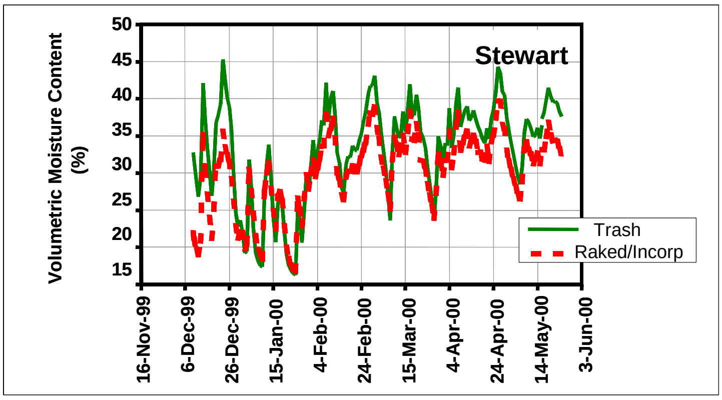


Figure 2. The volumetric water contents over a time period of approximately 7 months for the trash and raked/incorporated treatments at Site 3, Stewart.

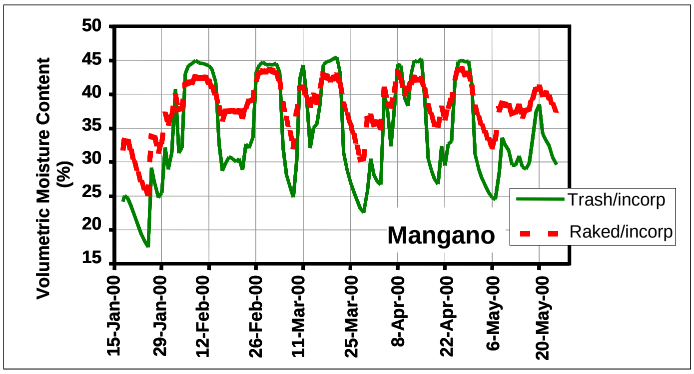


Figure 3. The volumetric water contents over a time period of approximately 5 months for the trash/incorporated and raked/incorporated treatments at site 4, Mangano.

Nitrogen availability

Mineral N contents in the top 0.3 m of soil the ranged from 23 to 72 kg/ha across the four sites during the two crops, with contents commonly being between 40 and 55 kg/ha (Figure 4). There was no consistent difference between mineral N contents at harvest (but prior to fertilising) and during the middle of the crop.

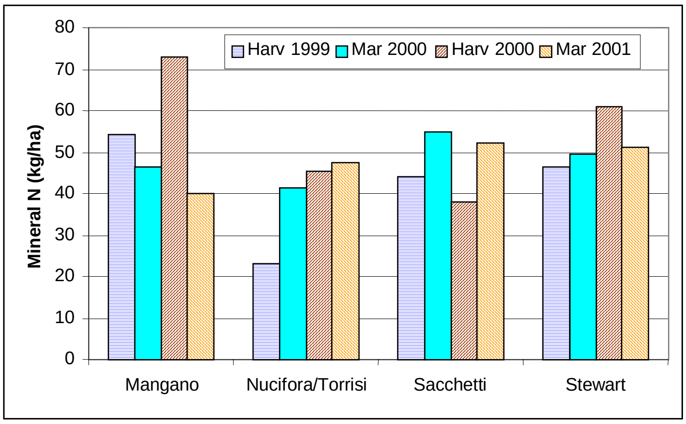


Figure 4. Mineral N (kg/ha) contents in the top 0.3 m of soil for the four demonstration sites averaged over two cropping seasons.

To 1.5 m soil depth there was 80 to 150 kg/ha of mineral in the soil across the four sites (Figure 5). There was consistently more mineral N at Sites 3 (Stewart) and 4 (Mangano) than the other two sites at both sampling times. This trend was not as pronounced in the shallower depths (Figure 4). There were no consistent trends in mineral N between the two sampling times (Figure 5).

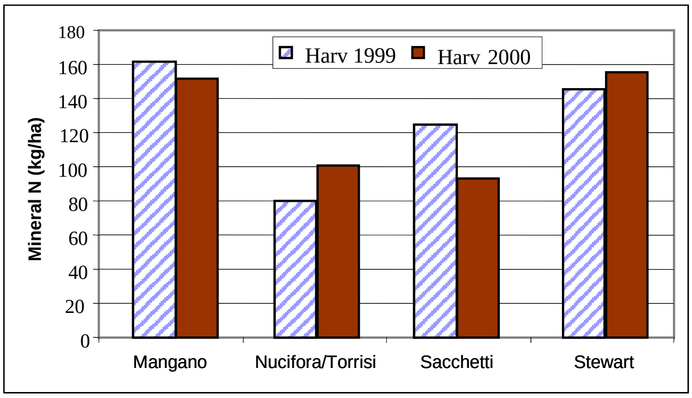


Figure 5. Mineral N (kg/ha) contents in the soil to 1.5 m depth for the four study sites averaged over two harvest periods.

There were no appreciable differences in mineral N contents between the different treatments (example data for Site 4 (Mangano) shown in Figure 6). The raked incorporated treatment was the only one that demonstrated some variability between the treatments by having higher mineral N values at the lower depths in the 1999 harvest and a consistently lower mineral N content in the 2000 harvest. However, this variability was not seen at the other sites.

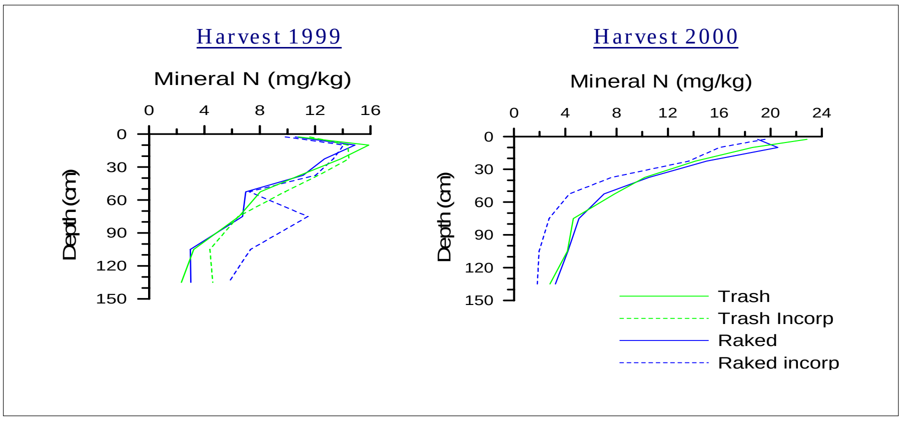


Figure 6. Mineral N (kg/ha) profiles for the four different treatments at the Mangano site over the two harvest years to 1.5 m depth.

Surprisingly, the majority of mineral N at all sites, depths and times was present as NH_4^+-N (Figure 7). NO_3^--N, which is generally the dominant form of mineral N in agricultural systems (Laegreid *et al*. 1999), generally accounted for < 25 % of the mineral N.

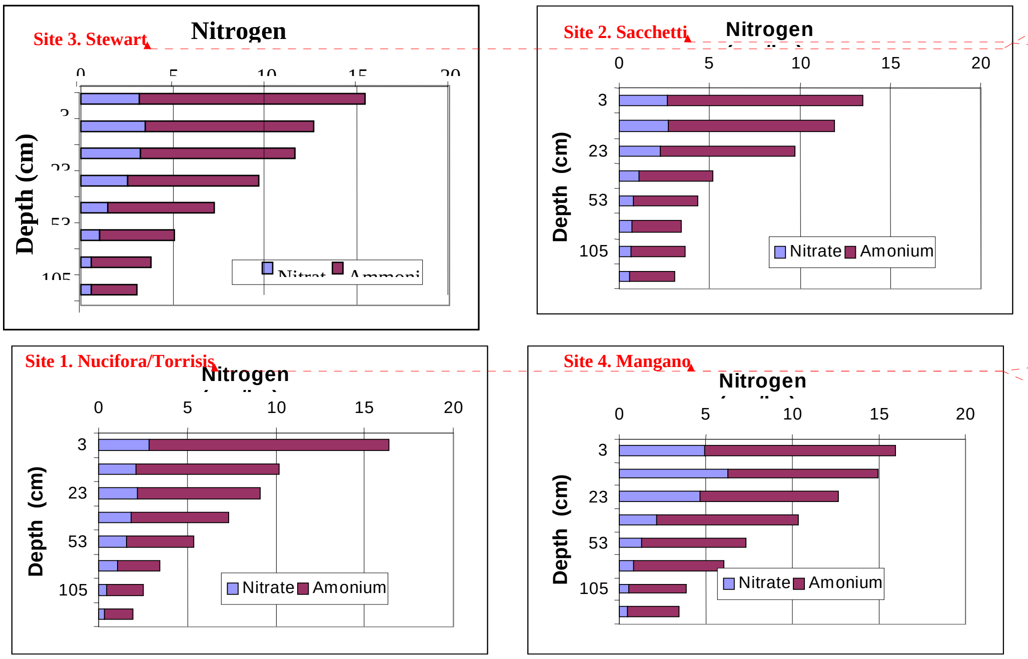


Figure 7. Nitrate- and ammonium-N at all four study sites to a depth of 1.5cm.

Leaf N concentrations were greater than critical concentrations for adequate N nutrition at three of the four sites during the 1R crop (in March 2001, Figure 8). However concentrations at the fourth site (Site 4, Mangano) were marginal at that time.

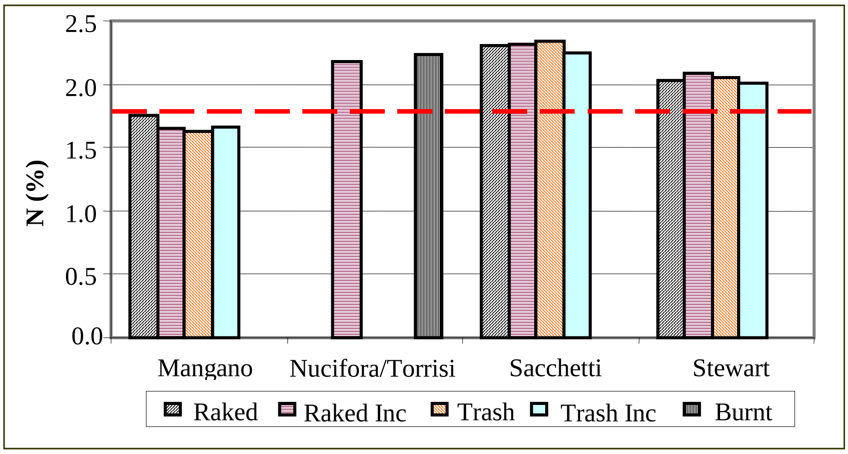


Figure 8. Leaf N concentrations at the four study sites (Site 4, Mangano; Site 1, Nucifora/Torrisi; Site 2, Sacchetti; and Site 3, Stewart) sampled in March 2001 for the different trash management treatments. The dashed red line shows the critical N concentration of adequate N nutrition (Calcino *et al*. 2001).

Fertiliser placement trials

Yields at harvest

At site 5, cane yields in both years were highest with sub-surface applied urea (Tables 4 and 5). However, yields were lowest in this treatment at Site 6 (Table 6). There was little consistent difference in CCS between different treatments at the two sites. The similarity in yields between the two surface applied treatments at Site 5 (Tables 4 and 5) indicates that either little volatilisation of N occurred where urea was applied, or that N rates were above optimum at the site so that volatilisation losses did not constrain yield. The same arguments apply to the similarity in yields between the two urea treatments at Site 6 (Table 6). Thus, the higher yield in the Nitram treatment at this site cannot be attributed to N volatilisation processes. The cause of the higher yield is not clear but the lack of replication at this site means that it could be due to chance.

In all trials, the Nitram treatment resulted in the lowest net income ($/ha, including N costs) because of the higher cost of the Nitram fertiliser (Tables 4, 5 and 6). Given that N losses from volatilisation did not appear to be significantly affect yield at either site, there appears to be little gained from the expense of applying Nitram rather than urea. The results also suggest that, at the N application rates used in the trials, there may be little production benefit from burying urea. Either volatilisation was not significant in these trials, possibly because of rainfall washing urea into the soil after fertilising, or the N fertiliser rates were high enough that volatilisation losses did not limit cane yield.

Table 4. Harvest and yield results, including costings, for the three fertiliser placement treatments at Site 5 (Cardillo), 2001.

Treatment	tcph	CCS	Gross income ($/ha)	Cost of N fertiliser ($/ha)	Income less N costs ($/ha)
Nitram surface applied	90.97	10.22	$1,475.49	$258.00	$1,217.49
Urea surface applied	89.91	9.99	$1,424.64	$130.00	$1,294.64
Urea sub surface applied	101.55	10.91	$1,495.37	$130.00	$1,365.37

Table 5. Harvest and yield results, including costings, for the three fertiliser placement treatments at Site 5 (Cardillo), 2002.

Treatment	tcph	CCS	Gross income ($/ha)	Cost of N fertiliser ($/ha)	Income less N costs ($/ha)
Nitram surface applied	101.54	12.90	$1,837.62	$258.00	$1,579.62
Urea surface applied	103.79	12.85	$1,864.06	$130.00	$1,734.06
Urea sub surface applied	108.81	12.53	$1,856.01	$130.00	$1,726.01

Table 6. Harvest and yield results, including costings, for the three fertiliser placement treatments at Site 6 (Mangano), 2001. Note, data are from single (unreplicated) strips.

Treatment	tcph	CCS	Gross income ($/ha)	Cost of N fertiliser ($/ha)	Income less N costs ($/ha)
Nitram surface applied	81.45	10.18	$1,636.16	$258.00	$1,378.16
Urea surface applied	74.18	9.50	$1,558.29	$130.00	$1,428.29
Urea sub surface applied	72.77	9.39	$1,550.85	$130.00	$1,420.85

Soil nitrogen availability

Detailed mineral N results for all sampling periods are tabulated in Appendix 2.

Mineral N contents were generally similar in both sites and in both surface and sub surface applied urea treatments (Figure 9), although mineral N was highest at Site 6 at the first and last sampling times. The possible reasons for the higher contents are not clear, but may be due to natural spatial variability within in the soil at that site (e.g., sampling fertiliser bands) affecting the results for this unreplicated site. The results of these trials suggest that burying urea (to protect it from volatilisation) does not result in higher mineral N contents in the soils (and hence better supply of N to sugarcane) in the short term.

At equivalent sampling times (after harvest and in March), mineral N contents in these two trials were similar to those in the trash management trials (Figure 4). Also as found in the trash management trials (Figure 7), the majority of mineral N in these trials was in the form of NH_4^+ (Table 7). This proportion of mineral N as NH_4^+ was not affected by the placement of the urea, but tended to be higher at Site 6.

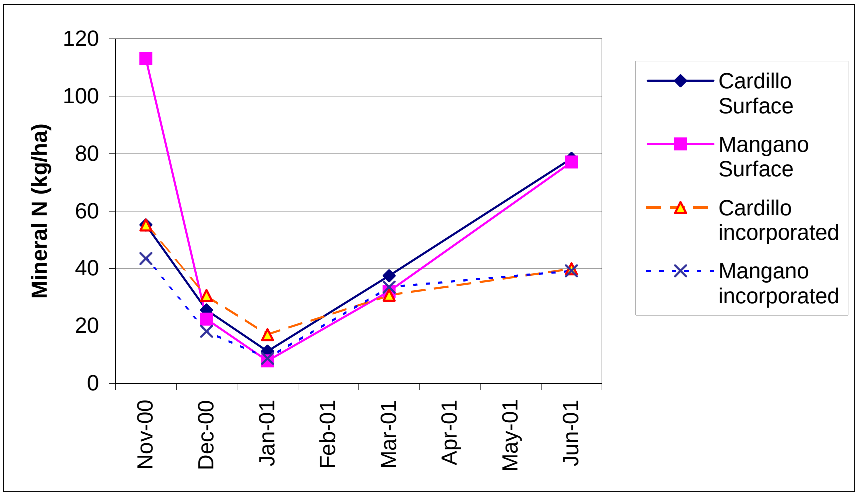


Figure 9. Mineral N for the surface and incorporated urea fertiliser treatments at the two N fertiliser placement trial sites.

Table 7. Average proportion of mineral N that was in the form of NH_4^+ in fertiliser placement trials.

Date	NH_4 (% of mineral N)			
	Site 5		Site 6	
	Sub surface	Surface	Sub surface	Surface
Nov-00			90	65
Dec-00	76	76	86	52
Jan-01	54	71	86	
Mar-01	76	80	82	75
Jun-01	90	89	90	92

Broad scale survey of plant nitrogen status

Amino-N varied between farms and between years (Figure 10). At a farm-average scale, it was generally within the range (100-250 µg/ml, Keating *et al*. 1999) associated with adequate N supply. Animo-N was lowest in 1999, the year of the highest yields (Figure 11) and tended to be highest in 2000 when yields were lowest. The relationship between yield and amino-N concentration is expected as N is stored in the sugarcane plant as amino-N: if all other things remain equal, big crops will use more N for growth and store less. Changes to fertiliser N management will complicate this relationship, and there were changes in N fertiliser application rates on some farms during the project (Figure 12).

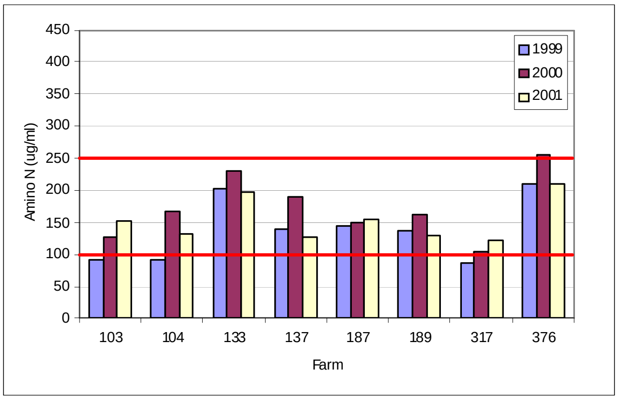
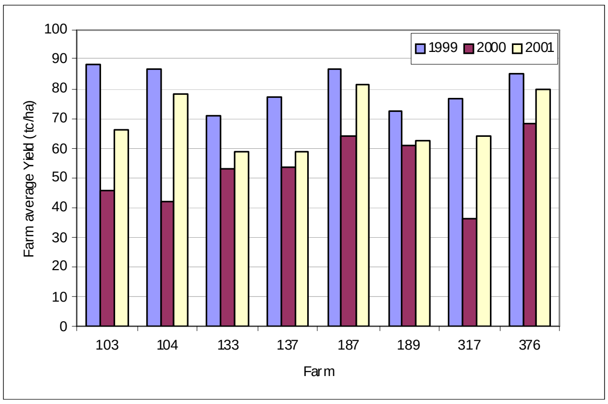


Figure 10. Amino-N concentrations in juice from eight farms in the Babinda Mill region over three



years.

Figure 11. Cane yields over three years for the eight farms involves in the juice N survey.

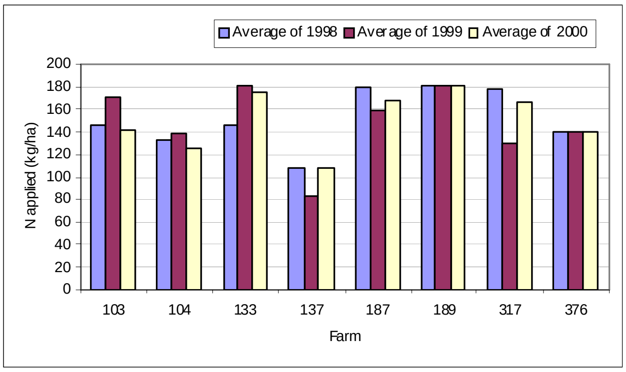


Figure 12. N fertiliser applications over three years for the eight farms involves in the juice N survey.

Generally the patterns in CCS between the farms (Figure 13) was similar to that used as the basis for choosing the farms: farm103 has higher CCS than 104, 133 higher than 137, 187 higher than 189, and 317 higher than 376 (although this pattern was reversed for the last pair of farms in 2000). Two of the farm pairs, (133 and 137) and (317 and 376), had consistently different amino-N concentrations. However, only in the second of these pairs were the differences in amino-N concentrations consistent with the expected effect of high N on CCS; that is the amino-N concentration on farm 376 was higher (Figure 10) and its CCS was lower (Figure 13) than on 317. The opposite result occurred for the farm pair 133 and 137 – higher amino-N was associated with higher CCS. These results, together with the fact that no farm consistently had high enough amino-N concentrations (i.e., > 250 μg/ml; Figure 10) to indicate luxury uptake of N by the sugarcane crops, suggest that it is unlikely that over-supply of N was suppressing CCS on these farms.

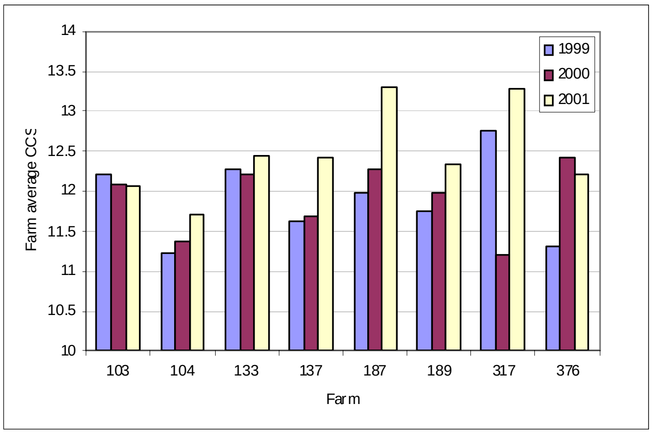


Figure 13. CCS over three years for the eight farms involves in the juice N survey.

While farm average results suggested little over or under supply of N to the sugarcane crops, there were individual blocks that had amino-N concentrations suggesting N deficiency (i.e. < 100 μg/ml) or luxury uptake of N (Figure 14). In 1999, more than 30 % of blocks sampled fell into the former category with the proportion being 15 % in 2001. In all three years during the project there were ~ 5 % of blocks with animo-N concentrations > 250 μg/ml. The resources of this project did not permit detailed exploration of the reasons for the low amino-N in specific blocks. However, while there were no consistent effects of crop class or variety on animo-N concentrations (data not shown), week of harvest seemed to affect amino-N concentrations: Blocks harvested late in the season in 1999 had consistently low amino-N concentrations (Figure 15). It is possible these blocks had a greater crop age at harvest, and so a greater yield on average. Because of difficulties establishing a juice sampling protocol in the Babinda Mill in 1999, the samples obtained were biased towards the end of the season. Thus the high proportion of blocks with low amino-N concentrations may be an over estimate of that occurring the whole Babinda region.

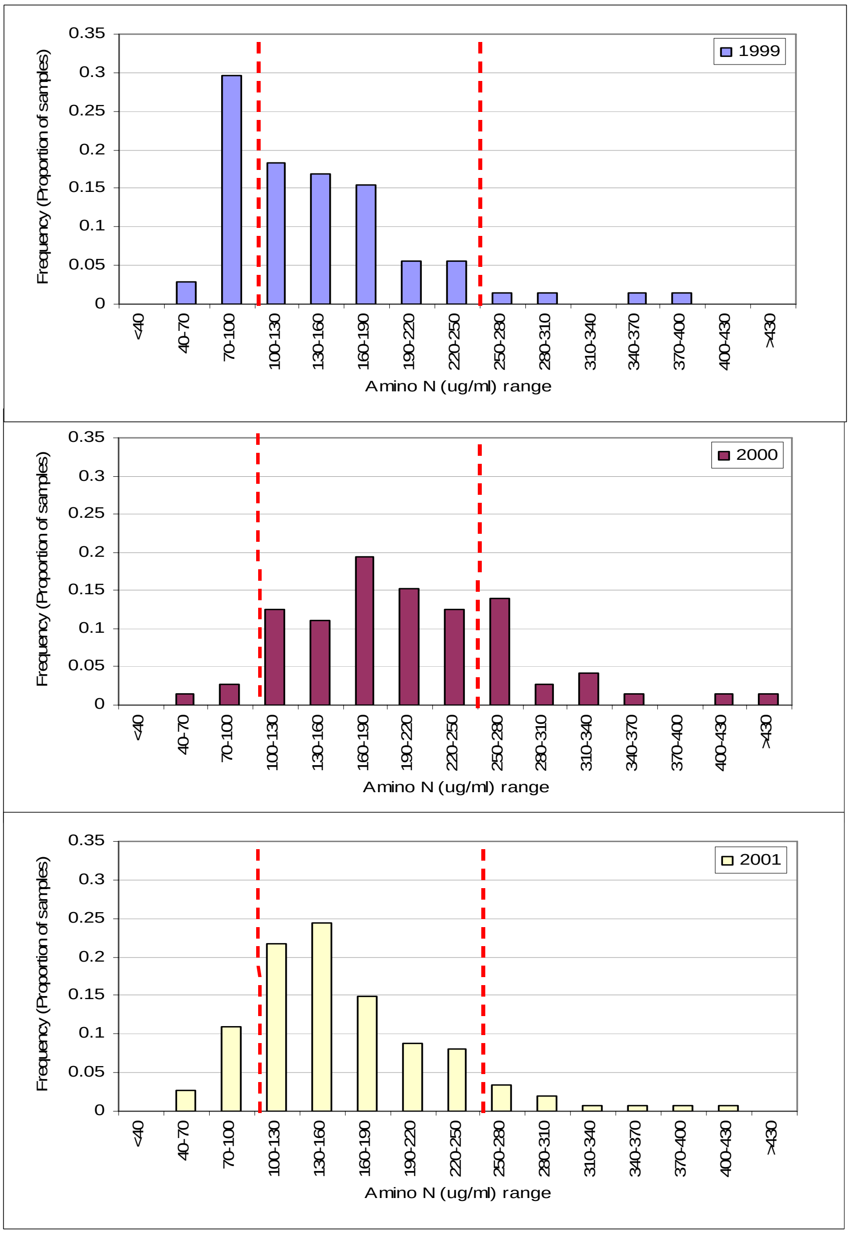


Figure 14. Frequency of amino-N concentrations for samples from all blocks sampled in the three years of the amino-N survey.

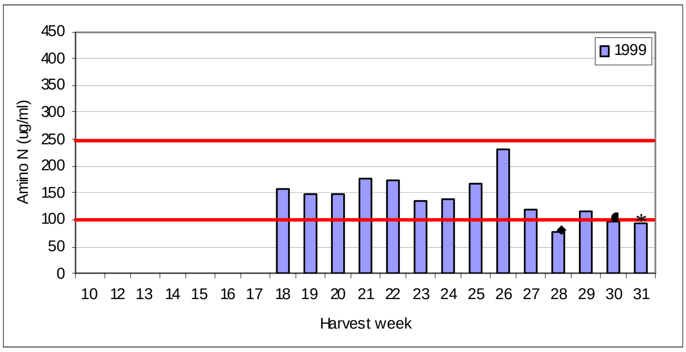


Figure 15. Variation in amino-N concentration with week of harvest during 1999.

Given that trash management was an issue of interest in the project, amino-N concentrations in burnt blocks were separated from trash blanketed blocks. There was no meaningful difference in amino-N concentrations in either trash management practices (Figure 16).

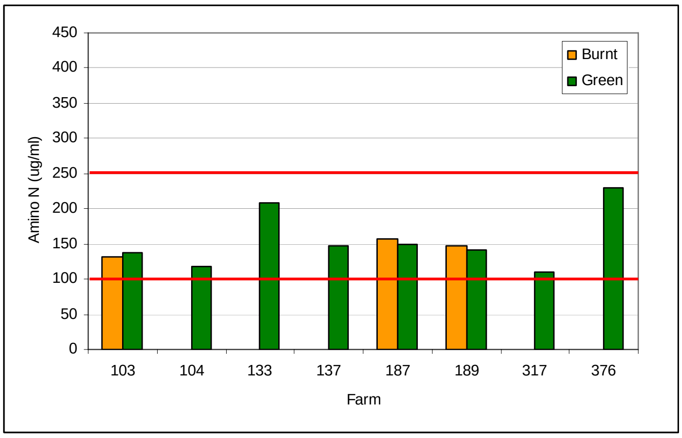


Figure 16. Variation in amino-N concentration between burnt and unburnt sugarcane, averaged over the three years of sampling.

DISCUSSION

Management practice effects on cane production

Trash management

The accepted hypothesis in the Babinda Mill area at the start of the project was that trash blanketing was contributing to lower CCS in the area because of (1) higher soil moisture preventing cane from drying off before harvest and encouraging suckering and lodging, and (2) higher soil N promoting suckering and lodging, and reducing CCS. While most growers had changed their N management (by reducing application rates), there was still concern about the interaction between trash and soil moisture. Growers were looking to rake trash from stools and/or incorporate trash into the soil following harvest to allow the soil to 'dry'. This was seen as particularly important in the 'wet season' – in dry seasons CCS was generally high enough to negate fears about the impact of trash on soil drying.

The trash management trial sites consistently failed to demonstrate any advantage of either raking trash from the stool, incorporating trash into the soil, or doing both. At Sites 2 to 4, there were no consistent yield or CCS effects (Table 3), or differences in soil moisture content (Figures 1-3) of trash raking and/or incorporation over trash blanketing. Because of poor plant crops at the trial sites, amounts of trash during the 1R crops may have been below average (as cane yield and trash amounts are correlated; Mitchell *et al*. 2000). However, trash loads would have been closer to average during the 2R crops as yields were average. Rainfall during the trials was above average and hence relevant to hypotheses in the district at the start of the project.

The consistently higher yields at Site 1 in the burnt treatment compared with the raking and incorporation treatment suggest that raking and incorporation of trash is economically disadvantageous, in the short term, in flood prone areas where trash blanketing is impractical. The reason for the result is not clear. Trash blanketing generally maintains or increases yields compared with burning in the wet tropics (Alan Hurney, pers comm.; Jessica Klok, pers. comm.), suggesting that the result is either site specific or due to the processes of raking and/or incorporation. As described above, damage during raking is a likely explanation for the lower yield in the raked incorporated treatments at this site. Even though raking did not consistently damage cane at the other sites, the result illustrates that care should be exercised whenever raking trash from the stool.

N Fertiliser placement

Subsurface placement of N fertiliser did not consistently increase yield. Provided ratoons are high enough for the canopy to give some protection against volatilisation of ammonium, surface applications of urea-based fertilisers into the stool area will be a more cost effective method of applying N fertiliser at the current application rates. The expense of non-volatile forms of N fertilisers at current N application rates cannot be justified from the yield results. However, results may be different if N rates can be reduced while productivity is maintained. Further work on N rates x placement, using a N balance approach and incorporating an analysis of volatilisation risks, would provide useful information on this issue.

Soil and plant nitrogen status

Soil mineral nitrogen

The mineral N data from this project showed two important and consistent results: (1) that soils in the Babinda Mill region had considerable amounts of mineral N at all sites and times (Figures 4, 5, 6 and 9), and (2) that the majority of mineral was in the from of NH_4^+ (Figure 7, Table 7). There is other evidence that supports these findings and suggests they are not confined to the Babinda region. Salter and Bonnett (2000) found similar mineral N (as NO_3^-) concentrations in their experiments at Euramo (south of Tully), supporting the first finding. They did not measure NH_4^+-N so their results would be an underestimate of mineral N at that site. Also, similar amounts of mineral N and similarly high NH_4^+:NO_3^- ratios have been found in trash blanketed and burnt sites north of Gordonvale (P. Thorburn and T. Webster, unpublished data), the Sugar Yield Decline Joint Venture site at Feluga (west of Tully; A. Garside, pers. comm.), at BSES in Tully (F. Robertson pers. comm.) and in tropical areas in other countries (Sierra and Marban 2000, R. Nee Kee Kwong, pers. comm.). The significance of the results from the other Australian studies become much clearer in the context of the widespread and consistent NH_4^+ dominance found in this study – they are not necessarily isolated occurrences or the result poor experimental methods.

These results challenge conventional thinking about N in the wet tropics and may have important, practical implications for N fertiliser management. This conventional thinking is

(1) that almost all mineral N in soils occurs as NO_3^-, and (2) NO_3^- is consistently leached from soils by heavy rainfall. There is a good basis for this conventional thinking. The first of these ideas is generally true (Laegreid *et al*. 1999), and is supported by data on soil mineral N in other areas of the sugar industry (e.g., P. Thorburn and F Robertson, unpublished data). The second idea is supported by results of studies in the Johnstone River catchment that found large amounts of NO_3^--N (up to 33 % of N fertiliser inputs) leached from the root zone (Prove *et al*. 1997) and large quantities of NO_3^--N (up to 3,500 kg/ha) stored deep in the soil profile (Rasiah and Armour 2001). However, the results of this study show that this conventional thinking does not apply to all the soils of the Babinda area.

N fertiliser management strategies have been developed in Babinda based on this traditional thinking: any N not taken up by the crop prior to the onset of the wet season is expected to be lost through the processes of leaching or denitrification and these N losses were limiting yield potential. Growers therefore strive to apply N early and adopt a program of split application of N in order to avoid losses. Some growers may also apply additional N to compensate for these expected environmental N losses.

However, the amounts of N in the soil at Sites 1-4 (especially to 1.5 m depth; 100-150 kg/ha, Figure 5) are similar to (or greater than) that needed for growth of a single crop and the high amount of mineral N persisted during most times of the year. Thus the soils of the Babinda area can not be considered ‘N-poor’, and their ‘N-rich’ character is due to the high amounts of NH_4^+ in the soil. NH_4^+ is readily taken up by sugarcane (De Armas *et al*. 1992) and is not subject to the major environmental loss processes of leaching and denitrification, so it would be a more ‘reliable’ form of mineral N in wet tropical environments.

The reasons for the high amounts of NH_4^+ in the soils of the Babinda area are not clear. However, the implications for N fertiliser management are so important that they should be investigated. The extent of this phenomenon in the wet tropics, outside the Babinda area, should also be investigated.

Since the soils are ‘N rich’, and this N is in the more ‘persistent’ form of NH_4^+, fertiliser N inputs can (should) be tailored to more closely reflect crop requirements and actions to combat N leaching (and its affect on crop N supply) may be unnecessary. Stalled crop growth and yellowing that is observed during prolonged wet seasons (and attributed to N losses from the system) may well due to waterlogging rather than the loss of available N.

Broad survey of plant nitrogen

The results of the survey of amino-N in sugarcane juice showed that the majority of sugarcane crops surveyed had an adequate supply of N, with some exhibiting luxury uptake of N (Figures 10 and 14). Thus it was unlikely that N was limiting yields of these crops. These results are in general agreement with the implications of the soil N studies, that the soils of the area were not ‘N poor’. These two results resulted in the owner of farm 376, which had consistently high amino-N concentrations (Figure 10), to experiment with reduced N fertiliser applications.

As reasoned above, the results of the amino-N survey failed to demonstrate any **gross** impact of N management on CCS, and so do not support the hypothesis that additional N in the crop-soil system from long-term trash blanketing in the area is limiting CCS. This conclusion is further supported by the similarity between amino-N in burnt and unburnt blocks (Figure 16).

OUTPUTS

There are several outputs arising from the project.

First is the trial sites that were established during the project. Apart from the trial results, these provided a focus for formal (e.g., field days) and informal discussion during the project. Also, at least two of the sites are still in use: Site 3 is being used by Ms Elizabeth Meier for one of the detailed experimental sites within her PhD program. The grower at Site 5 continues to maintain the fertiliser placement trial treatments, and these are monitored by Babinda CPPB staff.

The second output is the data generated during the project. This is proving valuable for illustrating concepts explored in, and results arising from the project in various forums.

The third output is the equipment constructed and/or purchased during the project, e.g. soil sampling apparatus, trash rakes, drying ovens, etc. This equipment is being used by staff from a number of organisations in north Queensland (not just project staff) and is proving a useful resource for the northern sugar industry.

Another output are the publications listed below.

EXPECTED OUTCOMES

This project has had, and will continue to have several outcomes. The first main outcome is the prevention of unnecessary expenditure by Babinda growers on trash rakes and raking for trash management. At the start of this project growers in the Babinda area were seriously considering investing in trash rakes for management of trash in their crops. As the results of this project became known in the region, purchase of trash rakes generally halted as did expenditure on raking. The savings in the Babinda region are likely to be in the order of the SRDC funds spent on this project, and savings are likely to occur in other wet tropical regions too.

The second main outcome of this project is a change in attitude about N cycling in soils of the Babinda region. The results of the project, that soils in Babinda are more likely to be N rich than N poor and crop yields unlikely to be N limited, were (and continue to be) presented to growers in the region. It was obvious from questions asked by growers as the project progressed that their concepts (mental models) of soil N cycling are changing. It is likely that these growers will be more receptive to innovative concepts about N fertiliser management in the future than they would have been if not exposed to this research. Indeed, one farmer commenced experimenting with reduced N fertiliser application rates during the project (as described above). This change in attitude about soil N cycling has impacted other sectors of the industry apart from growers in Babinda. Researchers in the Sugar Yield Decline Joint Venture are paying more attention to NH_4^+ concentrations in soils of their northern experimental sites (A Garside and M Bell, pers. comm.). They had previously observed high soil NH_4^+ concentrations, but dismissed these as an (unexplained) artefact of sample transport and handling. They now believe this to be a real phenomenon, and are considering it in the way they think about N cycling in the program. The support by CRC-Sugar and SRDC for the PhD program on N cycling in soils of the wet tropics, being undertaken by Ms Elizabeth Meier, was partially a product of the early results of this project.

The third outcome of this project is a move towards applying urea fertiliser on the surface of trash blankets, rather than burying it in the soil. At the fertiliser applications rates common in the Babinda region, burying fertiliser was shown to not have a production advantage. Thus, it may be an unnecessary expense and surface application of urea may increase profitability.

While this reasoning is sound, it may lead to higher losses of N via volatilisation (which would be generally undesirable). Growers may be as well off reducing urea application rates (and so saving input costs) and burying the urea. However, rationalisation of these concepts was beyond the scope of this project.

The fourth outcome of this project has been building the capacity of staff in the Babinda Cane Protection and Productivity Board (CPPB) in the area of soil and crop N dynamics. The project has been an 'action learning' experience for all investigators involved (in both the Babinda CPPB and CSIRO) and the personnel in Babinda now have cutting edge knowledge about soil and crop N dynamics in their area, and how to undertake investigations in this discipline. Staff in the Babinda CPPB also gained technical skills in the operation of datalogging equipment.

FUTURE RESEARCH NEEDS

It is important that the soil N results from this project be further investigated. The reason for the dominance of NH_4^+ in the soil mineral pool needs to be known, as does the extent of the phenomenon throughout the wet tropics. This knowledge is required to understand the implications of these results for (1) N fertiliser management in the wet tropics (and possibly more broadly in the sugar industry), and (2) perceptions of N 'pollution' arising from sugarcane production in the wet tropics. Ms Elizabeth Meier will be defining some **possible** causes of the NH_4^+ dominance within her PhD thesis. However, it is not the central topic of her thesis and she will not fully resolve the issue. As described above, it has been established that the phenomenon occurs outside the Babinda area. However, determining the extent, both spatially and temporally, and degree of the NH_4^+ dominance will require systematic investigation. Although this study found NH_4^+ to be the dominant form of mineral N in the soils studied, there still may be significant NO_3^- produced in the soils, which is subsequently lost to the environment. If this is the case, management practices to minimise environmental losses of N are still relevant. However, if little NO_3^- is produced in these soils then the environmental impact of sugarcane production in this region will be much lower than currently thought and the implications for N fertiliser management more profound. Thus it is vital for the industry that these questions be resolved.

Another question that arose in this project that was not fully resolved is the issue of fertiliser placement. Following the definition of N volatilisation rates from surface-applied urea fertiliser in the early 1990's (Freney *et al*. 1991), it has been recommended that urea be buried beneath trash blankets. However, Babinda growers questioned the profitability of doing this. As stated above it may be more **profitable** to surface apply urea and 'suffer' some N losses through volatilisation. Further, Babinda growers argue that the high probability of significant rainfall following urea applications greatly reduces the risk of volatilisation. Thus the advice to bury urea may be less relevant in the wet tropics. Addressing this issue (perhaps through a climatological analysis and more complete determination of N balances) should be included in future studies of N fertiliser management.

RECOMMENDATIONS

That growers in the wet tropics be advised that raking and/or incorporating trash does not increase profitability.

That the reason for, and extent of the dominance of NH_4^+-N in soils the wet tropics be researched.

That the value of the advice to bury urea beneath trash blanket be investigated (perhaps through a climatological analyses and more complete determination of N balances) in future studies of N fertiliser management.

ACKNOWLEDGEMENTS

We wish to thank Babinda growers, especially members of the Management Committee and those collaborating with demonstration trials, for their constructive and valuable input. We also acknowledge the assistance of many CSIRO staff who found themselves involved in this project even though it was not originally planned. In particular Ian Biggs for taking responsibility for amino-N analyses, Jody Biggs for playing a vital role in the datalogging and taking responsibility for the (considerable) soils database generated during the project, and Kerry Collins for assistance with much of the data analyses and reporting. Thanks too to Elizabeth Meier for her contributions in the latter parts of the project.

PUBLICATIONS ARISING FROM THIS PROJECT

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APPENDIX 1.

Harvest Yield Data

Site 1 Nucifora and Torrisi

Harvested 1R 14/7/00

Treatment	Treatment	CCS	tcph	tsph
1-1	Burnt	11.4	88.71	10.11
1-2	Raked incorporated	11.1	87.49	9.71
2-1	Burnt	10.8	100.44	10.85
2-2	Raked incorporated	10.8	76.51	8.26

Harvested 2R 11/7/01

Treatment	Treatment	CCS	tcph	tsph
1-1	Burnt	13.7	86.51	11.85
1-2	Raked incorporated	13.9	71.22	9.90
2-1	Burnt	13.1	79.92	10.47
2-2	Raked incorporated	13.9	74.44	10.35

Site 2 Sacchetti

Harvested 1R 28/8/00

Treatment	Treatment	CCS	tcph	tsph
1-1	Trash	13.70	36.55	5.01
1-2	Trash Incorporated	13.70	32.41	4.44
1-3	Raked	13.70	41.33	5.66
1-4	Raked Incorporated	13.30	33.86	4.50
2-1	Trash	13.50	49.51	6.68
2-2	Trash Incorporated	13.70	49.44	6.77
2-3	Raked	13.30	60.65	8.07
2-4	Raked Incorporated	13.70	53.70	7.36

Harvested 2R 1-11/01

Treatment	Treatment	CCS	tcph	tsph
1-1	Trash	12.90	98.46	12.70
1-2	Trash Incorporated	12.70	106.36	13.51
1-3	Raked	12.85	98.43	12.65
1-4	Raked Incorporated	12.50	102.60	12.83
2-1	Trash	12.90	109.24	14.09
2-1	Trash Incorporated	12.70	106.82	13.57
2-3	Raked	12.50	111.17	13.90
2-4	Raked Incorporated	12.70	105.67	13.42

Site 3 Stewart

Harvested 1R 29/9/00

Treatment	Treatment	CCS	tcph	tsph
1-1	Trash	14.50	38.97	5.65
1-2	Trash Incorporated	14.70	51.59	7.58
1-3	Raked	15.20	46.73	7.10
1-4	Raked Incorporated	14.90	40.84	6.09
2-1	Trash	14.60	46.51	6.79
2-2	Trash Incorporated	14.70	45.19	6.64
2-3	Raked	14.80	40.67	6.02
2-4	Raked Incorporated	14.55	31.11	4.53

Harvested 2R 8/10/01

Treatment	Treatment	CCS	tcph	tsph
1-1	Trash	13.80	69.89	9.64
1-2	Trash Incorporated	13.80	68.69	9.48
1-3	Raked	13.80	69.01	9.52
1-4	Raked Incorporated	14.00	65.23	9.13
2-1	Trash	13.80	69.64	9.61
2-2	Trash Incorporated	13.80	66.31	9.15
2-3	Raked	14.10	65.35	9.21
2-4	Raked Incorporated	13.70	71.03	9.73

Site 4 Mangano

Harvested 1R 2000

Treatment	Treatment	CCS	tcph	tsph
1-1	Trash	13.90	47.68	6.63
1-2	Trash Incorporated	13.90	48.54	6.75
1-3	Raked	13.90	47.22	6.56
1-4	Raked Incorporated	13.90	46.85	6.51
2-1	Trash	13.95	27.86	3.89
2-2	Trash Incorporated	13.95	27.38	3.82
2-3	Raked	13.95	23.00	3.21
2-4	Raked Incorporated	13.95	23.72	3.31

2R 2001 (Rep 1, Q152 only)

Treatment	css	tcph	tsph
Trash	10.25	90.52	9.28
Trash Incorporated	9.7	73.40	7.12
Raked	10.6	97.09	10.29
Raked Incorporated	9.5	101.26	9.62

APPENDIX 2.

Mineral N per hectare – Fertiliser Placement trials

Nov-2000

Cardillo preliminary sampling results in the fertiliser placement trials.

Depth (cm)	Kg Min N/ha
7.50	22.92
22.50	19.41
45.00	26.47

Mangano sampling results for November 2000 in the fertiliser placement trials.

Mangano Incorp		Mangano Surface	
Depth (cm)	Kg Min N/ha	Depth(cm)	Kg Min N/ha
7.50	18.20	7.50	45.39
22.50	15.79	22.50	39.98
45.00	12.83	45.00	22.91

Dec-2000

Cardillo sampling results for December 2000 in the fertiliser placement trials.

Cardillo Incorp		Cardillo Surface	
Depth (cm)	Kg Min N/ha	Depth (cm)	Kg Min N/ha
7.50	26.25	7.50	21.13
22.50	22.69	22.50	16.72
45.00	36.23	45.00	69.49

Mangano sampling results for December 2000 in the fertiliser placement trials.

Mangano Incorp		**Mangano Surface**	
Depth (cm)	**Kg Min N/ha**	**Depth (cm)**	**Kg Min N/ha**
7.50	18.96	7.50	16.70
22.50	9.97	22.50	15.56
45.00	23.04	45.00	45.63

Mar-2001

Cardillo sampling results for March 2001 in the fertiliser placement trials.

Cardillo Incorp		**Cardillo Surface**	
Depth (cm)	**Kg Min N/ha**	**Depth (cm)**	**Kg Min N/ha**
7.50	33.40	7.50	33.13
22.50	27.91	22.50	36.04

Mangano sampling results for March 2001 in the fertiliser placement trials.

Mangano Incorp		**Mangano Surface**	
Depth (cm)	**Kg Min N/ha**	**Depth (cm)**	**Kg Min N/ha**
7.50	38.06	7.50	34.63
22.50	27.14	22.50	26.89

Jun-2001

Cardillo sampling results for June 2001 in the fertiliser placement trials.

Cardillo Incorp		Cardillo Surface Urea		Cardillo Surface Nitram	
Depth (cm)	Kg Min N/ha	Depth (cm)	Kg Min N/ha	Depth (cm)	Kg Min N/ha
7.50	51.07	7.50	59.63	7.50	39.86
22.50	30.52	22.50	27.64	22.50	29.94
45.00	39.38	45.00	34.86	45.00	64.91

Mangano sampling results for June 2001 in the fertiliser placement trials.

Mangano Incorp		Mangano Surface Urea		Mangano Surface Nitram	
Depth (cm)	Kg Min N/ha	Depth (cm)	Kg Min N/ha	Depth (cm)	Kg Min N/ha
7.50	49.97	7.50	47.32	7.50	43.17
22.50	37.94	22.50	28.32	22.50	34.17
45.00	31.17	45.00	69.42	45.00	55.65

Proportion of mineral N as NH4

The breakdown of mineral N into NO_3 and NH_4 forms as recorded in the fertiliser placement trials.

Date	Farm	Treatment	Depth (cm)	NO_3	NH_4	TotN	%NH_4
21-Nov-00	Cardillo	Prelim.	0-600	19.17	61.11	80.28	76%
21-Nov-00	Mangano	Incorp	0-600	5.62	50.47	56.09	90%
21-Nov-00	Mangano	Surface	0-600	47.44	88.22	135.66	65%
14-Dec-00	Cardillo	Incorp	0-600	9.27	29.81	39.08	76%
14-Dec-00	Cardillo	Surface	0-600	10.23	31.57	41.80	76%
14-Dec-00	Mangano	Incorp	0-600	3.25	20.59	23.84	86%
14-Dec-00	Mangano	Surface	0-600	16.06	17.42	33.48	52%
22-Jan-01	Cardillo	Surface	0-300	3.30	7.93	11.22	71%
22-Jan-01	Cardillo	Incorp	0-300	9.73	12.14	22.57	54%
22-Jan-01	Mangano	Incorp	0-300	1.21	7.56	8.77	86%
7-Mar-01	Cardillo	Incorp	0-300	7.43	23.31	30.74	76%
7-Mar-01	Cardillo	Surface	0-300	7.66	29.80	37.46	80%
7-Mar-01	Mangano	Incorp	0-300	6.09	27.44	33.53	82%
7-Mar-01	Mangano	Surface	0-300	8.02	24.09	32.11	75%
14-Jun-01	Cardillo	Incorp	0-600	5.25	45.51	50.76	90%
14-Jun-01	Cardillo	Surf Urea	0-600	5.77	47.46	53.23	89%
14-Jun-01	Cardillo	Surf Nitram	0-600	7.83	43.32	51.14	85%
14-Jun-01	Mangano	Surf Nitram	0-600	3.51	50.77	54.28	94%
14-Jun-01	Mangano	Incorp	0-600	4.45	41.88	46.33	90%
14-Jun-01	Mangano	Surf Urea	0-600	4.58	52.10	56.68	92%