Sugar Research and Development Corporation

PROJECT CTA029

MONITORING CANE AT THE MILL TO IMPROVE NITROGEN MANAGEMENT ON THE FARM

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FINAL REPORT

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Project Title:	Monitoring cane at the mill to improve nitrogen management on the farm.
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Statement of Confidentiality:

No part of this report is considered confidential.

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1. Executive summary

Efficient nitrogen management remains a key element of the Australian sugar industry's drive towards enhanced sustainability. While nitrogen (N) fertilisers are a significant input cost, nitrogen losses to groundwaters or surface waters are one of the most significant environmental concerns. Whilst data on direct impacts on coastal ecosystems are sparse, elevated levels of nitrogen, phosphorus and sediment pose the greatest risk of sugar industry impact on the neighbouring sensitive freshwater and marine ecosystems.

While the risks of nitrogen losses to the environment are high, there are many features of the Australian sugar industry that mitigate against these risks. A perennial grass crop, with a relatively low requirement for nitrogen, sugarcane is better adapted than almost any other form of agriculture to the wet coastal environments of north-eastern Australia. Reduced tillage and retention of trash as a surface mulch further reduce the risks of nutrient and sediment loss to waterways and marine environments. With respect to nitrogen management, the greatest risk to the environment is associated with over-fertilisation. Growers are naturally wary of economic losses associated with inadequate nitrogen supply and there was evidence of over-fertilisation with industrial N fertilisers at the time this project was initiated. Also the lack of a tool for monitoring crop N status meant that growers had little knowledge about the amount of N added to fields from other additional sources, such as, mill mud or residual N leftover from small crops or fallows. Economic forces associated with current low sugar prices may have tempered grower's tendency to over-fertilise, but the problem of better matching N fertiliser inputs to crop requirements remains.

The development of a methodology to assess the adequacy of N supply in relation to crop requirements was at the core of this project. These crop requirements are in turn strongly driven by yield potential, N supply from soil and other non-fertiliser sources and N losses, principally via volatilisation, denitrification and leaching. The project built upon a pilot study which showed that the level of nitrogen (in particular N in the form of amino-N) in sugarcane stems at harvest time was responsive to the supply of N the crop experienced during its life cycle. This observation opened up the prospect to monitor N levels in cane delivered to mills, relate this back to specific blocks of cane and use this information to adjust nitrogen management in future seasons. The specific objectives of this project were to;

1. Confirm for additional sites, seasons and varieties the relationships between amino-N content of sugarcane juice and the N status under which the cane was grown.
2. Work with growers, extension staff and Productivity Boards to demonstrate how grower managed trials on-farm, can be combined with the monitoring of N in cane supplied to mills, to improve N fertiliser management back on the farm.

The project originally had a third objective, namely to "Develop promising leads in rapid and cost effective analyses of N compounds in the mill juice stream to a "proof-of-concept" stage." Instrumentation issues and industry developments with respect to installation on on-line NIR infrastructure meant that this third objective was transferred to the project CTA045, which is on going.

Objective 1 was addressed via laboratory analyses of cane sourced from a wide range of experimental studies in different seasons at a range of sites, involving variation in N fertiliser inputs, sugarcane varieties, irrigation inputs, and other agronomic variables.
Objective 2 was addressed via a series of grower-managed on-farm trials in which N fertiliser inputs were varied above and below the grower's "normal" management and the results were interpreted in relation to additional information obtained from soil analyses and amino-N analyses of the cane at harvest time.

The major outputs of this project relate to the knowledge necessary to underpin a monitoring technique aimed at assessing the N status of blocks of sugarcane at harvest time. Specific elements of this knowledge include;

(a) That variation in N supply (such as arises from differential N fertilisation practice) has the dominant influence on the amino-N concentration in cane stems at harvest time
(b) That all the varieties tested to date exhibit the phenomenon of elevated amino-N levels in cane stems/juice in response to excess N supply, although there was some varietal differences in the absolute concentrations that are observed under elevated N supply.
(c) That water stress has a modest influence, in the form of elevated amino-N concentrations in crops that have experienced yield-limiting levels of water deficit.
(d) That amino-N levels in cane stems exhibit a modest downward trend as a crop ages, but the age related differences within a typical harvest window are small and of little consequence in terms of interpretation of amino-N monitoring information.
(e) That all factors impinging on amino-N concentrations in cane stems can be interpreted via a conceptual model of demand for N for new growth (biomass) and supply of N from N compounds stored in stem tissues (principally amino-N) and where relevant, continued uptake from soil sources.
(f) A diagnostic relationship between relative sugar yield and amino-N concentrations which can be used to define three zones of N supply, namely excess, target and potentially deficient.

These outputs are complimented by the experiences on-farm, which highlight the generally limited responsiveness of cane and/or sugar yield to small changes in fertiliser N inputs. Earlier reports have noted this phenomenon (eg. Catchpoole and Keating 1995) and attribute it to the significance of other sources of N such as soil organic matter mineralisation. This suggests that a longer-term view of N fertilisation practice is justified, rather than a short term "fine-tuning" of N rates on a year by year basis. The use of an amino-N assay as an indicator of the N status of the preceding crop is complimentary to this longer term view. Over a period of years the monitoring of N status of crops as they are processed in the mill should enable patterns of N supply to be discerned, and these patterns can be used to make progressive adjustments to N management strategy on a block specific basis.

Industry outcomes as such remain in the future and will be achieved via other projects, in particular CTA045. The results of this project have reinforced the science underpinning the "N at the Mill" concept and justify the efforts in CTA045 to develop a practical method of implementing "N at the Mill" monitoring.

The significance of the project for the Australian sugar industry and wider community is that, assuming the practical monitoring challenges being address in CTA045 can be overcome, a "universal" monitoring of the N status of every block or rake of cane grown in the industry is within sight. This would be of immense value in terms of (a) better targeting N fertiliser inputs and in some cases, identifying savings in input costs to growers, (b) in demonstrating to the wider community the industry's intent to apply concepts of benchmarking and best practice, and (c) ultimately reduce N leakage from cane fields thus delivering improved water quality to the groundwaters and surfaces waters that surround the Australian sugar industry.

2. Background

Without N fertilisers, productivity of the Australian sugar industry would ultimately drop to about 30 - 40% of current levels and growers are very conscious of the need to have sufficient N available to meet their crops need. The cost of lost crop production, if insufficient N is supplied, is generally far greater than any cost saving from reduced N fertiliser rates. These concerns appear to have contributed to the current situation in the Australian sugar industry, where there is compelling evidence that excessive quantities of N fertiliser are being used in some situations. This evidence comes from both N experimentation and modelling (e.g., Keating *et al.* 1997) and recent surveys of farm practice (BSES 1996). In the latter case, excess N fertiliser use was identified on 60% of plant crops and 42% of ratoon crops in North Qld. This costs growers money (up to $20 million a year over the entire industry) that would be better spent on some other input or management practice, may sometimes lower CCS and cane quality and in some instances may contribute to soil acidification and contamination of surface and ground waters. There is a good scientific basis for the rule of thumb that the "last kilogram of N applied" is the "first kilogram of N lost"; hence relatively small reductions in total N use, will have proportionally much larger benefits in terms of reduced N losses. With approximately 80,000 tonnes of N fertiliser, worth $80 million, applied by canegrowers each year, the costs and potential quantities of N involved are substantial.

Both quantitative analyses with models and qualitative discussions with growers, indicate that there is a natural reluctance to reduce N rates in the face of risk and uncertainty from a range of climate, management and soil factors. This project is based on the hypothesis that growers will be more willing to go down the pathway of better matching their N fertilisation rates to their crop's needs, if they have some tangible measure or 'test' of the adequacy or otherwise of their current N management.

The current proposal grows out of a pilot study of the same name (CSC21s) in which the analysis of amino-N compounds in cane juice has been shown to be indicative of the N status of that crop; the notion being that this information can be used as a guide to growers over a period of years to better match their N management to their local circumstances. Some major findings from CSC21s were that;

- Approximately 60% of the N contained within cane stalks is found in the pressed juice.
- The proportion of the juice N present as amino acids ranges from 20% to more than 90% depending on the overall N supply.
- The amino acid, asparagine, was the dominant form of amino-N in cane stems, making up in excess of 80% of the amino-N pool under conditions of excess N supply.
- Amino acid N in cane juice responds strongly to N supply, particularly N excess.

This pilot study has also shown extensive variation in the N composition of cane supplied to a mill. This variation, particularly the occurrence of a proportion on the cane supply with what was assessed to have high amino-N content, strengthens our belief that a diagnostic test is both feasible and valuable. Project CSC21s was reported to SRDC in 1995.

This project pursued what we assessed to be the two critical issues in the proof of concept for "Monitoring N at the mill to improve N management on the farm". The first was technical, and related to enhancing our understanding of how the N composition of cane stems at harvest time was influenced by N supply and other agronomic factors. The second combined technical and human elements. It involved some participative research with growers, local extension personnel and productivity boards, in which a combination of on-farm trials, researcher monitoring and N analysis at the mill is used to test the concept that growers can become more efficient in their N management and that juice analysis at the mill is a useful instrument towards this goal.

3. Objectives

The project sought to build on the promising results of the CSC21s pilot study, wherein N composition of cane juice at the mill reflects the N status of the farm block supplying the cane. Specific objectives, as stated in the original project specification were;

1. Confirm for additional sites, seasons and varieties the relationships between amino-N content of sugarcane juice and the N status under which the cane was grown.
2. Work with growers, extension staff and Productivity Boards to demonstrate how grower managed trials on-farm, can be combined with the monitoring of N in cane supplied to mills, to improve N fertiliser management back on the farm.
3. Develop promising leads in rapid and cost effective analyses of N compounds in the mill juice stream to a "proof-of-concept" stage.

Objectives 1 and 2 have been met and are reported in detail in the sections that follow, together with the associated appendices. Objective 3 was subsequently removed from this project with SRDC's approval, and became part of CTA045 (see CTA029 Milestone Report No. 6, due date 31/12/1999). This happened because of industry developments in NIR technology meant it was inappropriate to separately develop NIR based methodologies for amino-N monitoring. Instead, this aspect of the work was strongly linked to industry development of NIR technology as part of the Sugar North-BSES consortium.

Project outputs from project proposal were stated as;

1. A proven method for rapid and cost-effective analysis of total amino-N in sugarcane juice.
2. Expanded set of relationships between amino-N in sugarcane juice and N status of cane crop
3. Assessment of the value grower-managed N-rate trials (in a group context) as a means of achieving more efficient N fertiliser management
4. Objective assessment of the additional value of a diagnostic test in promoting beneficial change in N fertilisation practice
5. Savings in N fertiliser costs and reduced N losses to the environment for a small number of growers and a methodology established to extend these benefits more widely.

Output 1 was associated with Objective 3 and hence has not been tackled in this project. Outputs 2 to 5 were achieved and are addressed in the reporting to follow.

4. Research Methodology

Objective 1

Confirmation of the findings from the CSC21s project was undertaken using similar techniques to those used in that project, i.e., (a) whole of mill region sampling and (b) use of experimental treatments.

(a) Whole of mill region sampling

Whole of mill region sampling was conducted at three mills in the Bundaberg region (Table 1) in the 1997 crushing season. Samples were collected over 5 x 24 hour periods during August to November at each of the mills. Resident mill juice-lab staff sampled the first expressed juice (FEJ) of every third rake passing through the mill.

Table 1. Details of mill-scale studies of variation in amino-N status of cane supply

N°.	Mill	Year	N°. of farms sampled	N°. of rakes sampled	Tonnes cane	Times sampled[1]	Sampling period
1	Bingera	1997	119	215	14,005	5	Aug - Nov
2	Fairymead	1997	106	188	13,557	5	Aug - Nov
3	Millaquin	1997	98	195	10,011	5	Aug - Nov

[1] Samples collected over a 24 hr period of mill operations

(b) Sampling of experimental treatments

Measurements of N status of cane crops, in particular the levels of amino-N, were obtained from experimental plots under defined management treatments (Table 2).

Each of the individual trials had their own principal objectives and sugarcane juice sampling was conducted as an add-on sampling and analysis.

Sample collection, processing and laboratory analysis methods were as described by Keating et al. (1999) (see publications in Appendix 1). The ninhydrin analysis of juice was based on the method of Amato & Ladd (1988). This was used as the routine laboratory bench analysis for amino-N content in sugarcane juice in this project. An HPLC based method (post-column ninhydrin-based derivitisation HPLC-based amino acid analyser (Model 6300, Beckman Instruments, Palo Alto, CA, USA) running in physiological fluids mode) was used to calibrate the more rapid Amato and Ladd method. HPLC allows the concentrations of the individual amino acids to be determined (i.e., the amino acid profile) as well as providing a measure of total amino-N.

Juice amino nitrogen concentration is expressed as μg amino-N per ml juice (see Keating *et al.* 1999). The equation for the conversion of ninhydrin reaction units (ug ninhydrin reactive N per ml juice) to total amino-N concentration is based on a reference method for amino-N determination via HPLC (Keating et al, 1999).

Table 2. Details of plot-scale studies of Amino-N response to management factors

Number	Location	No of samples	Treatments	Source
A	Bli Bli	45	5 N rates x 3 years x 3 reps (juice extraction by small mill)	G. Kingston (unpubl data)
B	Fairymead	60	5 N rates via trickle x 4 years x 3 reps	P. Thorburn (Dart *et al.* 2000)
C	Burdekin	1620	6 varieties x 3 N rates x 2 years x 3 reps x 2 harvest schedules	A. Rattey (unpubl data)
D	Bundaberg	72	6 varieties x 4 irrigation treatments x 3 reps	R. Ridge (Ridge & Hillyard 2000)
E	Burdekin	36	3 varieties x 3 N rates x 3 reps	A. Wood (unpubl data)

In addition to the experiments sampled and analysed in Table 2, there has been general interest throughout the sugar industry in the use of juice amino-N as an indicator of the N status of a particular sugarcane crop. This has led to several researchers (Dr Lisa McDonald (CRC Sugar); CSR Macknade; Mulgrave Mill; Pivot Fertiliser Company (nitrification inhibition trial, Gordonvale); and BSES extension staff (Julian Collins, Jim Sullivan, Peter Lawrence, and Greg Shannon) requesting that small numbers of juice samples from either research trials or grower's paddocks be analysed for amino-N and for an interpretation to be provided on the crop's N status. We have been happy to do this work in conjunction with our own research. These various small sample runs have not been included in this report.

Objective 2

Grower managed trials - Bundaberg

A total of six trials were set up in the Bundaberg district, consisting of a plant (P) and a first ratoon (1R) crop in each of the 3 mill districts (Bingera (BIN), Millaquin (MQN), Fairymead (FMD)). Trials were located on a range of soil types and involved a range of varieties. Two trials were formally replicated (3 reps) while the other four trials consisted of large blocks within a single field, with internal sampling but no formal randomised replication.

The trials commenced with differential fertiliser application in the 1998/99 season and continued in the same location with the same fertiliser treatments for a further 2 seasons. The grower's standard N fertiliser rate and management practice was used as the reference treatment and this was compared with a +20% rate and a –20% rate. There were some year-to-year differences in N rates used at any given site associated with either crop class of the farmer's application equipment.

Further details of the grower manager trials are provided in Appendix 8.

Table 3. Details of sites for the grower managed trials, Bundaberg district

Farm	Mill+	Soil type	Crop class at start of trial	Variety	"Standard" N rate (kg N/ha)
Borg #22699	MQN	Yellow podzolic	Plant (10/98)	Q151	136-140
Dingle* #3172	FMD	Gleyed podzolic	1R (06/98)	Q151	161
Greensil #25056	MQN	Kraznozem	1R (10/98)	Q124	120
Jensen* #10268	BIN	Red podzolic	1R	Q124	170
Penningh* #10057	BIN		Spring Plant	Q124	122
Spyrou* #537	FMD	Red earth	Ploughout & replant (10/98)	Q141	98-157

* No formal replication, 3 internal samples taken for yield and amino-N estimates.
\+ MQN = Millaquin, FMD = Fairymead, BIN= Bingera

Supporting activities

Juice extraction methods

Three methods of juice extraction were used at various stages of this project. First expressed juice is collected in commercial sugar mill juice labs. This represents the undiluted juice from the N°. 1 mill in the milling train. This is the juice used for all sugar analyses used in the cane payment formulae and general sugar quality measures. In small trials two methods are used for the extraction of juice from cane stems. The 'small mill' is a rapid method where de-leafed stems are fed between two rollers, which squash the stem and the juice collected. There is no attempt to fibrate or break up the stem cells prior to pressing. The third method is the 'Jeffco/Carver' method as detailed in Muchow *et al.* (1993). This method fibrates the cane stem in a 'Jeffco' cutter/grinder and then the sample is pressed in a hydraulic press ('Carver' press) at 10000 KPa for 60 seconds to extract the juice. It is generally felt that the 'Jeffco/Carver' extraction mimics the whole of the milling train of a commercial sugar mill in the efficiency of juice extraction from sugarcane stems. The 'small mill' method while rapid is generally only of use for relative measures within an experiment. One problem with both the 'small mill' and 'Jeffco/Carver' is that they require hand sampling of a representative sample of the cane in the trial plot. While Muchow *et al.* (1993) give details on obtaining representative samples from a cane field there still exists greater variability in this type of sample collection compared with whole of block sampling offered by a commercial harvester and collection of the juice in the mill lab.

The 'Jeffco/Carver' method is the standard reference method used in this project. Small numbers of 'small mill' samples were examined, but these data are not shown as they represent incomplete amino-N extraction (see appendix 3). Whole of mill region sampling by necessity, at present, can only be undertaken using FEJ from N^{o}.1 mill. Comparisons of samples extracted via FEJ from N^{o}. 1 mill and juice collected via a 'Jeffco/Carver' system needs to exercise caution. The amino-N extraction efficiency from the 'Jeffco/Carver' press system is generally higher (in the order of 20%) than that generally possible in the N^{o}. 1 mill (Figure 1).

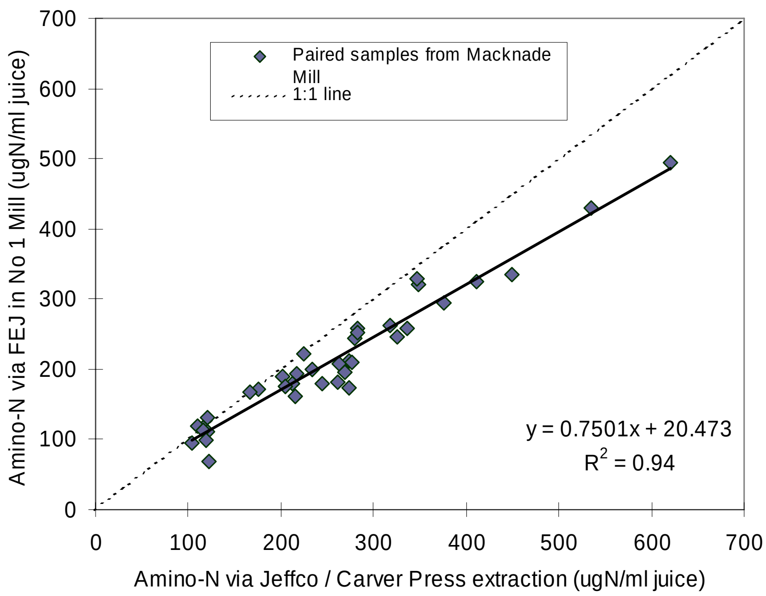


Figure 1. Amino-N in juice samples determined by different extraction methods.

5. Results

5.1 Variability in N status of cane at a mill region scale

Sampling of cane supply at the three Bundaberg mills over the 1997 crushing season confirmed the extensive variation in amino-N in FEJ previously observed at Macknade Mill. This is illustrated in Figure 2. Some of the variation shown in Figure 2 can be ascribed to crop class (plant > 1R> later ratoons), mill region (BIN> MQN> FMD) harvest time (mid season > early and late season), but the bulk of the variation cannot be interpreted at this scale. Hence the studies of experimental treatment effects on amino-N in cane stems reported in the next section. Further details of these studies are provided in Appendix 2.

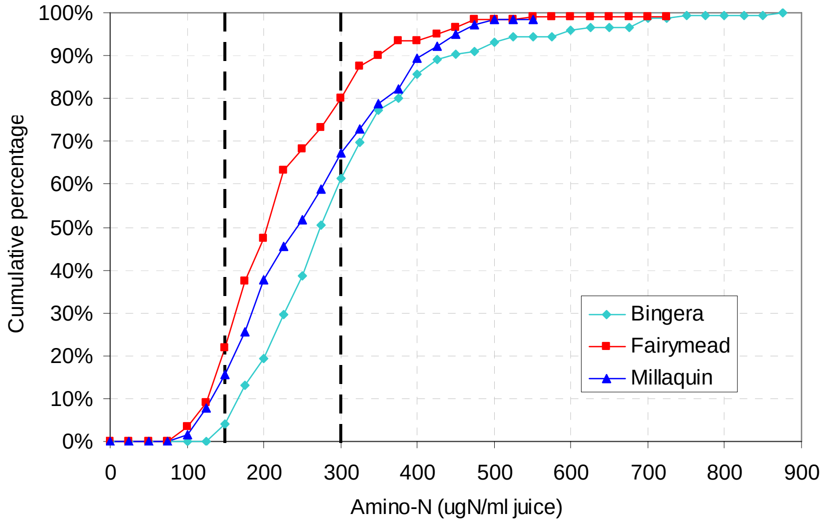


Figure 2. Cumulative distribution function for amino-N in FEJ at the Bundaberg sugar mills – Bingera, Fairymead, and Millaquin. Samples were collected during the 1997 crushing season from 5 x 24 hour sample collection periods. Samples have been combined for each of the mills.

5.2 Factors influencing amino-N levels in cane stems

An extensive series of experimental studies enabled us to investigate the effects of key agronomic variables on amino-N levels in cane. These results are summarised below and an overview provided at the end.

Study A: 3 N rates x 3 years at Bli Bli

This trial illustrates how amino-N levels are highest for plant crops (data from harvest 1998), particularly where excess levels of N fertiliser are applied (Figure 3). The lower values of amino-N in 1999 and 2000 harvests (first and second ratoon crops) is indicative of the widely observed lower N status for ratoon crops relative to plant crops. Despite this, the effects of higher N fertiliser rates are still evident in the amino-N data. When amino-N levels are compared with crop yield (in terms of relative sugar yield, with the highest yielding treatment in any year assigned a value of 1), a classical diagnostic response surface is evident (Figure 4).

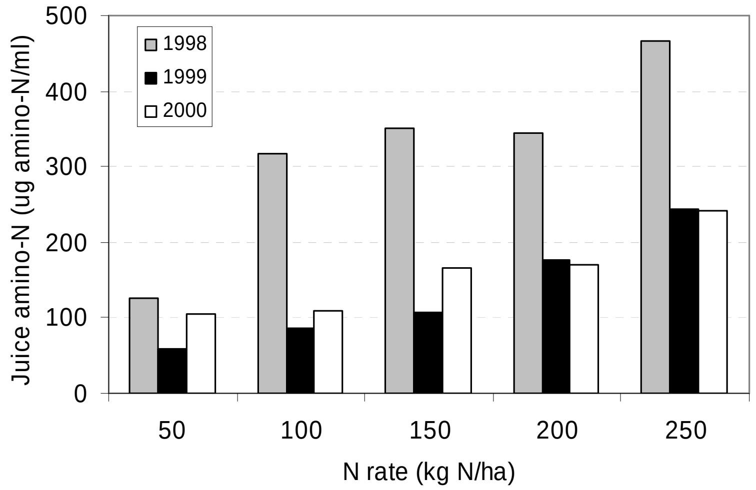


Figure 3. Response of juice amino-N to N rate over 3 seasons at Bli Bli (G Kingston/BSES trial). Juice extracted by 'Jeffco/Carver' method on samples collected 3 months before final harvest.

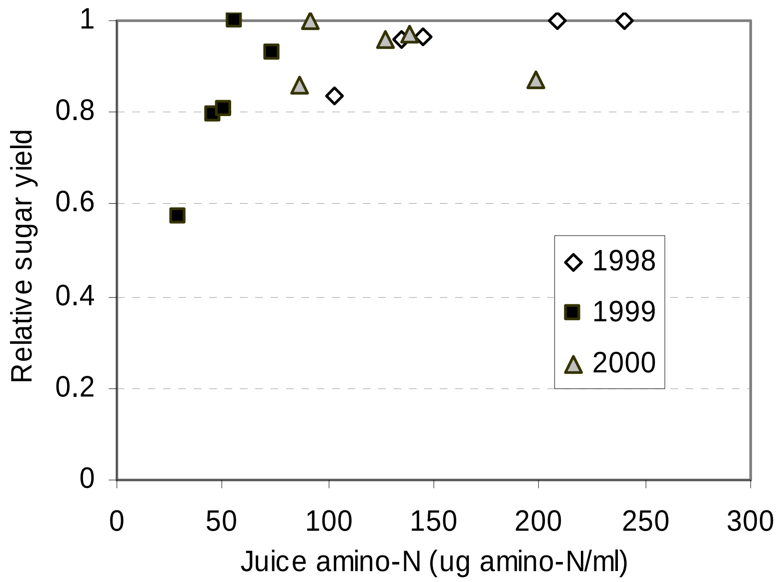


Figure 4. Relationship between relative sugar yield and juice amino-N based on data from 3 seasons of N rate trials at Bli Bli (G Kingston/BSES Trial). Juice amino-N values from 'Jeffco/Carver' extracts of samples collected 3 months prior to final harvest, while relative sugar yield was determined from samples collected at final harvest.

Further details of the results of this study are provided in Appendix 3.

Study B: N rate x trickle tape trial at Fairymead, Bundaberg

This trial consisted of five N rates from 0 to 240 kgN/ha supplied via a trickle system, compared with a single side dressing of 160 kgN/ha at planting or soon after ratooning.

The key features of the data arising from this five year trial include;

(a) the very high amino-N status of cane in all treatments in the plant crop (1997 data in Figure 5).

(b) The generally gradual decrease in amino-N levels in harvested cane from the first ratoon onwards. This may be evidence for a progressive immobilisation of nitrogen arising from the continuous carbon inputs to the soil over the life cycle of a multi-ratoon cane crop. When soil is disturbed in a ploughout/fallow/replant operation, this excess of carbon is broken down, releasing N that is seen in the generally favourable N supply in plant crops.

(c) The maintenance of high concentrations of amino-N in juice from harvested cane in the treatment receiving 240 kgN/ha via trickle.

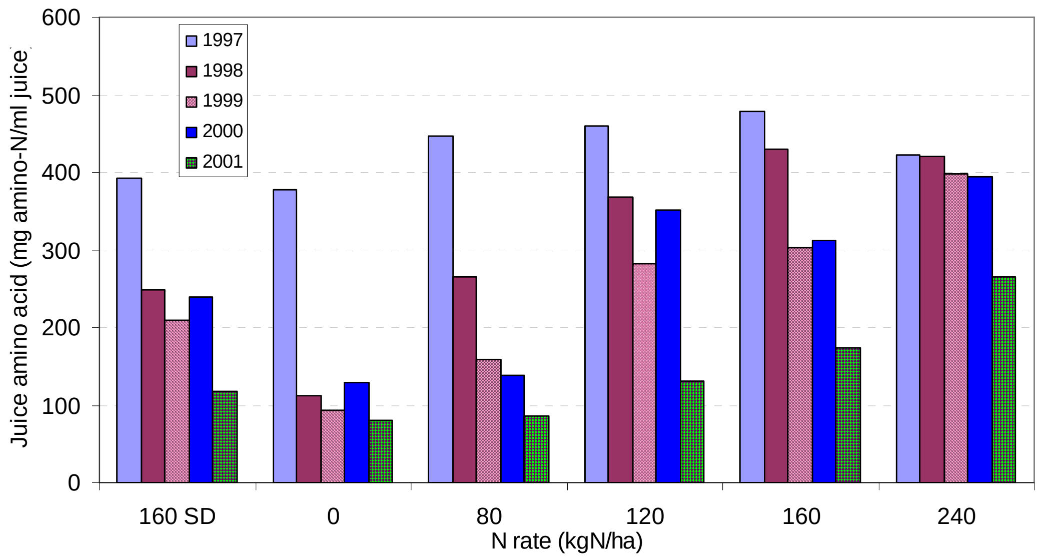


Figure 5. Amino N in juice from stems at harvest from the trickle N rate trial, Fairymead, Bundaberg, over five seasons (1997 was the plant crop).

The trial did exhibit significant rep to rep variation in yields, N response and amino-N concentrations associated with soil type variation. These effects are discussed further in Appendix 4. The relationship between relative sugar yields and amino-N levels in juice at harvest time was of the same form as found in the Bli Bli trial reported above, although these was considerable scatter associated with lower yields in some treatments where the cane was exhibiting high levels of amino-N (Figure 6). The reasons for this scatter at high amino-N status is uncertain, but we can say it is unlikely to be associated with nitrogen deficits. In some cases it could be related to lodging and depressed CCS associated with excess nitrogen supply.

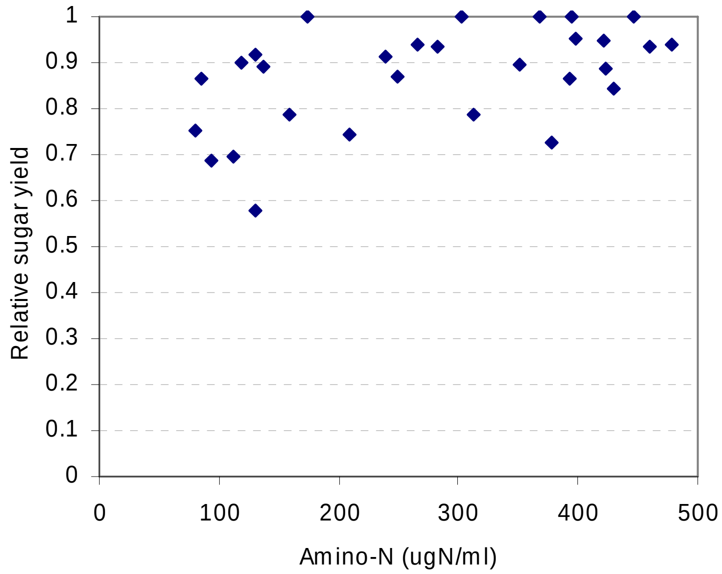


Figure 6. Relationship between relative sugar yield and juice amino-N based on data from 5 seasons of N rate trials in the trickle trial at Fairymead, Bundaberg. Relative sugar yield is calculated such that the highest yielding treatment in any particular season is assigned a value of 1.

Further details of this trial are provided in Appendix 4.

Study C: Variety x N rates x harvest times in the Burdekin (Alan Ratty/BSES trials)

This study represented the most significant set of data on amino-N content of cane stems yet collected. In all, 1620 juice samples were analysed from 6 varieties (15 varieties for some sampling dates), grown over 2 years at 3 N rates. A unique feature of these data is the multiple samples coming from early and late harvest schedules, providing insights on how amino-N levels vary within a harvest window.

Full details are provided in Appendix 5. For our purposes here, we shall highlight the insights with respect to (i) varietal effects on amino N, (ii) the diagnostic relationship between juice amino-N and relative sugar yield and (iii) within harvest season effects on amino-N concentrations.

(i) Varietal effects
The varietal differences were small at low rates of N where limitations in N supply were restricting amino-N levels, however they were more significant under high rates of N supply where luxury uptake of N was giving rise to high, but somewhat variable, concentrations of amino-N in the cane juice (Figure 7a, 8a).

(ii) Diagnostic relationships
The data on amino-N concentration of cane stems and cane yield at harvest time (Figs 7a,b; 8a,b) provide the basis for the diagnostic relationships between relative

sugar yield (within individual varieties) and amino-N concentration (Fig. 7c; 8c). These relationships follow the characteristic pattern observed previously, namely yield reductions associated with amino-N concentrations less than the range 50-100 µg amino-N/ml juice. Values above this range are interpreted as being associated with optimal or excess N supply.

(iii) Within harvest season effects

Relationships presented in Figure 7 and 8 relate to amino-N concentrations at the time of cane harvest. We were interested in knowing how sensitive the amino-N levels were to time of harvest, within the generally relevant harvest window (e.g., May till November). These effects are examined in Figure 9.

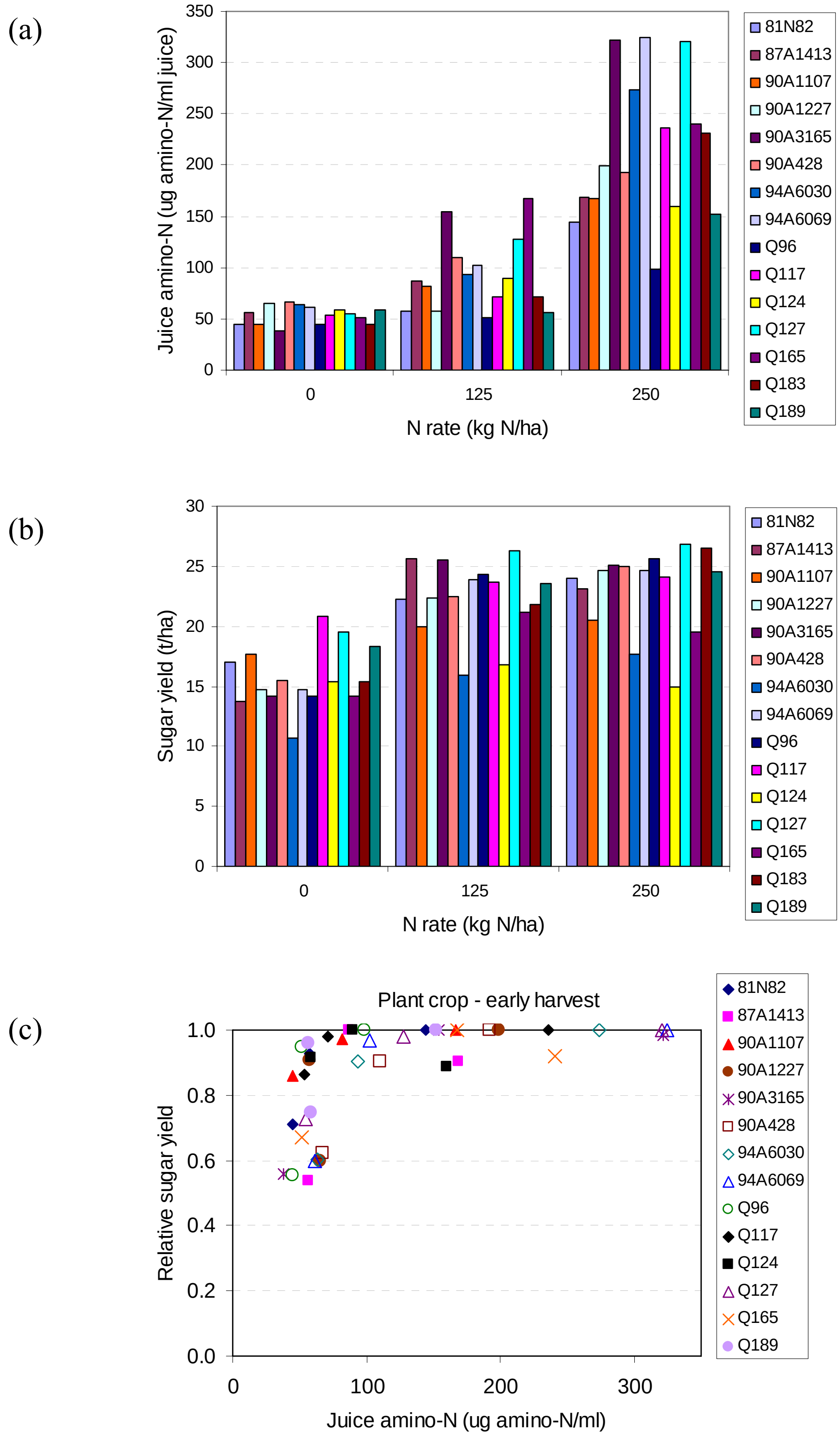
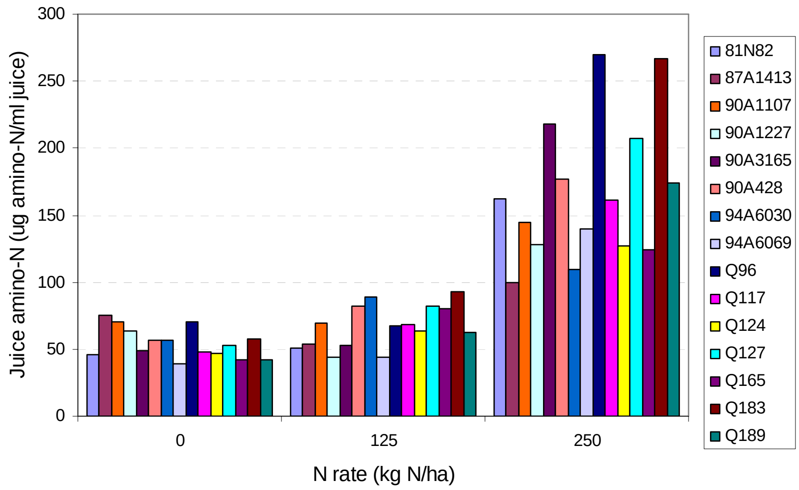


Figure 7. Results from the final harvest (July '00) from the plant crop for 15 cultivars or breeding lines in Expt 1 of the Alan Ratty trial in the Burdekin (a) Juice amino-N against N rate (b) Cane yield against N rate (c) Relative sugar yield (for N rate within a variety) against juice amino-N.

(a)



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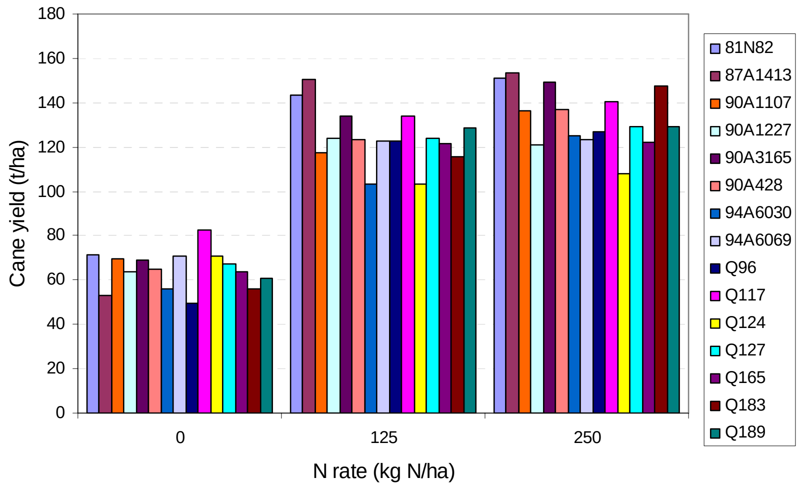

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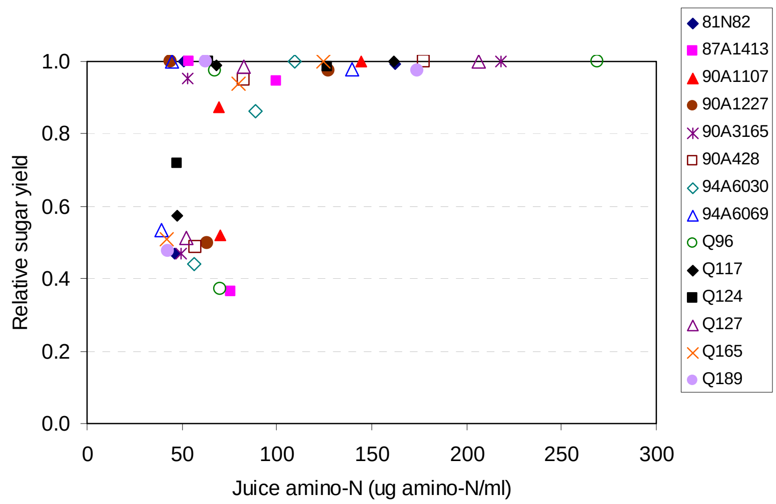
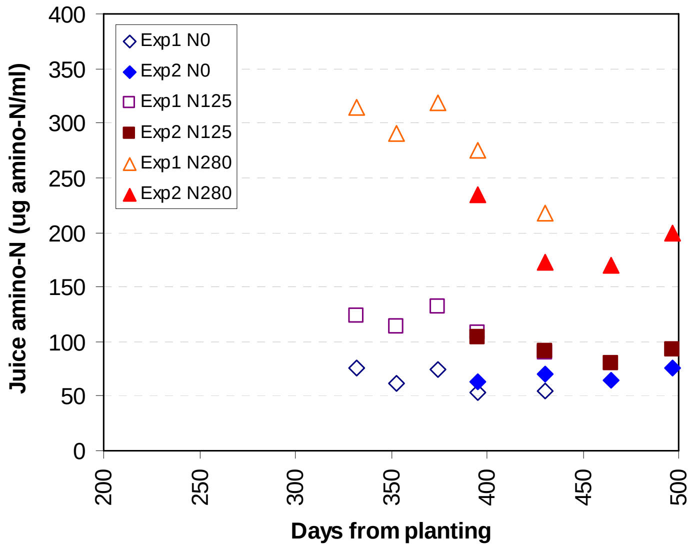


Figure 8. Results from the final harvest (July '01) from the first ratoon crop for 15 cultivars or breeding lines in Expt 1 of the Alan Ratty trial in the Burdekin (a) Juice amino-N against N rate (b) Cane yield against N rate (c) Relative sugar yield (for N rate within a variety) against juice amino-N.

(a)



(b)

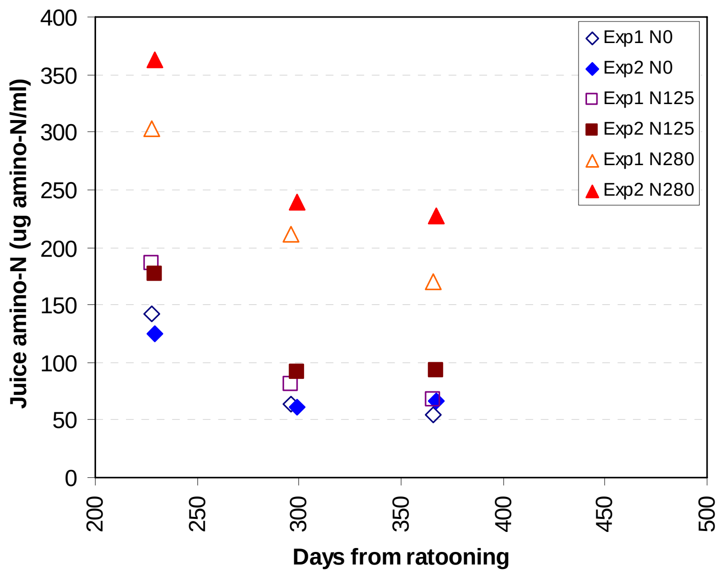


Figure 9. Amino-N concentrations (averaged over 15 varieties) versus days since planting or ratooning for Study C in the Burdekin (a) Plant crops in 2000, (b) First ratoon crops in 2001. Sampling in 2000 extended from 27th Mar. to 11th Sept. Sampling in 2001 extended from 16th Feb. to 10th Sept. Exp1 is the early harvest experiment (ratooning occurred in July 2000) and Exp2 is the late harvest experiment (ratooning took place in September 2000), both experiments were planted on the 30th April 1999.

The large effect of excess fertiliser N supply (e.g., the 280 kgN/ha rate) on amino-N levels is the most striking feature of the results in Figure 9. The gradual decline in amino-N concentrations for the plant crops over the late growing season and subsequent harvest season (Figure 9a) can be explained in terms of a pool of amino-N residing in the cane stems, being remobilised to support the N requirements for continued growth. It is interesting that the decline in stem juice amino-N appears to be linked to the physiological age of the crop. During the plant crop both experiments were planted together so at each sampling the age of the crop and the prevailing climatic conditions are the same. This is shown up by the closeness of the amino-N value for the N treatments during the overlapping time periods of the two experiments. However in the ratoon crop because of the different dates of harvesting the plant crop the plants of the two experiments are of different physiological ages at the time of the overlapping sampling times. When plotted as physiological age (Figure 9b) there is little difference between the two experiments but if the data is plotted as sampling date, such that the climatic conditions of each sampling time are consistent but the age of the crop different then large differences between the two experiments are seen. The amino-N concentrations were relatively stable for crop durations greater than 300 days irrespective of the timing of harvest and ratooning the previous season (Figure 9b). These data suggest that time of ratooning and harvest should not introduce significant difficulties in the interpretation of amino-N concentrations in cane stems. Amino-N concentrations will be higher in young crops (less than 400 days for plant crops and less than 300 days for ratoon crops), and this effect can be interpreted in terms of accumulation of amino-N in cane stems during early crop development and depletion of amino-N in later stages of crop growth.

Further details of these results are provided in Appendix 5.

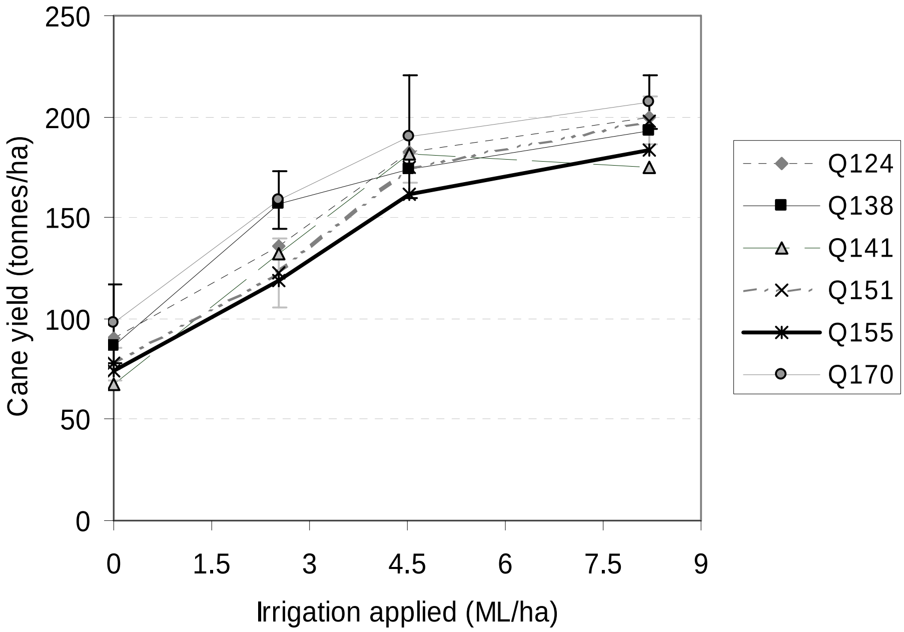
<u>Study D: Variety x irrigation trial in Bundaberg (Ross Ridge/BSES)</u>

The primary value of this trial to the “N at the Mill” project was that it enabled an assessment of the effects of severe water stress on amino-N concentrations. The trial, conducted by Mr Ross Ridge at BSES Bundaberg in 1997/98, consisted of 6 varieties grown as plant crops at 4 irrigation levels, ranging from zero to 8.2 ML irrigation/ha. Further details of the trial are provided in Ridge and Hillyard, (2000).

Cane yields were strongly constrained by the level of irrigation supplied in this trial (Figure 10a), with the non-irrigated treatment yielding less than half the cane of the well irrigated treatment. There were also small varietal differences in cane yield levels. Amino-N levels were generally elevated in the order of 10 to 30% by the severe levels of water stress observed in un-irrigated treatment (Figure 10b), an effect that can be explained in terms of shifts in the relative balance of N supply (from fertilisers and the soil) and N demand (from crop growth). The variety Q151 and to a lessor extent, Q170, exhibited higher amino-N concentrations in their stems irrespective of irrigation treatment.

Further details are provided in Appendix 6.

(a)



(b)

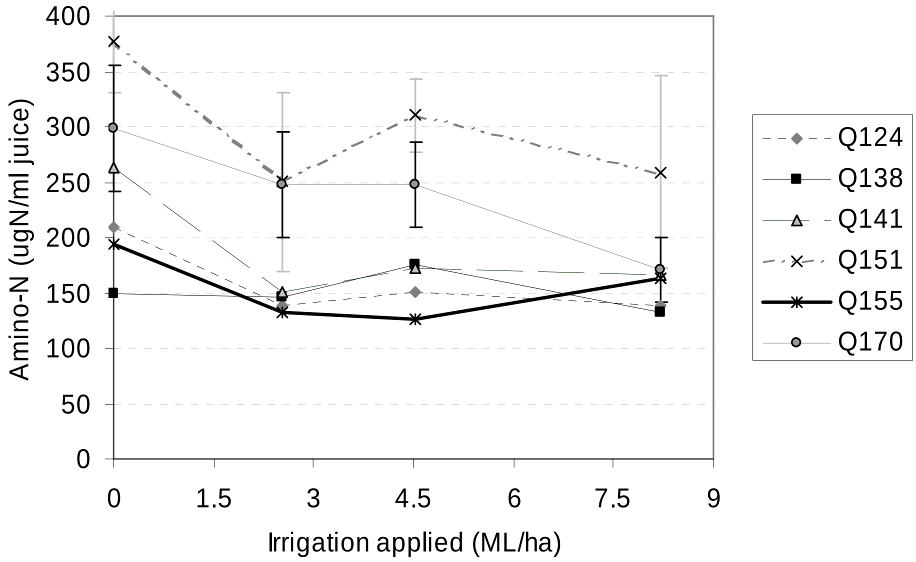


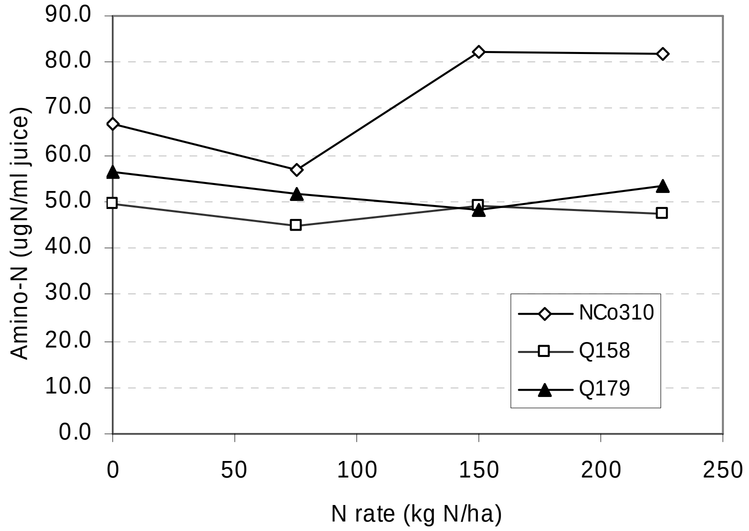
Figure 10. Response of a plant crop in Bundaberg to irrigation amount (a) cane yield (b) amino-N in cane stems at harvest. Trial conducted by Ross Ridge, BSES.

Study E: Variety x N rates at Macknade (A. Wood/CSR)

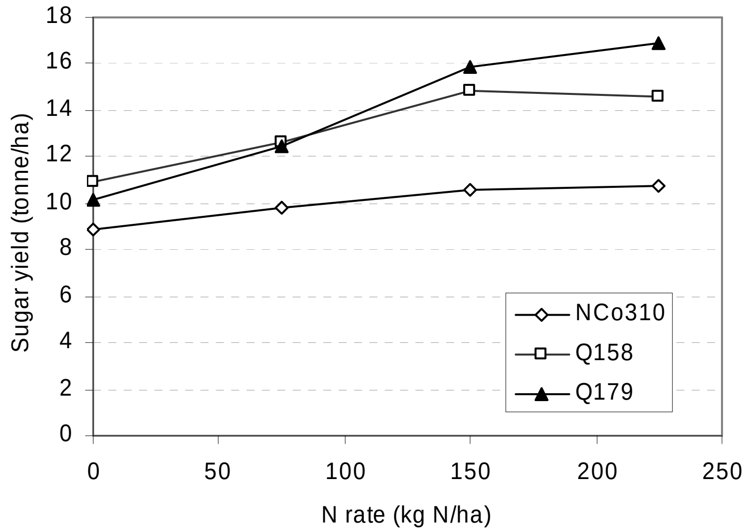
This trial provided additional observations on amino-N levels in cane stems in a highly N responsive situation. The trial (conducted by Dr Andrew Wood) at Macknade, consisted of 3 varieties by 4 N rates (0, 75, 150 and 225 kgN/ha). The results were characterised by uniformly low amino-N levels in the cane juice at harvest. Concentrations ranged from 45 to 80 µg amino-N/ml juice, with little by the way of a relationship with N rate (Figure 11a). These low amino-N levels were associated with a strong N rate response (Figure 11b), less so for the cultivar Nco310, which performed poorly. These data fit on the "N limiting" part of the diagnostic curve (Figure 11c), and the results can only be interpreted in terms of a strongly limiting N supply environment (possibly associated with N losses). In other words, in this particular trial and season, the amino-N data provided no evidence of excess N supply, even in the 225 kgN/ha treatment. The yield response data tends to support this contention.

Further details are contained in Appendix 7.

(a)



(b)



(c)

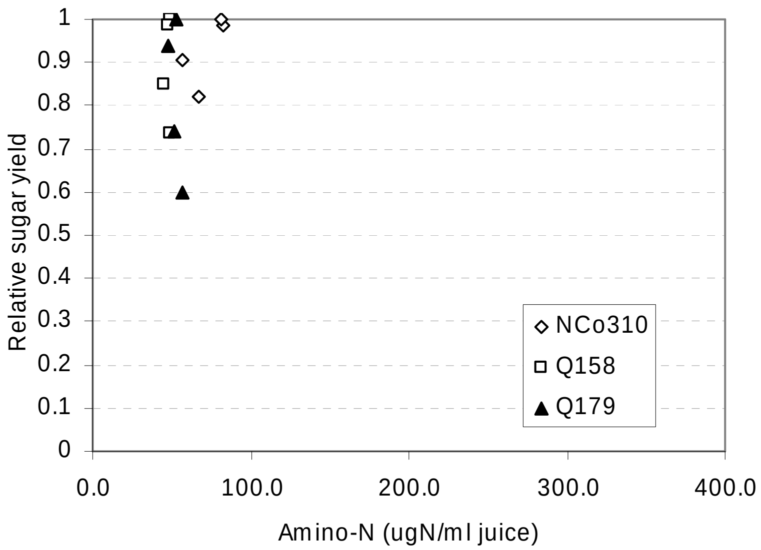


Figure 11. Results from the variety x N rate trial at Macknade in 2000/01. (a) Amino N vs N rate, (b) Cane yield vs N rate, (c) relative sugar yield vs amino-N.

5.3 Comparison of diagnostic relationships

The diagnostic relationships between amino-N and relative sugar yield published to date is reproduced in Figure 12. This relationship was based on data gathered prior to and in the early years of CTA029. The additional information gathers in the latter years of CTA029 is shown in Figure 13.

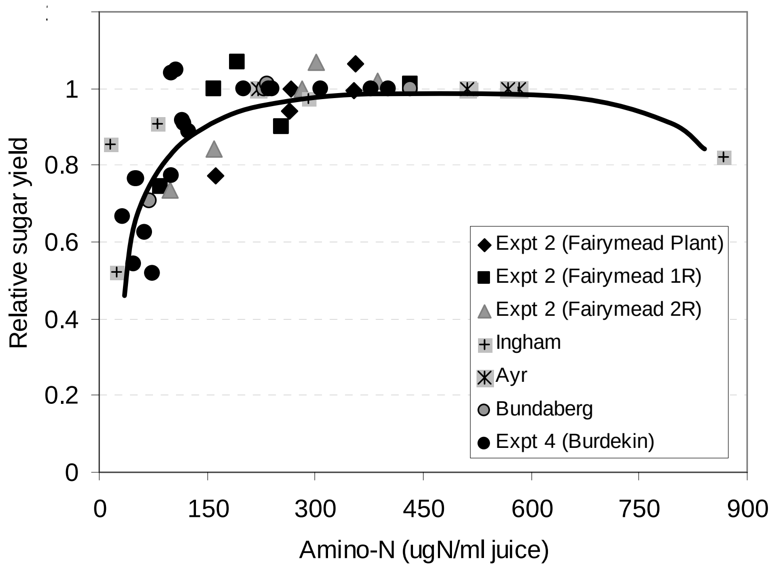


Figure 12. Sugar yield (as a fraction of yield in an N non-limiting treatment) versus amino-N in cane juice. Line indicates an idealised diagnostic response (see Keating et al., 1999 for details of Ingham, Ayr and Bundaberg data and Keating et al., 2000 for details of other datasets).

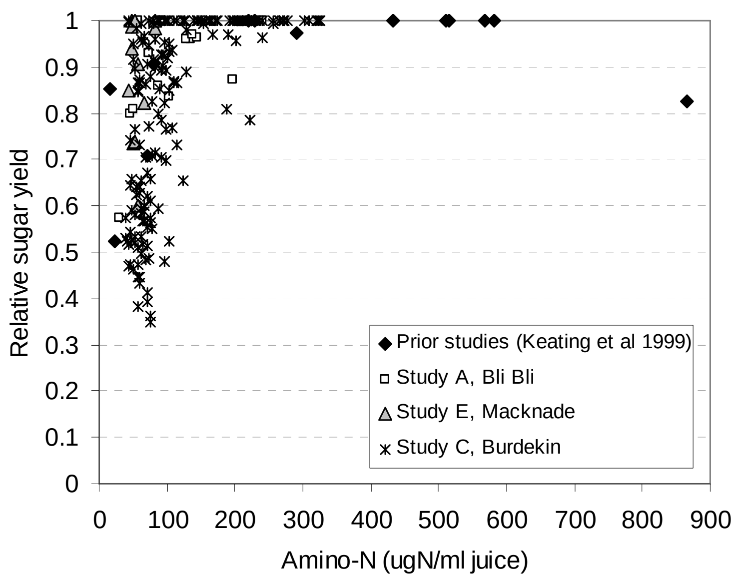


Figure 13. Combined information on relationships between relative sugar yield and amino-N concentrations in cane juice.

These new data are consistent with the earlier published diagnostic relationships. Our proposed interpretation is summarised in Table 4.

Table 4. Summary of the proposed interpretation of the diagnostic relationship between amino-N measured in cane juice at harvest time and relative sugar yield (where N supply is the factor limiting sugar yields).

Amino-N values (µg N/ml juice)*	**Description**	**Interpretation**
Less than 150	Low range	No suggestion of excess N supply. May indicate either optimal balance of N supply and demand or insufficient N resulting in sugar yield limitations. Monitor closely in subsequent years and consider N strip trials to test for N limitations.
150 to 250	Target range	No suggestion of either N excess or N deficits
Greater than 250	Excess range	Evidence of N excess, monitor in subsequent seasons and consider reasons for high N status (eg., excess N rates, recent mill mud additions, nitrate in irrigation water, fertile soil with high organic N status etc)

*Based on juice extracted after a 'Jeffco/Carver' extraction process.

In summary, the influence of increasing N supply to the sugarcane crop consistently results in a higher juice amino-N concentration. This effect has been observed throughout the data generated, though a few exceptions are apparent. In these exceptions other growth factors are likely to be compounding the issue.

In general other external influences on crop growth have not influenced juice amino-N concentration unless general plant growth has been severely constrained. A general observation is that plant biomass can 'dilute' the stem amino-N concentration, such that a poor biomass crop can have an elevated amino-N concentration even though it is clearly not N supply that is limiting growth. Conversely, a high biomass crop can have a low amino-N concentration when it has completely utilised the plant's N reserves (stored in the stem as amino compounds), without experiencing yield limiting N deficiency. It is for this reason that we believe the amino-N test is best suited to identifying situations of excess N supply, rather than identifying situations of N deficiency. The former are more difficult to detect, while the latter are generally obvious to growers through low productivity or N deficiency symptoms in the crop canopy.

5.4 On-farm trials and amino-N monitoring to assist growers in N fertiliser management

The on-farm trials involved six farms in the three Bundaberg mill districts, over a period of three seasons. Variation in N rate was the only treatment applied. Rates were based on the farmer's standard practice, and varied upwards and downwards by 20%. The results are reported in detail in Appendix 8 and an overview will be provided here.

The impressive result from the 6 sites and 3 seasons (i.e., 18 N response surfaces) was just how unresponsive cane or sugar yield generally was to these changes in N fertilisation rates.

1998/1999

Of the six N rate trials established in the Bundaberg area, five did not record significant yield responses to changes in fertiliser N. The sixth trial exhibited a 15% yield reduction when N rates were reduced 20% below grower's standard practice. The detailed report (Appendix 8.1) examines soil nitrogen and stem amino-N measurements as an aid to interpretation of these results. Soil sampling indicated that large quantities of mineral nitrogen (residues from previous crops) were present at planting or ratooning at three sites and these went someway to explain the general lack of responsiveness to current N fertiliser additions. Amino-N level in cane juice at harvest was generally useful in assessing the overall N supply situation. Excessive levels of N supply were indicated on one farm, two others were pushed into the excessive range by the +20% N rate treatment. The three other farm blocks recorded amino-N levels at harvest within the provisional target range (100 to 250 ugN/ml juice).

The report on the 1998/1999 trials in the Bundaberg district (Milestone 6) is presented in Appendix 8.1

1999/2000

In 1998/99, little in the way of cane or sugar responses to changes in N rates was observed and the research team expected more impact in this second year of imposition of treatments on the same land. This did not eventuate and for the second year running, raising or lowering N rates by upwards of 40 kg N/ha above and below the farmer's standard rates had little impact on yields. The maximum response observed was 12% change in sugar yield, while in most trials, the differences were less than 3%. Yields remain moderately high in most trials (90 to 120 tonnes cane/ha) with only one low yielding situation (60 tonnes cane/ha) and the lack of N response can only be explained by sufficient N supply from other sources such as soil mineral-N and in crop mineralisation.

Soils were sampled after harvest and mineral-N level measured to 180 cm. The high levels of mineral-N observed in four of the six farms when the trials were first set up in 1998 were no longer present. Crop uptake was clearly a major reason for this, although it is not possible to determine the extent to which any of the nitrate component of this mineral-N might have been leached below the crop root zone.

Amino-N levels in the juice at harvest were in the range 130 to 330 ugN/ml juice. The majority of these trials and treatments were within the provisional target range (150 to 300 ugN/ml juice) and no clearly excessive or clearly N limited levels of amino-N were observed. Under these circumstances the amino-N monitoring did not make a major contribution to improved N management. Overall, the N supply from the farmer's standard N fertiliser rates on these fields was sufficient to ensure yield was maximised and there was no evidence of excessive N supply. The results were consistent with response surface relating relative sugar yield to amino-N is juice at harvest time, but the limited range in amino-N and lack of any significant yield responses meant this diagnostic response surface was not unduly tested.

The turn-around between harvesting, sample collection and laboratory-based analysis was identified as a problem inhibiting rapid feed-back to growers in time for use in fertiliser decision making. At this point in the project we concluded that the rapid "on-line" assay (based on something like NIR which is being investigated in CTA045) is essential to properly undertake effective interactions with growers.

The report on the 1999/2000 trials in the Bundaberg district (Milestone 8) is presented in Appendix 8.2

2000/2001

The lack of significant levels of N response in the first two years of these on-farm trials led us to continue the treatments for a third year. The results of the third year of N rate trials are included alongside a summary of the first and second year results, in Appendix 8.3.

The key findings in the third year were that;

a) The low levels of responsiveness to changing N fertiliser rates (plus or minus 20% from the grower's standard practice) was maintained, although there were suggestions that after three years of reduced N fertiliser inputs, sugar yields were starting to be affected. Of the five sites where harvest data were available, three sites (Borg, Jensen, Dingle) registered lower yields (7, 11 and 20% reductions respectively) in the minus 20% treatment.
b) The amino-N levels were generally within the "target" range, although there was some evidence that amino-N levels were falling in cane harvested from the treatments receiving reduced N inputs.

An example of these three seasons of data from one farm is reproduced in Figure 14. Note the very flat response surfaces for cane or sugar yield to applied N fertiliser. The small differences in sugar yield observed, while they may have been of economic significance to the grower, were not statistically significant given the variability typically experienced in on-farm field trials. Note also the generally falling levels of amino-N in the cane juice as the trial moved from a plant crop through a first ratoon onto a second ratoon. Amino-N levels were lowest for the treatments receiving the reduced N fertiliser rate, but with the exception of the plant crop, were still with the "target" range of 100 to 300 ug amino-N/ml juice.

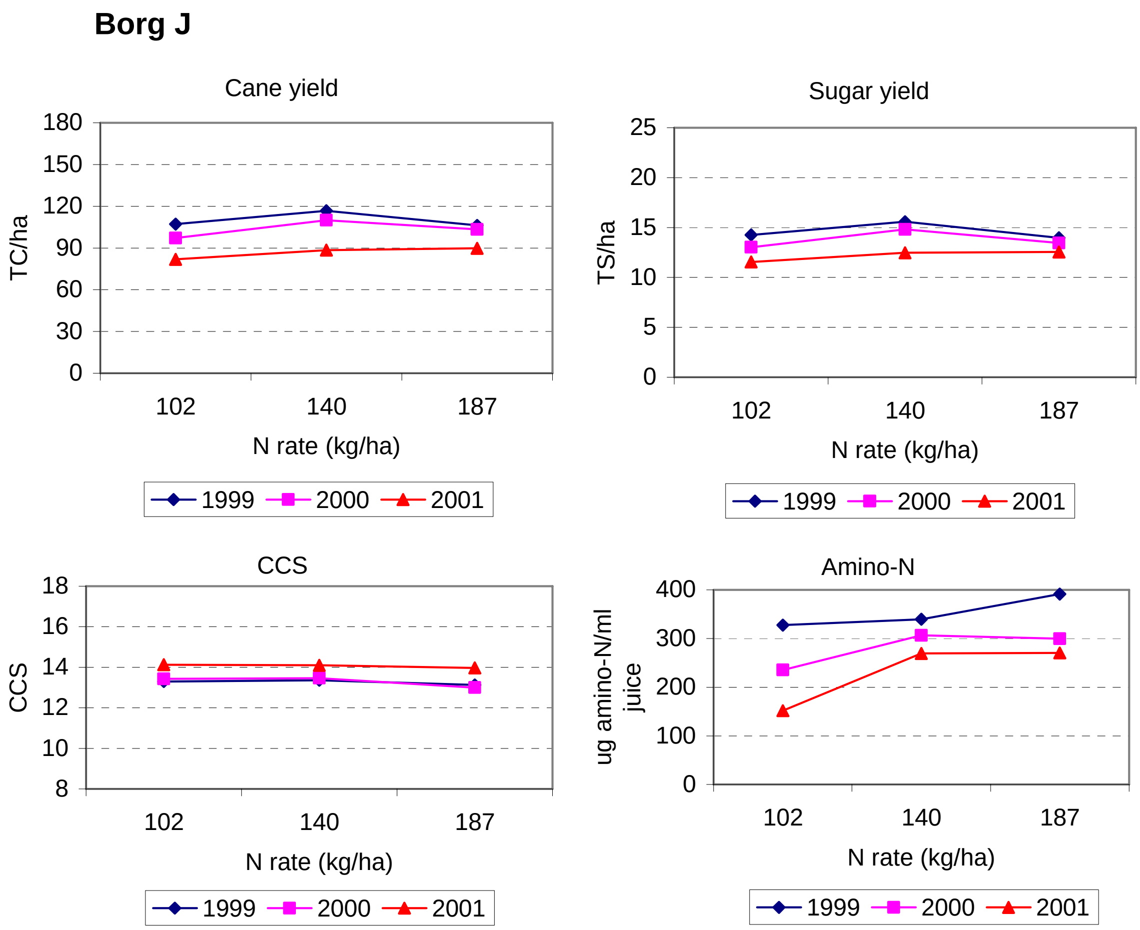


Figure 14. Results of three years of on-farm trials for the Borg farm in the Bundaberg district.

The generally low level of response to changing N fertiliser rate observed in these on-farm trials is highlighted in Figure 15. Here, the response in sugar yield to increasing or decreasing N rate is presented, with the grower's standard rate used as a reference. Of the 32 observations (sites x N rate change x years) only 2 involve a sugar yield change of 20% or greater. One of these (Spryou 2001) was a low yield, drought affected crop in which N supply may not have been responsible for the observed yield differences observed. The other (Dingle 2001) was a case where there does appear to have been a 20% sugar yield reduction associated with the third year of reduced N fertiliser inputs.

A further 11 observations involved sugar yield changes in the 8-12% range. There was no consistent pattern in these small responses. Many involved the highest sugar yield being observed at the grower's standard N rate, some involved higher yields in the treatments where N rates were changed away from the grower's standard, others lower yields at these changed N rates. The remaining 19 observations involved sugar yield changes (both positive and negative) in the 0 to 8% range, and these are generally too small a change to be detected with any degree of confidence in these on-farm trials.

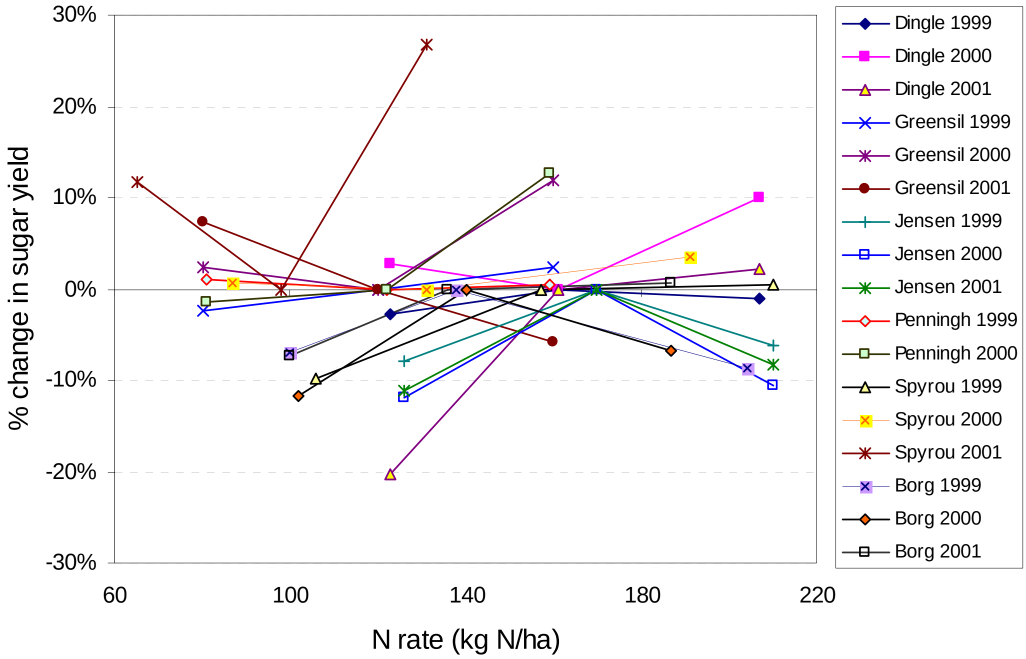


Figure 15. Percent change in sugar yield with change in N rate, referenced to the grower's standard N rate (i.e. %change = 0 for the standard N rate).

While the levels of amino-N observed in these on-farm trials were interpretable in ways consistent with past amino-N observations from experimental studies, the amino-N data provided little extra value in the circumstances of the on-farm trials. The reasons for this are evident from Figure 16. With a few exceptions, the amino-N levels observed were all within a relatively narrow range, a range that we have come to refer to as the "target" range. Hence, there was no evidence of "excess" N supply conditions in these trials, something that has limited the value of the additional amino-N information. Earlier "whole of mill" sampling for the Bundaberg district (eg. see Figure 2) and other mill districts (see Keating et al, 2001), identified a proportion of rakes/blocks of cane with amino-N levels much higher than those observed in these on-farm trials. We believe the value of the amino-N testing will be in the identification of these "excess" N supply situations.

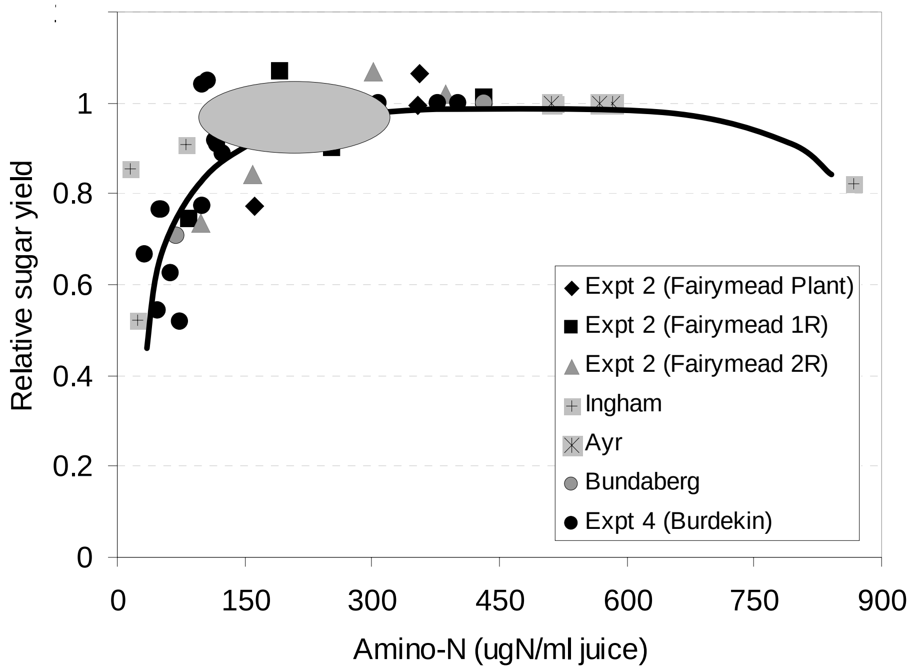


Figure 16. Generalised diagnostic relationship between amino-N and relative sugar yield. The shaded oval area identifies the location of on-farm trial results in terms of this relationship.

6. Outputs

The major outputs of this project relate to the knowledge necessary to underpin a monitoring technique aimed at assessing the N status of blocks of sugarcane at harvest time. Specific elements of this knowledge include;

(g) That variation in N supply (such as arises from differential N fertilisation practice) has the dominant influence on the amino-N concentration in cane stems at harvest time
(h) That all the varieties tested to date exhibit the phenomenon of elevated amino-N levels in cane stems and juice in response to excess N supply, although there was some varietal differences in the absolute concentrations that are observed under elevated N supply.
(i) That water stress has a modest influence, in the form of elevated amino-N concentrations in crops that have experienced yield limiting levels of water deficit.
(j) That amino-N levels in cane stems exhibit a modest downward trend as a crop ages, but the age related differences within a typical harvest window are small and of little consequence in terms of interpretation of amino-N monitoring information.
(k) That all factors impinging on amino-N concentrations in cane stems can be interpreted via a conceptual model of demand for N for new growth and supply of N from N compounds stored in stem tissues (principally amino-N) and where relevant, continued uptake from soil sources.
(l) A diagnostic relationship between relative sugar yield and amino-N concentrations which can be used to define three zones of N supply, namely excess, target and potentially deficient.

These outputs are complimented by the experiences on-farm, which highlight the generally limited responsiveness of cane and/or sugar yield to small changes in fertiliser N inputs. Earlier reports have noted this phenomenon (eg. Catchpoole and Keating 1995) and attribute it to the significance of other sources of N such as soil organic matter mineralisation. This suggests that a longer-term view of N fertilisation practice is justified, rather than a short term "fine-tuning" of N rates on a year-by-year basis. The use of an amino-N assay as an indicator of the N status of the preceding crop is complimentary to this longer term view. Over a period of years, the monitoring of N status of crops as they are processed in the mill should enable patterns of N supply to be discerned, and these patterns can be used to make progressive adjustments to N management strategy on a block specific basis.

7. Expected outcomes

This work is not yet at a stage where the outcomes can be definitively stated. There is great potential for a major impact, but whether or not this is realised will depend on the results of an on-going related project, which is trying to develop an NIR method for rapid monitoring of amino-N in a mills processing stream. Should such a method be developed, we would expect the outcomes that could flow to consist of;

(a) A reduction of nitrogen fertiliser usage in the Australian sugar industry of the order of 10-15%, without net loss of sugar yield. This would amount to an annual saving of input costs in the order of $8-12M.

(b) Reductions in N loss to the environment in the order of 30% of current losses. This estimate is based on the assumption that a disproportionately higher fraction of N losses to the environment arise from situations where excess N fertilisation takes place. Hence targeting N input reductions to blocks where N excess is greatest will have disproportionately greater effect in reducing N losses.

(c) Inclusion of "N at the Mill" monitoring in emerging environmental assurance/accreditation schemes, such that the industry could demonstrate a best practice approach to nitrogen fertilisation that was available (ultimately) on every block of cane supplied to a sugar mill.

8. Future research needs

One major challenge stands in the way of the widespread use of the nitrogen status of cane delivered to mills as a means of assessing the N supply under which the cane was grown. This is a rapid, cost effective and reliable means of estimating the N composition of cane as it is processed in the mill. This project (CTA029) has focused on amino-N as the primary target for monitoring and has focused on the factors leading to variation in amino-N composition. The results confirm the potential value of an amino-N monitoring systems as an effective means of identifying crops exposed to excess N supply during their growth cycle. Another project (CTA045) has been attempting to use NIR as a method of estimating amino-N. Problems have been encountered in CTA045 in getting sufficient robustness in the NIR based assessment of amino-N. One of the reasons for this has recently been discovered and relates to variable extraction efficiency of amino-N in the milling train. One final attempt in underway to build a robust NIR calibration for amino-N. If this fails, we have one remaining fallback strategy. That is to revert to using total N in the cane supply in lieu of amino-N, on the grounds that total N should be easier to monitor with NIR on whole cane supply. These possible ways forward will be evaluated in the current final year of CTA045.

We remain hopeful that a mill-based indicator of the N status of cane crops will be possible. The focus is on indicating excess N supply and the level of accuracy required is not high. A monitoring system that identifies high, within target and low ranges should be sufficient. Growers will be as interested in the relative differences in the N status of the crops consigned to the mill as in the absolute values. We will be advising growers to monitor the N status of all their blocks for a number of years before making any major changes in their N management practices. Under these circumstances, a high level of accuracy in the monitoring system will not be required.

The Australia sugar industry remains under significant pressure to demonstrate it is operating in an environmentally responsible manner. Should we succeed in getting a workable N monitoring system in place, then there would be opportunities for research to benchmark industry N fertilisation practice and to monitor the effectiveness of the new “N at the Mill” monitoring scheme in raising the efficiency of N fertiliser usage in the industry (e.g., in terms on tonnes of sugar produced per tonne of fertiliser N applied). Such monitoring practices and benchmarking could then flow onto environmental management systems (EMS) and other environmental accreditation schemes that the industry develops in the years to come.

9. Recommendations

1. We recommend no dissemination of these results take place until the results of the companion project, CTA045, are known, in the latter half of 2003.
2. Should CTA045 develop a monitoring system that can be deployed cost-effectively in mills, then we recommend N monitoring at the mill be included in best practice guidelines for sustainable sugar production. A major communication program would be warranted at that point.

10. Acknowledgements

A large number of people have made very significant contributions to this project.

In particular we would like to sincerely thank the following farmers who supported the on-farm trials; Greensil, Borg, Penningh, Spyrou, Dingle, and Jensen.

A number of researchers allowed us to perform laboratory analyses on samples from their experimental trials and who provided access to data to assist in the interpretation of these analyses. In particular, we thank; Ross Ridge (BSES), Graham Kingston (BSES), Allan Ratty (BSES/Sugar CRC), Andrew Wood (CSR), Mike Smith (Bundaberg Sugar), Russell Muchow (CSIRO), and Peter Thorburn (CSIRO).

BSES extension staff in the Bundaberg district were instrumental in the establishment and monitoring of the on-farm trials. Particular thanks goes to; Julian Collins, Jim Sullivan, Ann Doak and (in Ingham), Greg Shannon.

Current or past CSIRO staff supporting this project in addition to the authors of this report include Mayling Goode, Keith Smith, Peter Thorburn and Russell Muchow.

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Keating, B.A., Verburg, K. Huth, N.I. and Robertson, M.J. (1997) Nitrogen management in intensive agriculture: sugarcane in Australia, *In:* Intensive sugarcane production: meeting the challenges beyond 2000 (Keating, B.A. and Wilson, J.R. eds). CAB International Wallingford, UK.

Muchow, R.C., Wood, A.W., Spillman, M.F., Robertson, M.J. and Thomas, M.R. (1993) Field techniques to quantify the yield determining processes in sugarcane. I. Methodology. Proc. Aust. Soc. Sugar Cane Technol., 15, 336-343.

Ridge, D.R. and Hillyard, J. 2000 Varietal response to irrigation amount and method in the Bundaberg area. Proc. Aust. Soc. Sugar Cane Technol., 22, 256-263.

12. Publications arising from project

Copies contained in Appendix 1.

Collins J, Webster AJ and Keating BA (2000). Predicting nitrogen at the mill. BSES Bulletin 71: 20-21.

Keating BA, Goode ML, Smith KJ, Kingston G, Wood A and Muchow R (1998) Monitoring nitrogen at the mill to improve nitrogen management on farm. Proc. Aust. Cane Technol. 20: 554-555. *(Poster paper)*

Keating BA, Kingston G, Wood AW, Berding N and Muchow RC (1999) Monitoring nitrogen at the mill to guide N fertilisation practice on farm. Proc. Aust. Sugar Cane Technol. 21: 10-19.

Keating BA, Kingston G, Muchow RC, Wood AW and Smith MA (2001) A monitoring system based on amino-N at harvest time to improve nitrogen management in sugarcane systems. Proc. 10^{th} Aust. Agron. Conf. Hobart, 2001.

Appendices

Appendix 1. Copies of publications arising from this project

Appendix 1.1

Keating BA, Kingston G, Wood AW, Berding N and Muchow RC (1999) Monitoring nitrogen at the mill to guide N fertilisation practice on farm. Proc. Aust. Sugar Cane Technol. 21: 10-19.

Appendix 1.2

Keating BA, Kingston G, Muchow RC, Wood AW and Smith MA (2001) A monitoring system based on amino-N at harvest time to improve nitrogen management in sugarcane systems. Proc. 10^{th} Aust. Agron. Conf. Hobart, 2001.

Appendix 1.3

Collins J, Webster AJ and Keating BA (2000). Predicting nitrogen at the mill. BSES Bulletin 71: 20-21.

Appendix 1.4

Keating BA, Goode ML, Smith KJ, Kingston G, Wood A and Muchow R (1998) Monitoring nitrogen at the mill to improve nitrogen management on farm. Proc. Aust. Cane Technol. 20: 554-555. *(Poster paper)*

Appendix 2. Bundaberg mills – in mill sampling, 1997

Title:	In mill sampling at three Bundaberg mills.
Principal researcher:	Brian Keating
Year:	1997
Publication:	Keating BA, Kingston G, Muchow RC, Wood AW and Smith MA (2001) A monitoring system based on amino-N at harvest time to improve nitrogen management in sugarcane systems. Proc. 10th Aust. Agron. Conf. Hobart, 2001.

Introduction

The pilot project CSC21S reported the variation in N levels in sugarcane juice extracted at the mill for samples collected from Macknade Mill. As part of CTA029 it was proposed to expand this study to investigate if this variation was present in other mill districts. The Bundaberg region is a major sugar-producing region in the Australian industry serviced by three sugarcane mills (Fairymead, Millaquin, and Bingera). This allows for not only three mills to be sampled for variation in the N concentration of cane supplied to mills

Methods

Samples were collected over a 24 hour period on five separate days over the three mills (Fairymead, Millaquin, and Bingera) during the 1998 crushing season. Methods of juice analysis as per Keating *et al.* (1999). At each 24-hour sampling period the first expressed juice (FEJ) was collected from every third rake crushed.

Table 1. Details of mill-scale studies of variation in amino-N status of cane supply

Nº.	Mill	Year	Nº. of farms sampled	Nº. of rakes sampled	Tonnes cane	Times sampled[1]	Sampling period
1	Bingera	1997	119	215	14,005	5	Aug - Nov
2	Fairymead	1997	106	188	13,557	5	Aug - Nov
3	Millaquin	1997	98	195	10,011	5	Aug - Nov

[1] Samples collected over a 24 hr period of mill operations

Results and Discussion

The cane rakes sampled from the three mills during the five sampling periods was on average 12500 tonnes of cane (Figure 1). Millaquin had the highest percentage of burnt cane supplied (44%) compared to 38% and 30% for Fairymead and Bingera respectively. Fourteen different varieties were identified in the samples collected, of which Q141 made up 25% and Q141 and Q151 18% each. The sampling strategy adopted then has provided a broad representative cross-section of the Bundaberg sugar cane industry in 1997.

A histogram of FEJ amino-N concentrations (Figure 2A) shows that while each mill has a different profile for all samples collected, the majority of rakes had amino-N values within the 'target' range (150-300 µg amino-N ml^{-1}) (Keating *et al.* 1999). The percentage of rakes higher than the target range was 38.6% at Bingera, 32.6% at Millaquin, and 20% at Fairymead (Figure 2B). Bingera mill also recorded the least number of rakes below the 'target' range, while Fairymead had the largest number below the target.

The distribution of amino-N concentration of rakes supplied to the Bundaberg mills is similar to the distribution recorded for the Macknade Mill in pilot study (Keating *et al.* 1999). This shows variation in amino-N concentration of sugarcane supplied to mills is consistent for southern as well as northern sugar regions.

Figure 3 shows a plot of the average juice amino-N concentration of all rakes sampled at each of the sampling periods for each of the 3 mills. While Fairymead was relatively uniform over the crushing season, both Millaquin and Bingera both had mid-season peaks. Cane sampled from Fairymead mill is generally lower in its juice amino-N level compared to the other two mills (Figure 3).

For all samples collected there is no significant difference between green or burnt harvesting (Figure 4). There are also differences in the juice amino-N concentration of the different crop classes (Figure 5), as has been observed previously. This varied between the three mills but generally plant and first ratoon crops had higher juice amino-N concentrations compared to older ratoon crops. This crop class effect can explain some of the differences seen between the five harvests as different ratios of crop classes are harvested at the five harvests with Bingera having on average more plant crops represented in the samples collected. Significant differences between varieties were only evident between the variety with the highest amino-N (Q151) and the four lowest varieties (Q138, Q141, Q146, and Q150) (Figure 6).

The variation does reinforce the need to know the causal agent for the variation in the juice amino-N concentration. While the global N response curve for juice amino-N can be applied across different varieties, different harvesting strategies, and different crop classes, the interpretation of the juice amino-N value will require knowledge of the crop class, variety, etc.?

References

Keating BA, Kingston G, Wood AW, Berding N and Muchow RC (1999) Monitoring nitrogen at the mill to guide N fertilisation practice on farm. Proc. Aust. Sugar Cane Technol. 21: 10-19.

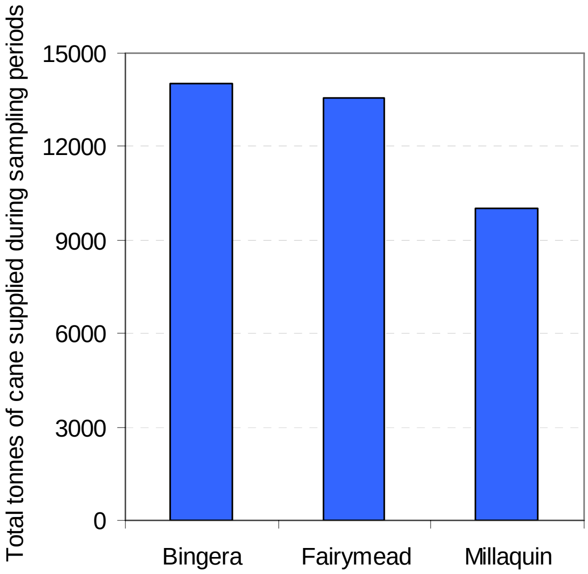


Figure 1 Tonnage of cane delivered in the rakes sampled during the 5 collection periods for the three mills.

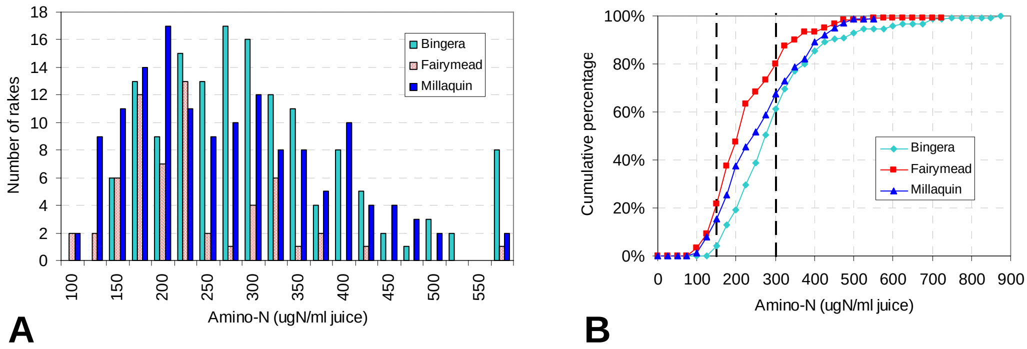


Figure 2 Histogram of sample juice amino-N concentrations for all 3 mills with the 5 sampling periods combined.

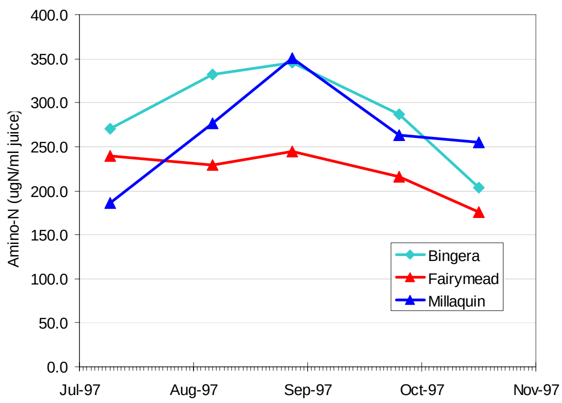


Figure 3 Variation in average juice amino-N content of all rakes sampled during the crushing season at each of the 3 Bundaberg mills as measured at each of the 5 sampling times during 1997.

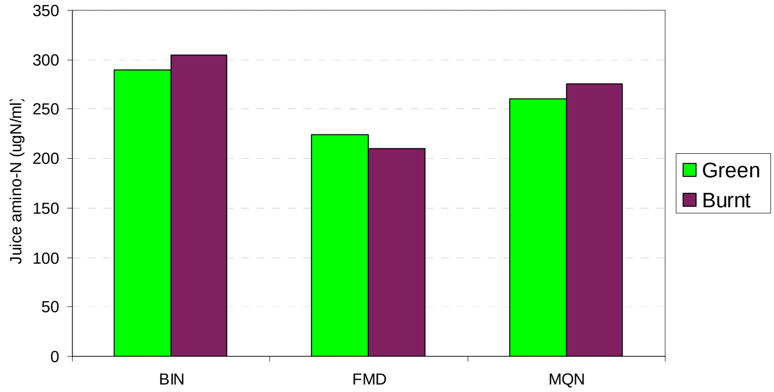


Figure 4 Juice amino-N content of green Vs burnt harvested cane for the 3 mills over the 5 sampling periods

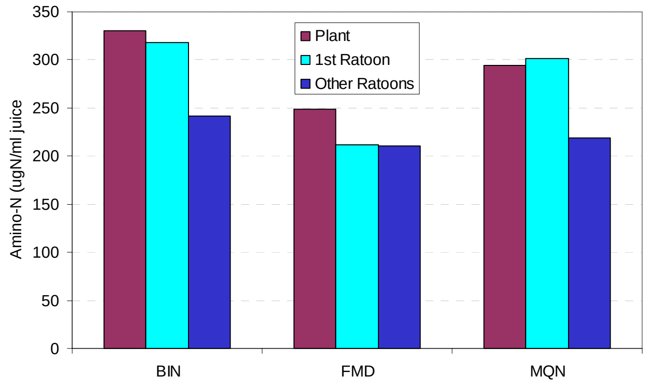


Figure 5 Juice amino-N by crop class for the 3 mills over the 5 sampling periods.

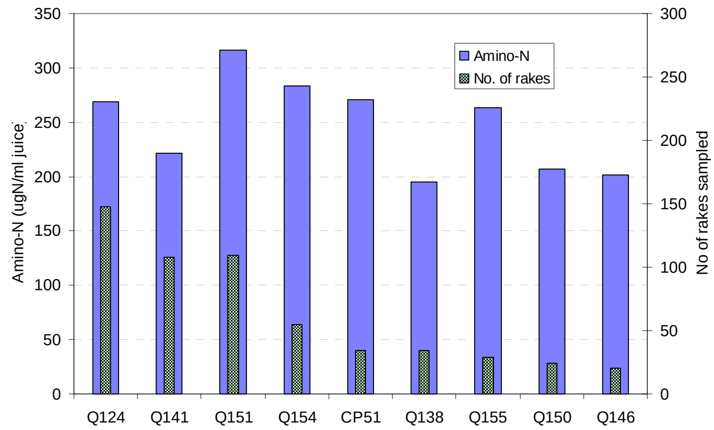


Figure 6 Juice amino-N concentration for 9 of the 14 varieties identified in the rakes sampled. Remaining 5 varieties made up less than 2% of rakes sampled.

Appendix 3. Bli Bli Variety x N trial

Title: Bli Bli Variety x nitrogen x lime experiment
Principal researcher: G. Kingston, BSES, Bundaberg
Year: 1998 – 2000
Publication: Unpublished

Introduction
This trial was established to investigate the interaction of altered soil pH by the application of lime and different N fertiliser rates on cane yield and soil N mineralisation. As part of the "N @ Mill" project juice samples were collected at each sample time for ninhydrin amino acid analysis.

Methods

Table 1 Experimental diary and treatments applied to Bli Bli experiment.

CROP	N Rates	Other treatments	Plant/Ratoon	Harvest	Treatments applied	Mid-season harvest
Plant	50, 100, 150, 200, 250	+Mo, +lime	7/7/97	16/10/98	5/12/97	July 98
1st ratoon	"	+Mo, +lime	16/10/98	17/11/99	3/11/98	July 99
2nd ratoon	„	+Si, +lime	17/11/99	22/10/00	20/12/99	August 00

The experimental site was a humus podsol soil type adjacent to Mt Coolum, near Nambour on the Sunshine Coast. A crop of Q154 cane was planted on 7th July 1997, with treatments being applied on the 5th December 1997. The experimental design consisted of a lime or molybdenum treatment and five N rates (50, 100, 150, 200, and 250 kg N per ha) over 3 replicates of each treatment. After the plant crop the molybdenum treatment was changed to a silicon treatment.

The samples collected for this project were taken from the plus lime treatments for the plant (1997-98) and 1st ratoon (1998-99) and both plus lime and plus silicon treatments were sampled in the 2nd ratoon crop (1999-2000). Mid-season samplings were conducted in each of the 3 years. For mid-season harvests, juice was extracted from cane stems by the 'Jeffco/Carver' method and at end-of-season harvests, juice was extracted by the 'small mill' method. At the mid-season harvest for 2nd ratoon crop, (August 2000) both 'small mill' and 'Jeffco/Carver' methods were used to compare the relative juice extraction efficiency of each method.

Results and Discussion
The use of small mill juice extraction at end-of-season harvests has meant that this data cannot be included in the global juice data collected in the rest of this project. Figure 1 shows the reduced amino-N values measured from samples extracted by 'small mill'. It can also be seen in Figure 1 that the range of amino-N values is much reduced in the 'small mill' extracted samples compared to the 'Jeffco/Carver' extraction method. This could be an indication of the cellular site of storage of amino acids in the sugarcane stem, a factor that is being investigated further in project CTA045.

This study has reinforced the basic observation that increasing N supply results in higher juice amino-N content (Figure 2). Crop class affects juice amino-N, with successive ratoon crops having lower juice amino-N concentrations compared to plant crops (Figure 2). The recovery of the juice amino-N in the end-of-season sampling 2000 (Figure 2B) possibly indicates an artefact of the ‘small mill’ extraction method.

While the juice extraction method makes the end-of-season data unreliable, it does still show a response to N rate which is not as evident in other parameters measured (Figure 3).

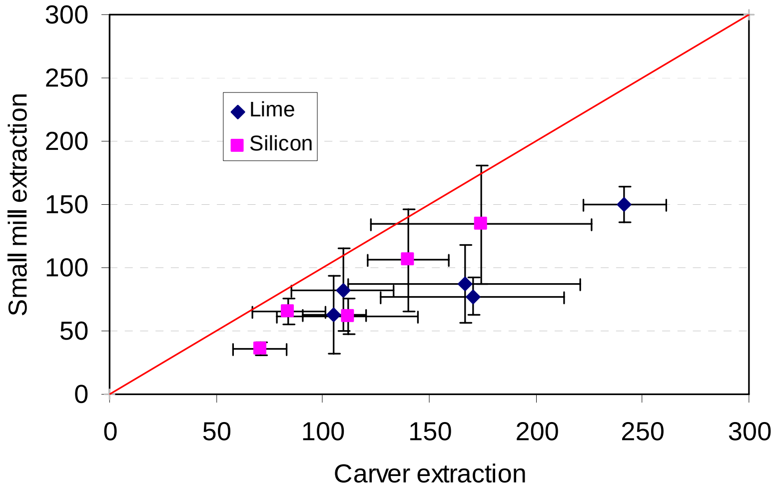


Figure 1 Juice amino-N measured from juice either extracted by 'Jeffco/Carver' or 'small mill' methods. Juice was collected in August 2000, 2 months before final harvest of the 2nd ratoon crop.

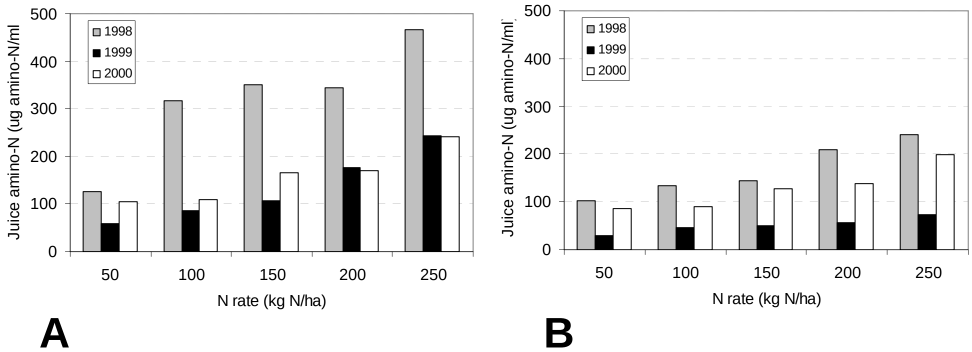


Figure 2 Juice amino-N concentrations for samples collected from Study A from 1998 (plant crop) to 2000 (2nd ratoon). Samples were either collected at mid-season (2 to 4 months prior to end-of-season harvest) and the juice extracted by 'Jeffco/Carver' method (Figure 2A), or end-of-season and juice extracted by 'small mill' (Figure 2B).

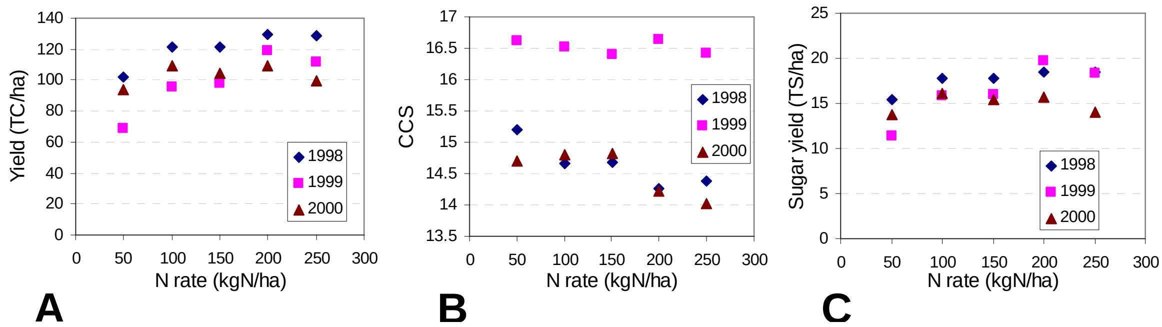


Figure 3 End-of-season yield parameters for Study A. Parameters presented are Cane yield (A), CCS (B), and sugar yield (C).

Appendix 4. N rate via trickle tape trial

Title:	Fairymead trickle irrigation trial
Principal researcher:	P. Thorburn CSIRO, Brisbane
Year:	1998 – 2001
Publication:	Dart *et al.* ASSCT (2000)

Introduction
Investigation of reduced N application rates if the N is supplied with irrigation water via buried 'trickle' tape.

Methods
For experimental layout and treatment application see Dart *et al.* (2000).

Results and Discussion
The effect of dropping juice amino-N with successive ratoons is clearly visible (Figure 1). This trial suffered from a large soil variation between replicates (Figure 2). This has resulted in much variation in the juice amino-N values for each treatment. There is a rapid drop in the 0 N treatment and gradual reduction in the 80 N treatment. This reduction in the 80 N treatment could be beginning to be N limiting in the 4th ratoon crop. This shows the need for careful monitoring of the crops N status showing the progressive power of the juice N data to the grower.

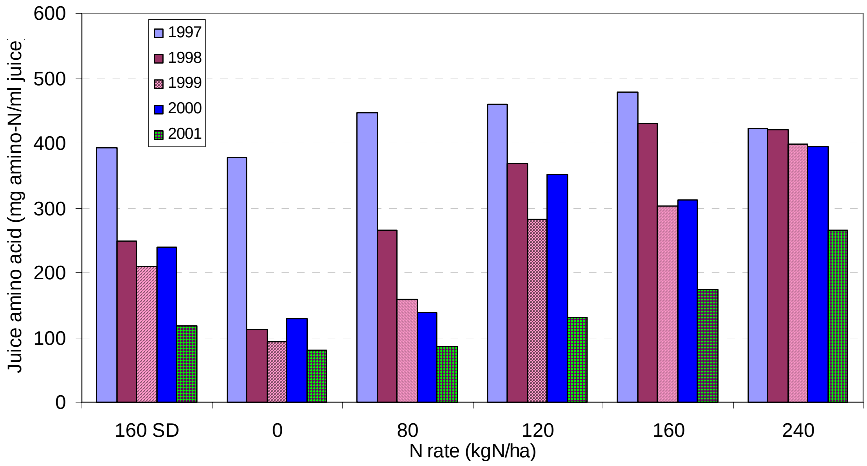


Figure 1 Juice amino-N for all harvests, juice extraction by 'Jeffco/Carver' from hand-sampled plots.

Figure 3 shows the comparison of juice amino-N (Figure 3A) and stem %N (Figure 3B). While stem %N shows a similar response to increasing N supply, there is not the same drop in N concentration with successive ratoon crops. This suggests that while stem %N may be a good substitute for juice amino-N, if on-line monitoring is not possible, the sensitivity of the technique is possibly reduced.

References

Dart, I.K., Bailie, C.P. and Thorburn, P.J. 2000 Assessing nitrogen application rates for subsurface trickle irrigated cane at Bundaberg. Proc. Aust. Sugar Cane Technol. 22, 230-235.

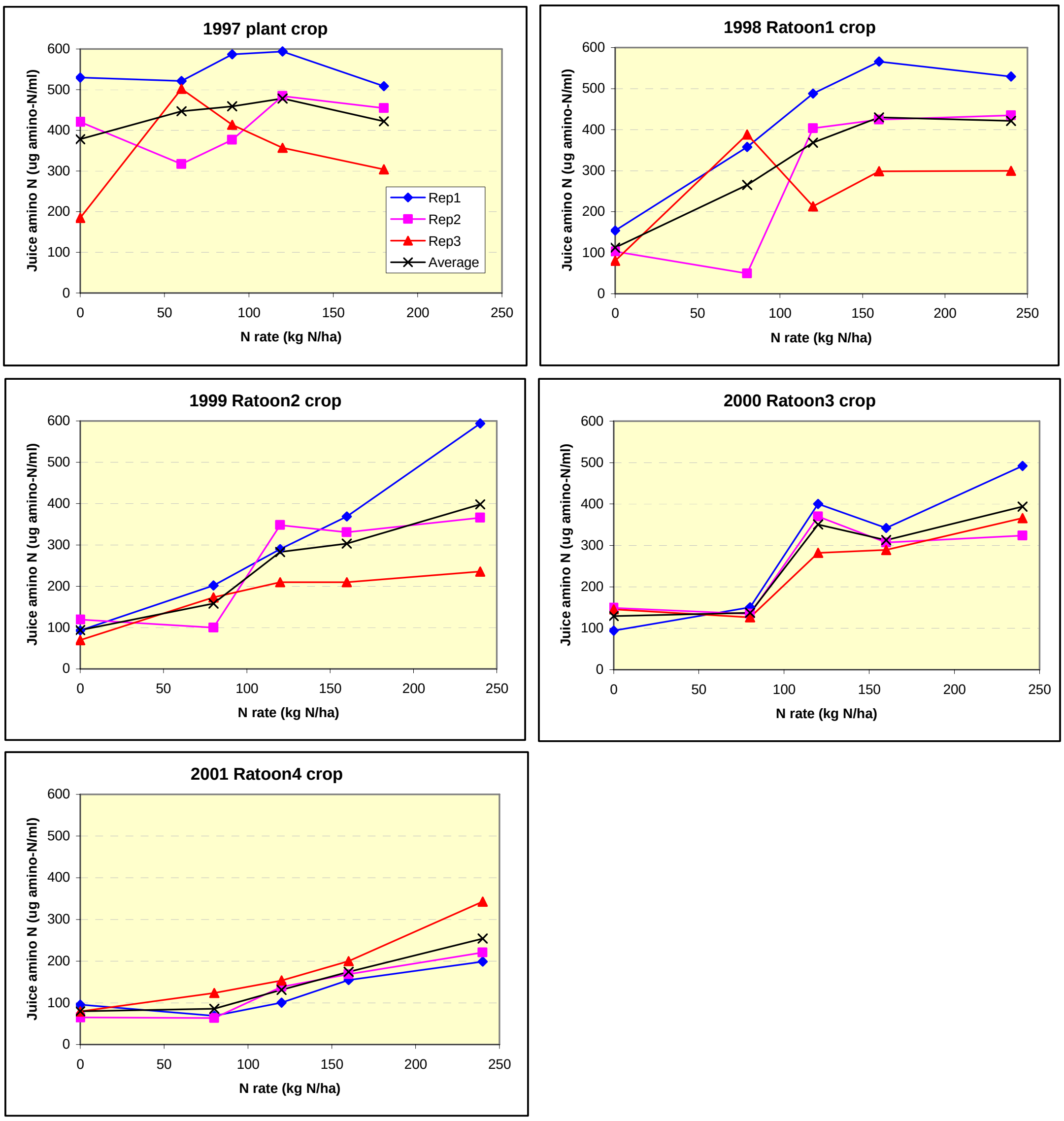
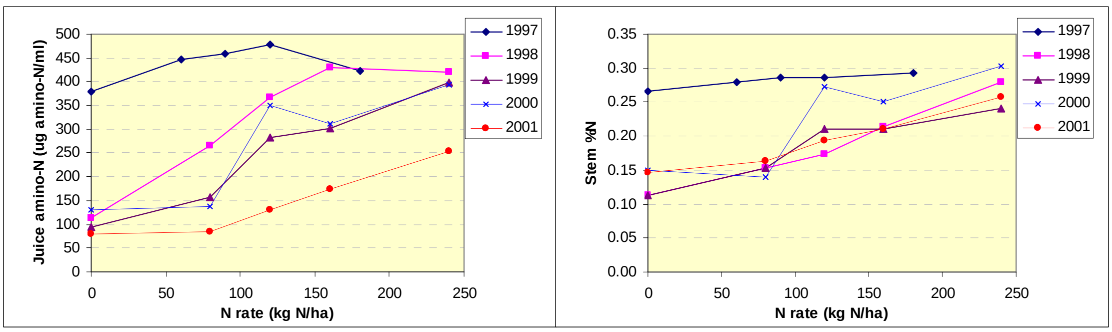


Figure 2 Juice amino-N for each harvest, plotted against the N rate treatment. For each harvest the juice amino-N for each replicate and the overall trial average for each treatment is shown.



A **B**

Figure 3 Juice amino-N (A) and Stem %N (B) for the crops from the Fairymead N rate trial.

Appendix 5. Variety x N rate x harvest schedule trial

Title:	Variety x nitrogen x harvest time trial
Principal researcher:	Allan Rattey (BSES)
Year:	2001
Publication:	Unpublished

Introduction

Trial objectives to be met by assessing a fully irrigated trial in the Burdekin sampled periodically for CCS through plant, 1st, and 2nd ratoon crops, with total cane yield determined at harvest only. Crop age objectives will be investigated in ratoon crops only.

1. Identify if significant interaction between variety and harvest time for period April to September. To be tested by two harvest schedules; one April/June and second June/September.
2. Test for significant interaction between Variety x N for April to September period.
3. Assess if N x Harvest time, and Harvest time x Crop age interactions play a role in increasing profitability and sugar yield, especially early in season.
4. Determine interactions of Variety x N x Harvest time compared with main effects of Variety, N, Harvest time, Variety x Harvest time and Variety x N.
5. Develop recommendations to increase profitability by strategically altering management procedures (N, Crop age, and/or Harvest time) to better suit varieties and optimize interactions.
6. Assess APSIM to accurately predict CCS

Trial planted (30th April 1999) with 15 varieties, three N treatments, two harvest schedules and three replicates per schedule. Early harvest, schedule one, will be CCS sampling from April to harvest in mid June. Harvest schedule two will involve CCS sampling every two months from April through to harvest in September.

Methods

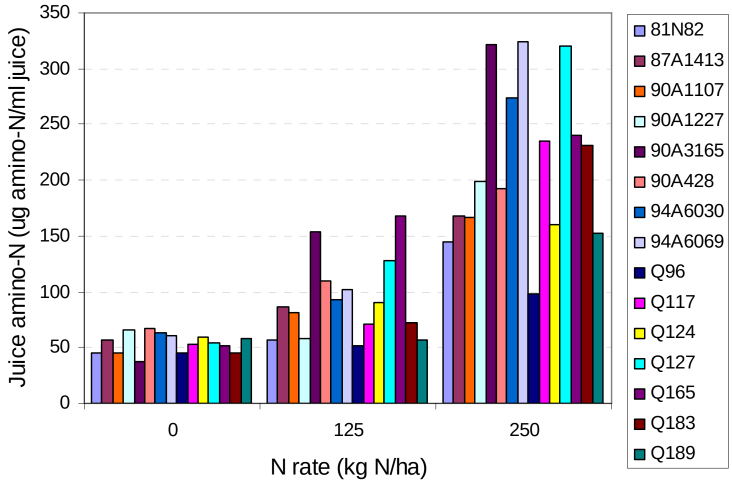
Juice was extracted using a 'Jeffco/Carver' type method. Frozen juice samples were sent to Brisbane for filtering and ninhydrin analysis.

Results and Discussion

- The higher N rate leads to higher juice amino-N for all varieties and all sampling times.
- Varieties do show different time scale characteristics in amino-N, especially for the 280 kg N ha^{-1} treatment, see Q127 compared to Q117.
- Ratoon crop show different time scale profiles to plant crop for most varieties.
- In some varieties see an increase in juice amino-N toward the end of the season. Possibly reflects a change in plant growth due to changes weather.
- The differences in cane yield at harvest between N rates and varieties not as evident as for juice amino-N.

- Amino-N by relative sugar yield show 150 µg amino-N/ml as an inflection point.
- The 125 kgN/ha treatment is a change point, having juice amino-N values similar to the 0 kg N ha^{-1} treatment but yields similar to the 280 treatment.

(a)



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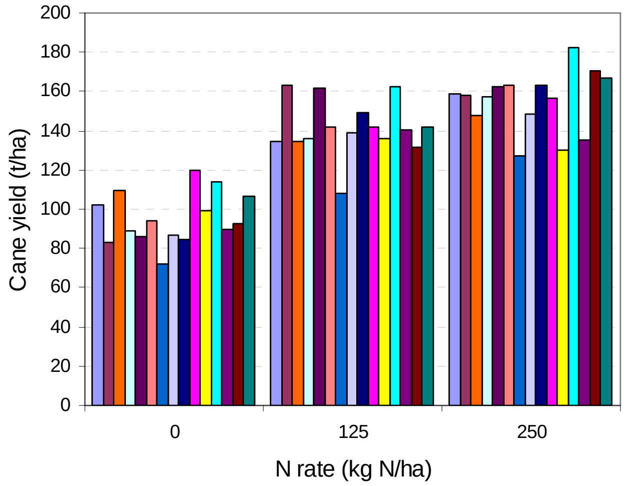

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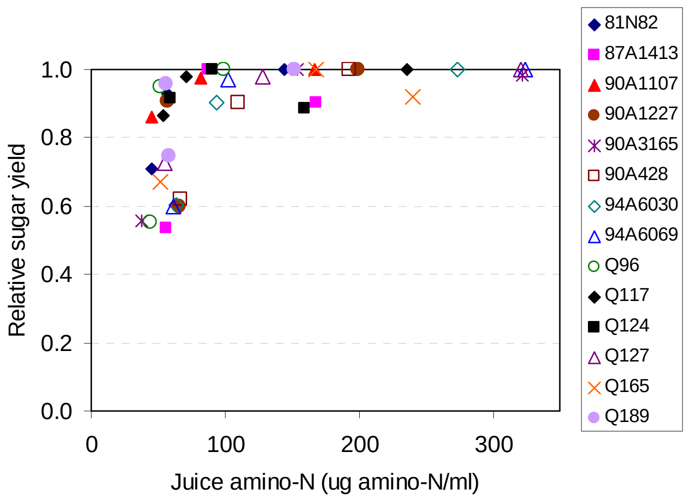


Figure 1. Results from the final harvest (July. '00) from the plant crop for 15 cultivars or breeding lines in Expt 1 of the Alan Ratty trial in the Burdekin (a) Juice amino-N against N rate (b) Cane yield against N rate (c) Relative sugar yield (for N rate within a variety) against juice amino-N.

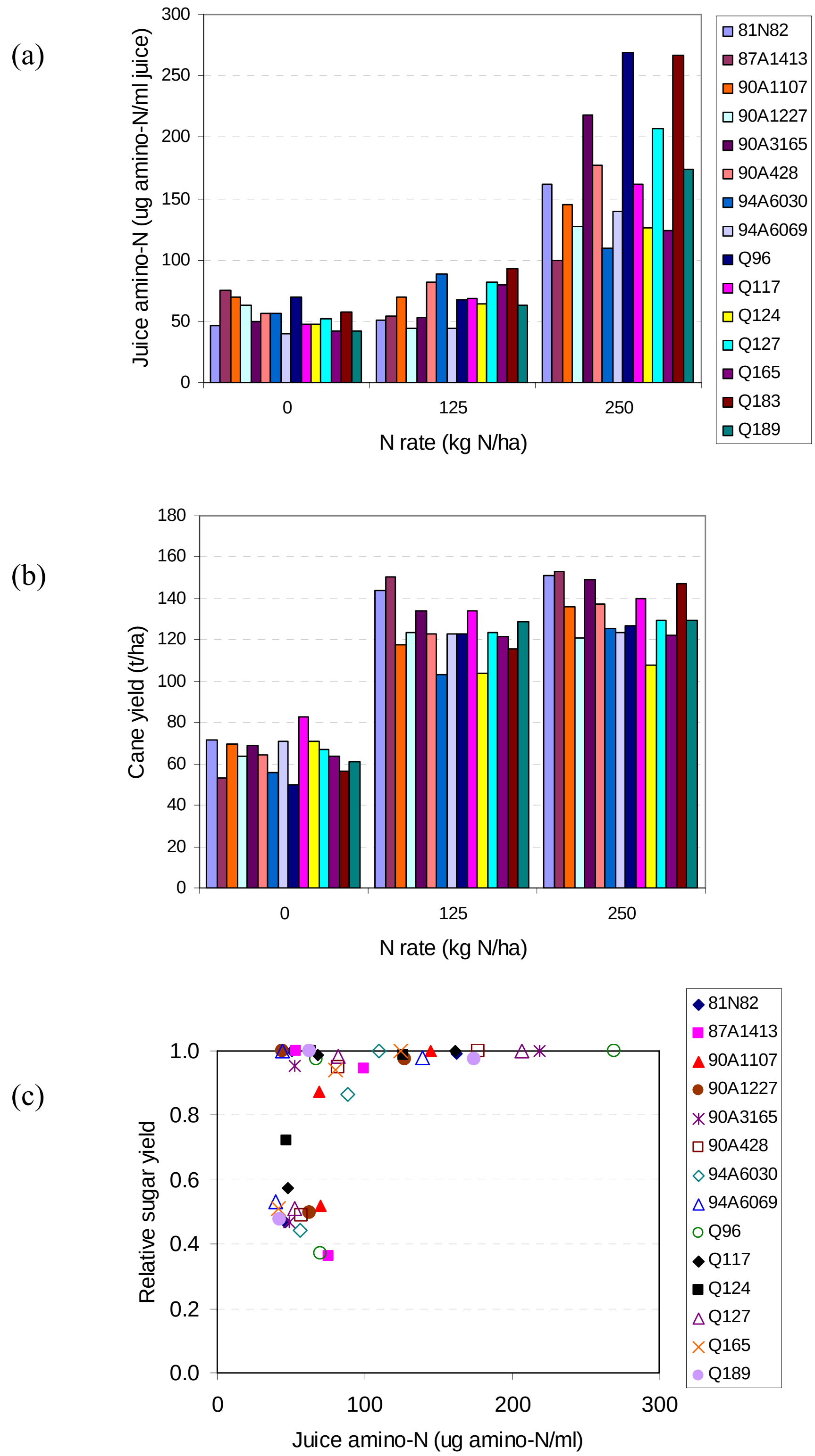
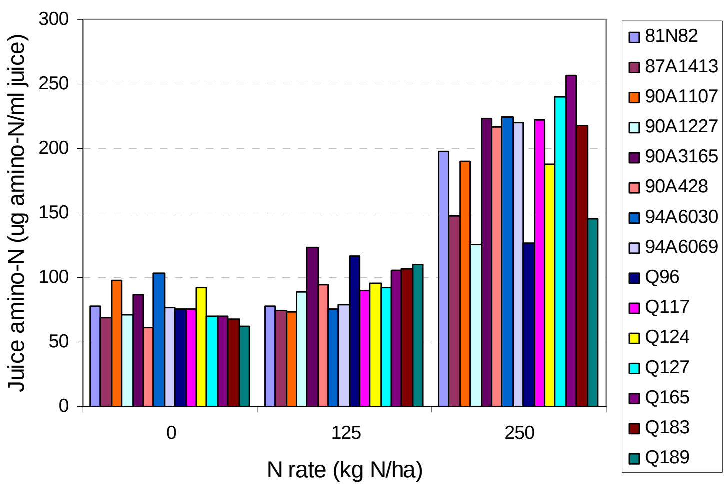


Figure 2. Results from the final harvest (July. '01) from the 1st ratoon crop for 15 cultivars or breeding lines in Expt 1 of the Alan Ratty trial in the Burdekin (a) Juice amino-N against N rate (b) Cane yield against N rate (c) Relative sugar yield (for N rate within a variety) against juice amino-N.

(a)



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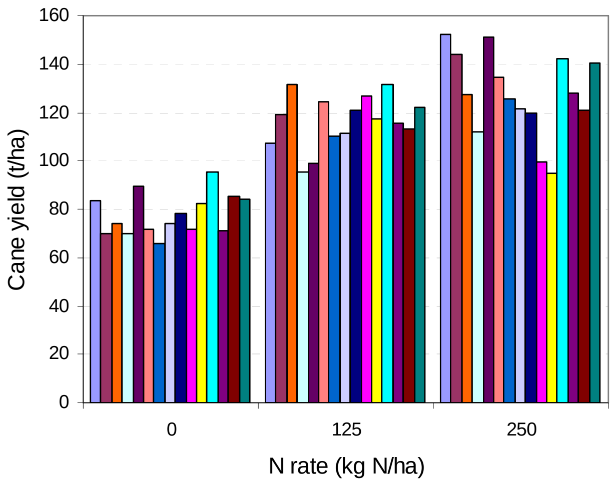

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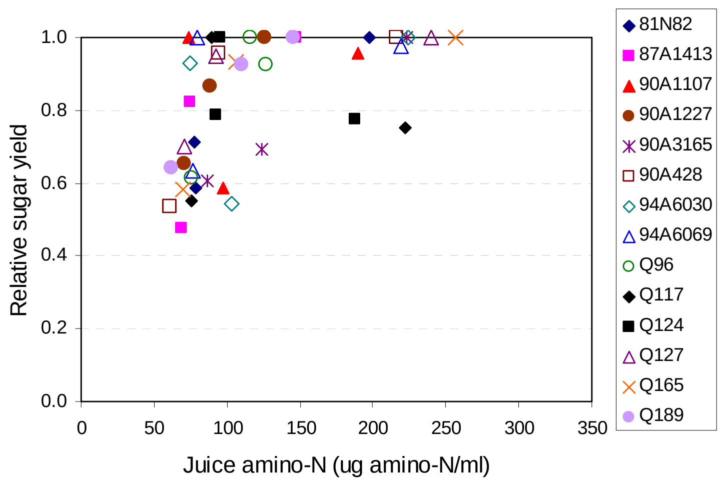

Figure 3. Results from the final harvest (Sept. '00) from the plant crop for 15 cultivars or breeding lines in Expt 2 of the Alan Ratty trial in the Burdekin (a) Juice amino-N against N rate (b) Cane yield against N rate (c) Relative sugar yield (for N rate within a variety) against juice amino-N.

(a)

(b)

(c)

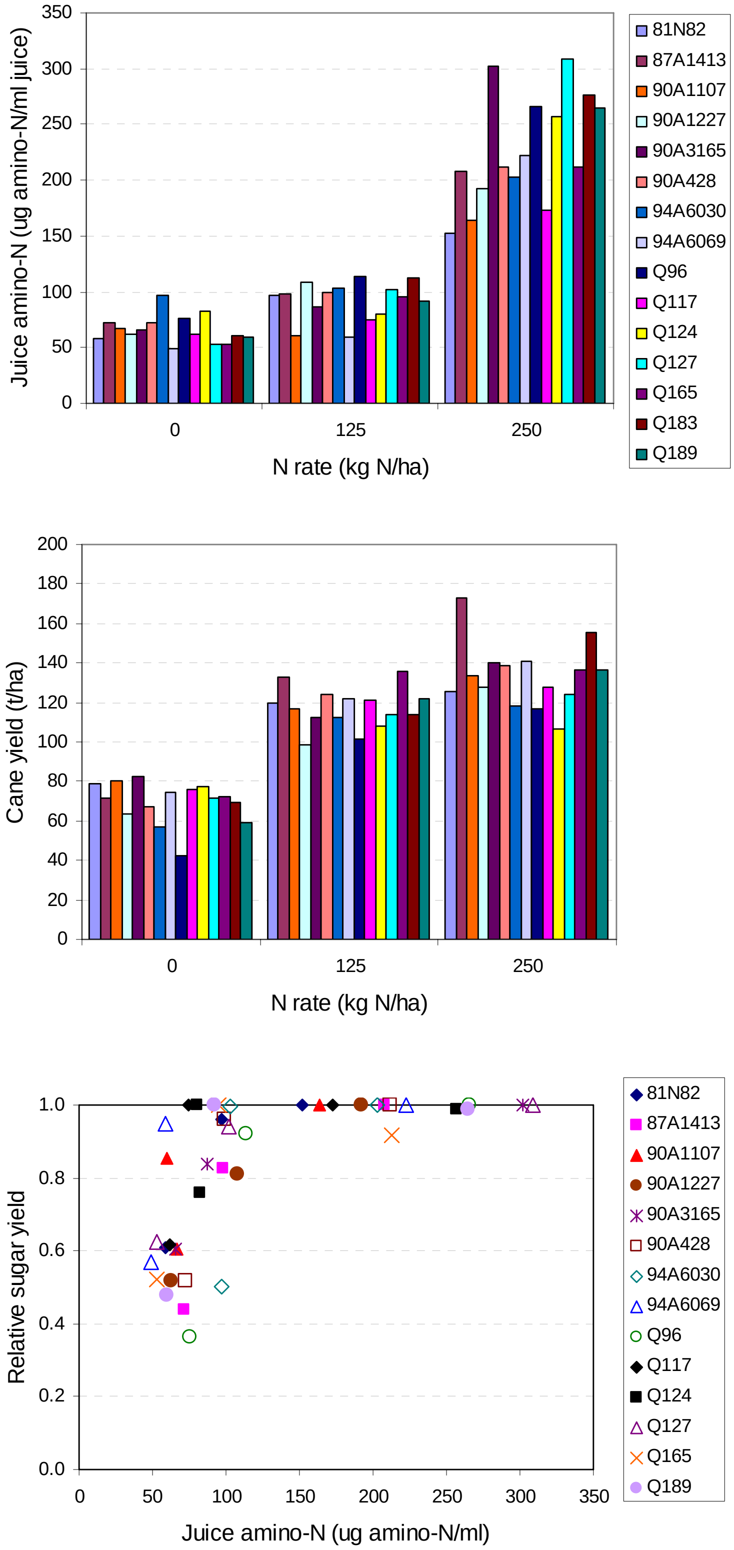

Figure 4. Results from the final harvest (September '01) from the 1st ratoon crop for 15 cultivars or breeding lines in Expt 2 of the Alan Ratty trial in the Burdekin (a) Juice amino-N against N rate (b) Cane yield against N rate (c) Relative sugar yield (for N rate within a variety) against juice amino-N.

Appendix 6. Bundaberg irrigation x variety trial (Ross Ridge)

Title: Irrigation trial, Bundaberg region
Principal researcher: Ross Ridge,
Year:
Publication: Ridge, R and Hillyard, J 2000 Varietal response to irrigation amount and method in the Bundaberg area. ASSCT 22, 256-263.

Introduction

Methods
For experimental design see Ridge & Hillyard (2000).

Results and Discussion
There is a general trend of higher juice amino-N in the lower irrigation treatments but this effect appears to be variety dependent. The effect also appears to disappear in higher irrigation treatments.

- There is a strong yield depression with lower irrigation application. This may cause a greater concentration of juice amino-N due to the lower biomass but this effect cannot explain the lack of difference in the 2.4 Ml treatment.
- There is no difference in leaf %N.
- There is a variety difference evident. This is not evident in either yield or leaf %N. A variety difference is evident in CCS at low irrigation applications but largely disappears at higher irrigation treatments.

(a)
(b)
(c)
(d)

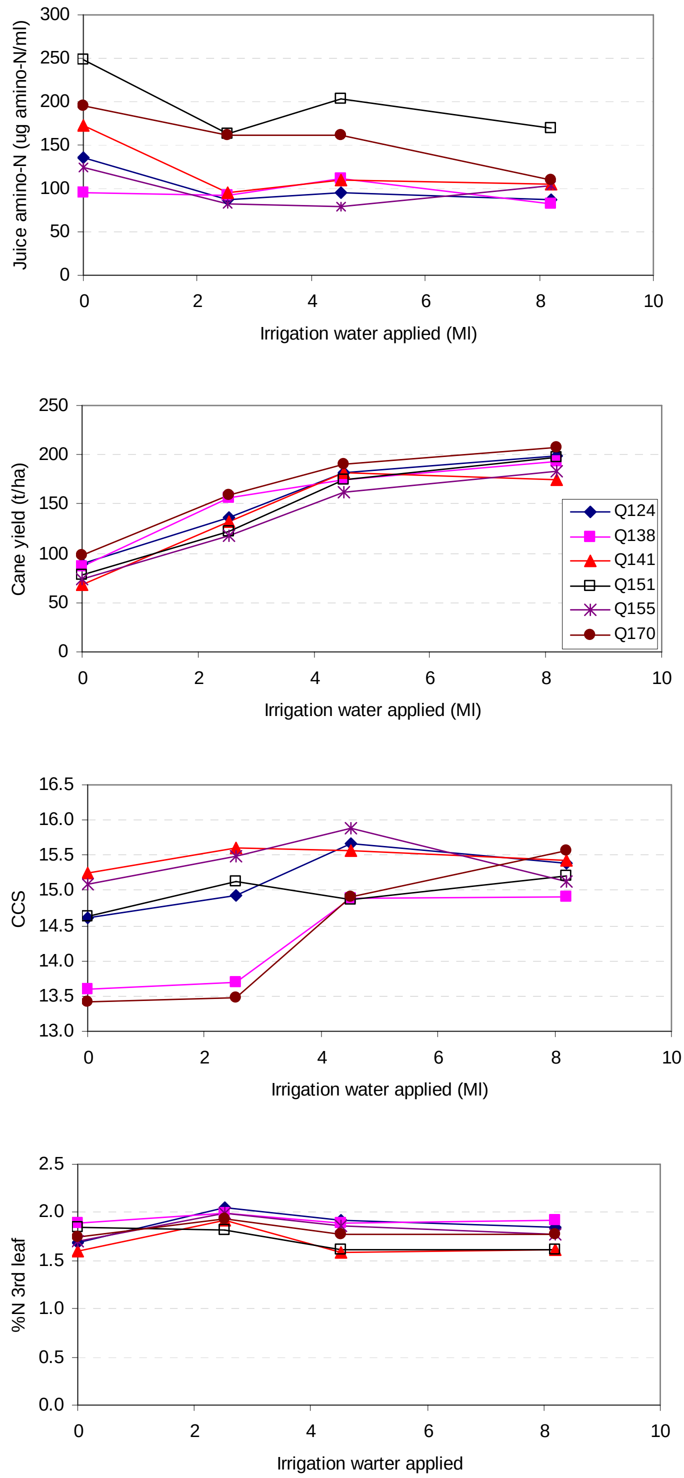

Figure 1 Influence of water stress on sugarcane parameters including juice amino-N concentration (a), cane yield (b), CCS (c), and 3rd leaf %N (d). Data from Ross Ridge irrigation trial (Ridge & Hillyard 2000).

Appendix 7. Macknade variety x N rate trial

Title:	Variety X nitrogen trial
Principal researcher:	Andrew Wood
Year:	2001
Publication:	Unpublished

Introduction

Methods

Results and Discussion

- No amino-N response with N rate or variety
- All amino-N values low, <100 µg amino-N ml^{-1} juice
- Significant (α=0.05) yield response, which is variety specific.
- Sugarcane appears to be utilising all available N with no storage pools. Except Nco310 which may have some N limitation

(a)

(b)

(c)

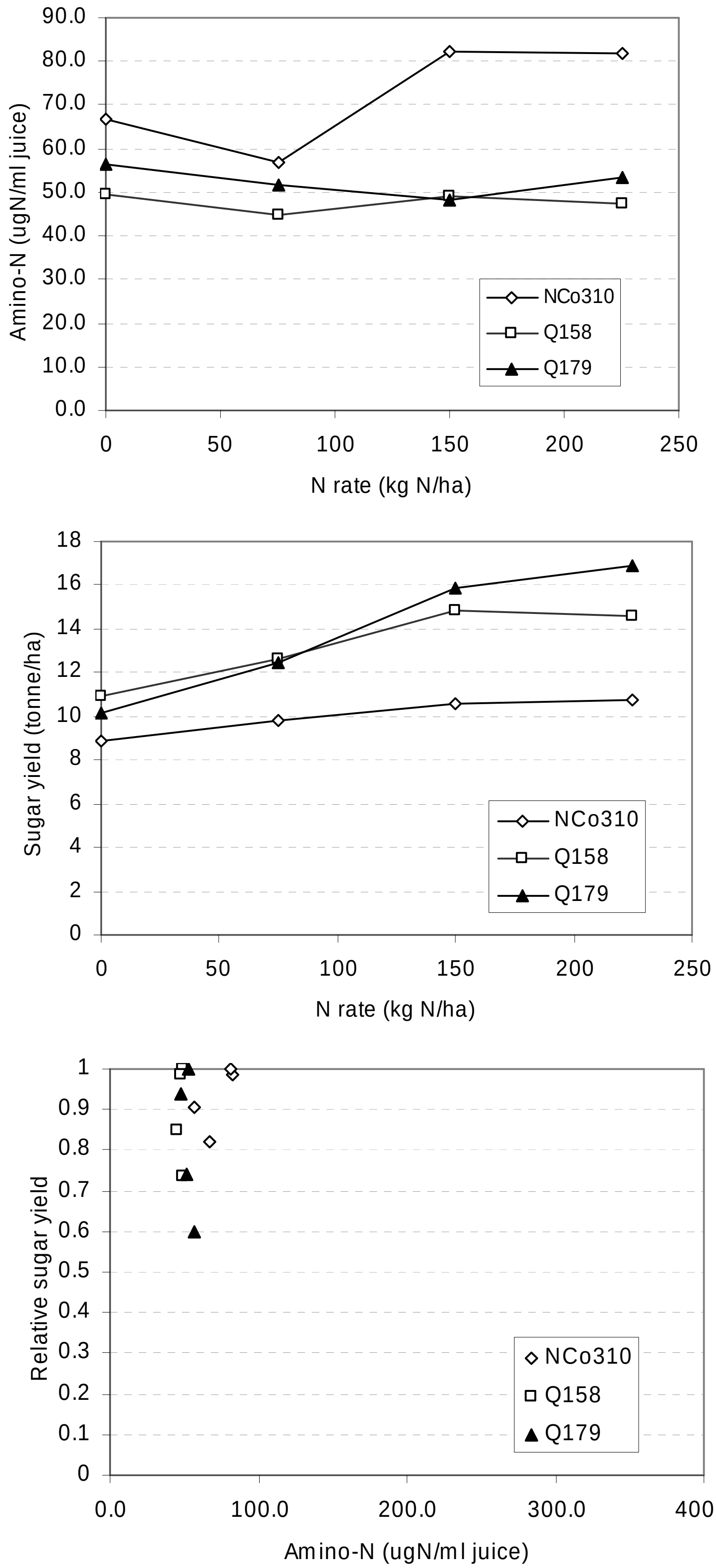

Figure 1. Results from the variety x N rate trial at Macknade in 2000/01. (a) Amino N vs N rate, (b) Cane yield vs N rate, (c) relative sugar yield vs amino-N.

Appendix 8. Bundaberg on-farm N rate trial

Appendix 8.1 : Report on on-farm trials to evaluate "Amino-N monitoring in cane supply at the mill" conducted in the 1998/1999 season in the Bundaberg district.

Prepared by BA Keating as part of the SRDC Project CTA029 : "Monitoring cane at the mill to improve nitrogen management on farm" with assistance of the project team.

Project team members

CSIRO : Brian Keating, Ian Biggs, Keith Smith, Russell Muchow
BSES : Graham Kingston, Julian Collins, Jim Sullivan, Ann Doak, Greg Shannon
Bundaberg Sugar : Mike Smith
CSR : Andrew Wood

Background

Nitrogen management in sugarcane has been problematical because growers have had little means of assessing their N management practices. The risks of inadequate N supply (in terms of reduced cane yields) are perceived to be high, and at least when sugar prices are good, the relative costs of N fertilisers are considered small in comparison to the value of the crop. There has been some evidence that growers have tended to over supply nitrogen fertiliser and pay inadequate attention to other sources of N supply such as N residues from prior small crops, N supplied from mill muds or N accumulated in the soil profile over fallow periods.

This research project aims to provide growers with a way of monitoring the adequacy of the N supply their crops are experiencing. Earlier work has shown that the nitrogen found in cane stems at harvest time is sensitive to the N supply the crop has experienced (see Keating et al 1999). In particular, the amino-N levels in stems or juice have proved to be a reasonably sensitive indicator of N supply. The monitoring technique appears particularly promising in identifying cane blocks that are exhibiting excessive levels of N supply (Figure 1). While cane that is deficient in N (leading to reduced yields) will exhibit low amino-N levels in stems or juice, the project team do not consider that the amino-N test will uniquely identify N deficiency, a rare condition in any case in the sugar industry. The strength of the approach will not be in the precision of estimation and interpretation of stem/juice amino-N levels, but in the "universal sampling" opportunity afforded by a test on the harvested cane at the mill. By monitoring amino-N levels in cane supply from all blocks on a farm, a grower will be able to develop a picture of block to block variation in N supply. Over time, with knowledge of variation in soils and management history on their farm, a grower should be able to use the amino-N information to "fine tune" their N management practices.

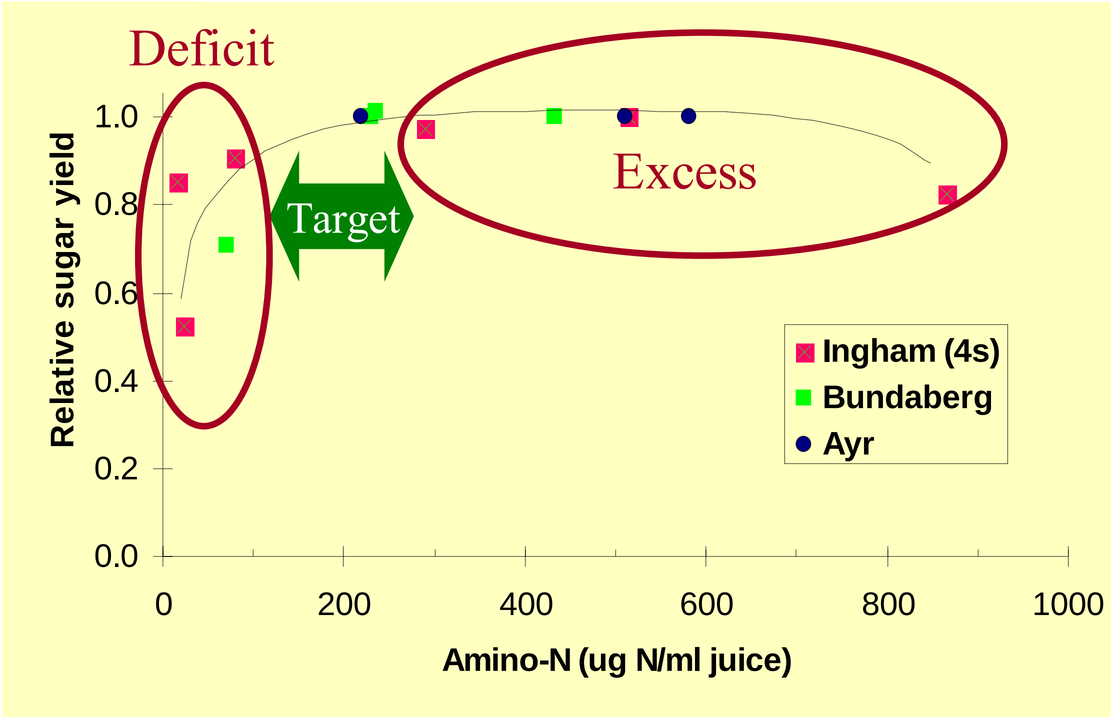

Figure 1. Sugar yield in relation to amino-N in cane juice (from Keating et al 1999). Lines indicate an idealised diagnostic response and a provisional "target" region is identified as 100 to 250 ug N/ml juice.

The trials reported here were aimed at exploring how the amino-N information might be used by growers. We have used the "strip trial" approach to focus these investigations. Taking the growers current practice as the "standard treatment", we have asked the question "what would happen to cane yields and CCS if N rates were 20% higher or lower?" We have asked this question with the growers in the context of the additional information provided by the amino-N monitoring technique. Specifically, what would we conclude based on the amino-N levels in cane grown under the grower's standard practice ? What does the amino-N test tell us about N supply in the plus or minus 20% N rate treatments ? Overall, can we interpret why growers are getting the responses or lack of responses we observe and how does the amino-N test help in this interpretation ?

General Methods

N rate trials were established in the Bundaberg district over the 1998/99 season. Two trials were set up in each of the Bingera, Millaquin and Fairymead mill districts. One trial in each mill district was on a plant crop and the other on a first ratoon crop. Three N rates were investigated, based around the growers "standard" practice (T2) together with a reduction of approximately 20% (T1) and an increase of approximately 20% (T3). Other fertilisation practices were based on growers' standard practices, and in all cases trials received what amounts to standard industry rates of K, P and S.

The plots were large, typically based on 6 to 16 rows, 200 to 300 m long. A number of trials were formally replicated based on randomised complete block designs (Table 1) while others did not contain formal replication in the field, but had multiple sampling take place within a treatment. Hand cut samples (based on 9 stalks per plot) were cut prior to machine harvesting. These samples were processed via a Jeffco cutter/grinder and juice extraction in a Carver Press. Machine harvests were consigned to the mill as separate rakes for replications and treatments and yields and CCS obtained from mill data. Juice samples (first expressed juice after No. 1 mill) were collected for all samples at the mill and frozen immediately for subsequent amino-N analysis (using standard methods outlines by Keating et al 1999).

Other details of the trials are provided in Table 1.

Soil was sampled from all trial sites at the start of the experiment to a depth of 1.8m. Three positions in each block were sampled, each sample being made up of 3 bulked cores. Samples were extracted (fresh) with KCl and mineral nitrogen (NO3 and NH4) determined using standard colorimetric methods (Catchpoole and Keating 1995). Total N and total C were determined on dried samples via mass spectroscopy. While the aim was to sample initial conditions prior to fertiliser application, this was not always possible and in the case of the 3 plant crops (Spyrou, Borg and Penningh farms), a small planting dose of nitrogen (18, 46 and 47 kgN/ha respectively) was applied prior to sampling. This fertiliser addition will be considered in interpretation of the soil sampling results.

Table 1. Experimental details for N strip trials conducted in Bundaberg over the 1998/99 season.

Farm	Mill+	Soil type	Crop class	Variety	Low N rate (kgN/ha)	"Standard" N rate (kgN/ha)	High N rate (kgN/ha)	Reps	Soil sampling date	Side dress date	Mill harvest date
Borg #22699	MQN	Yellow podzolic	Plant (10/98)	Q151	101	138	204	3	14/10/98	20/11/98	20/08/99
Dingle #3172	FMD	Gleyed podzolic	1R (06/98)	Q151	123	161	207	*	10/98	30/10/98	22/06/99
Greensil #25056	MQN	Kraznozem	1R (10/98)	Q124	80	120	160	3	13/10/98	27/11/98	12/11/99
Jensen #10268	BIN	Red podzolic	1R	Q124	126	170	210	*	03/11/98	06/11/98	05/09/99
Penningh #10057	BIN		Spring Plant	Q124	81	122	159	*	04/11/98	07/11/98	01/09/99
Spyrou #537	FMD	Red earth	Ploughout (07/98) replant (10/98)	Q141	106	157	210	*	03/11/98	11/98 14/12/98	16/10/99

* No formal replication, 3 internal samples taken for yield and amino-N estimates.
+ MQN = Millaquin, FMD = Fairymead, BIN= Bingera

Farm specific methods and results

Farm: Borg

Crop performance/N response

Yields varied non-significantly from 107 to 117 tonnes/ha in response to variation in N rates from 100 to 204 kgN/ha (Figure 2a). CCS also varied non-significantly from 13.1 to 13.4 (Figure 2b), and corresponding sugar yields ranged from 14.0 to 15.6 tonnes/ha (Figure 2c). Amino-N levels were high (339 ugN/ml juice) under the grower's standard practice (Figure 2d), dropping slightly at the –20% N rate and rising significantly under the +20% N rate.

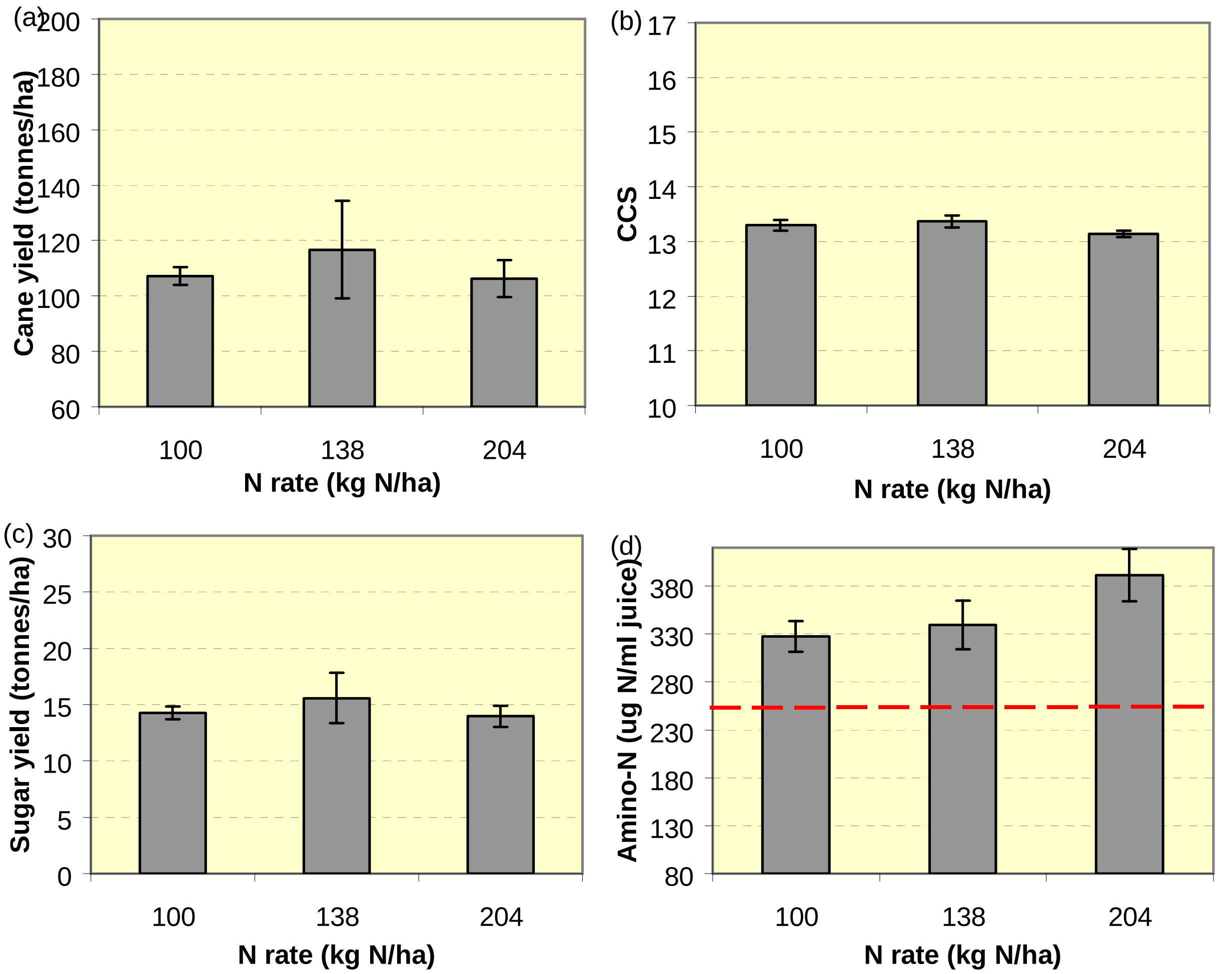

Figure 2. Results from the N strip trial at the farm of J Borg in the 1998/99 season. (a) Fresh cane yield (tonnes/ha), (b) CCS, (c) Sugar yield (tonnes/ha), (d) Amino-N (ugN/ml juice) (amino-N levels above dashed line are indicative of excess N supply)

Initial soil conditions

The profile contained on average 262 kg mineral-N (dominantly in the nitrate from) at the time of soil sampling (Figure 3a). On this farm, this sampling took place after an initial plant fertilisation application of 46 kgN/ha had taken place (still evident as a bulge in the 0-30 cm layers). In terms of organic N sources, this soil had relatively low total N and C levels, and moderately high C:N ratios (Figure 3b, c, and d).

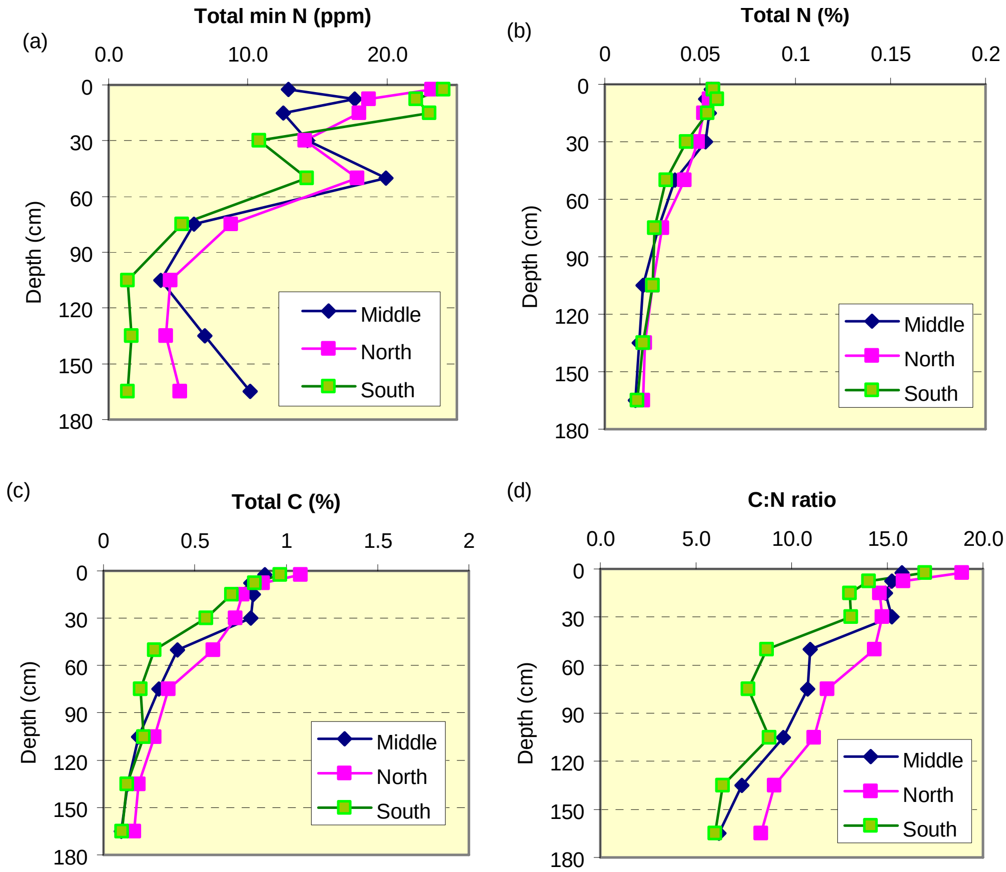

Figure 2. Initial soil nitrogen status in block used for N strip trial on the farm of J Borg. Soil sampled in Oct 1998. (a) total mineral N (ppm), (b) total N %, (c) total carbon %, (d) C:N ratio.

Interpretation

Varying N rates from 100 to 204 kgN/ha had no significant effect on yields in this plant crop. The high levels of mineral N in the profile at planting (in excess of 200 kgN/ha after allowance for the N applied at planting) explains why crop performance was insensitive to N fertiliser rate on this occasion.

The amino-N levels under the grower's standard fertiliser practice were high (> 300 ugN/ml juice). The preliminary interpretation of the amino-N information would have been that there was evidence of excess N supply and in similar situations in future years, a reduction in N rate could be considered. The lack of a significant yield response when N fertiliser rate was reduced by 20% indicates that the amino-N information was a useful indicator of crop N status. Amino-N level in cane juice was further raised in response to the +20% N fertiliser treatment, providing evidence that this crop was over-supplied with N.

Farm : Dingle

Crop performance/N response

Yields varied non-significantly from 86 to 90 tonnes/ha in response to variation in N rates from 123 to 207 kgN/ha (Figure 4a). CCS also varied non-significantly from 13.6 to 13.3 (Figure 4b), and corresponding sugar yields ranged from 11.7 to 12.0 tonnes/ha (Figure 4c). Amino-N levels were moderate (201 ugN/ml juice) under the grower's standard practice (Figure 4d), dropping somewhat at the –20% N rate and rising significantly (>300 ugN/ml juice) under the +20% N rate.

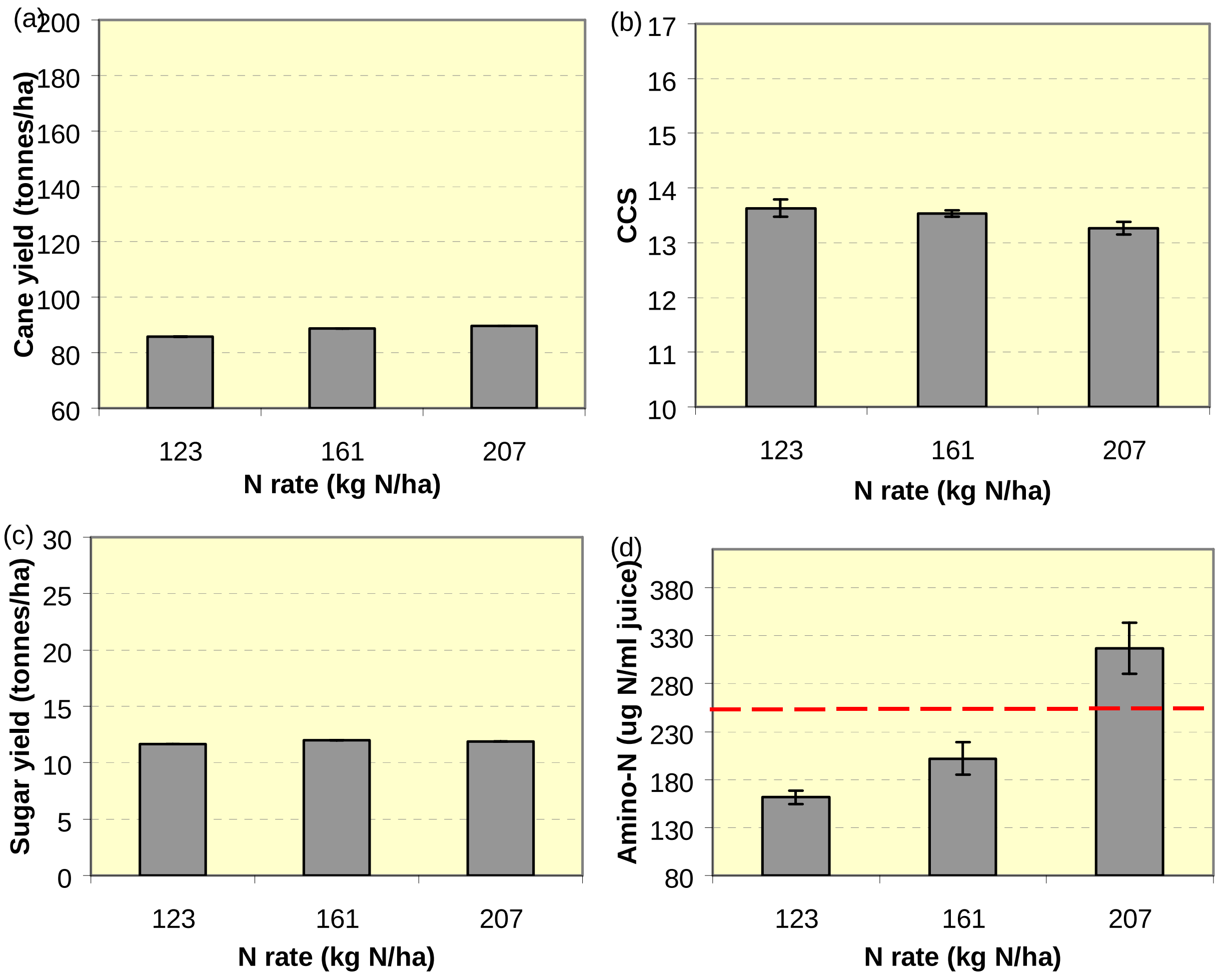

Figure 4. Results from the N strip trial at the farm of Dingle in the 1998/99 season. (a) Fresh cane yield (tonnes/ha), (b) CCS, (c) Sugar yield (tonnes/ha), (d) Amino-N (ugN/ml juice). (amino-N levels above dashed line are indicative of excess N supply)

Initial soil conditions

The profile contained on average 19 kg mineral-N (dominantly in the ammonium form) at the time of soil sampling (Figure 5a). In terms of organic N sources, this soil had moderate to high total N and C levels, and moderately high C:N ratios (Figure 5b, c, and d).

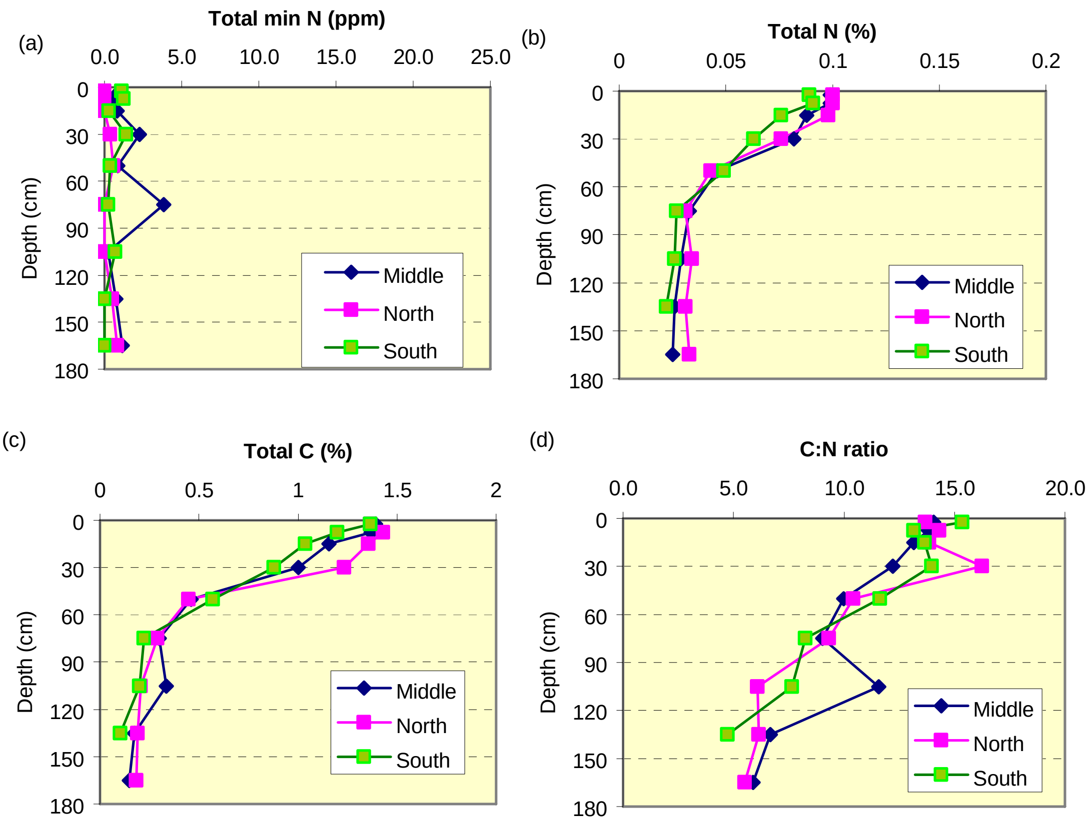

Figure 5. Initial soil nitrogen status in block used for N strip trial on the farm of Dingle. Soil sampled in Oct 1998. (a) total mineral N (ppm), (b) total N %, (c) total carbon %, (d) C:N ratio.

Interpretation

Varying N rates from 123 to 207 kgN/ha had no significant effect on yields in this first ratoon crop. The levels of mineral N in the profile at ratooning were very low for reasons that are not clear at this stage, although the fact that the land had just grown a plant crop will be part of the reason. Periods of waterlogging in the gleyed podzolic soil may be another contributing factor to the very low nitrate levels observed soon after ratooning. Despite these low mineral N levels, the soil plus fertiliser N supplied was still sufficient to produce N non-limited crop performance at even the lowest N rate used (123 kg N/ha). The yield levels were relatively low (< 90 tonnes cane/ha) and this would have contributed to the lower crop demand for N.

The amino-N levels under the grower's standard fertiliser practice were moderate (201 ugN/ml juice), suggesting the N supply status of this crop was also within the target range. The amino-N levels in cane increased into the excessive range (>300 ugN/ml juice) under the +20% fertiliser treatment, suggesting this was an excessive level of fertiliser input for the yield levels achieved inn these crops. The yield data in relation to N rates support this suggestion. Amino-N levels dropped in the –20% fertiliser treatment, but remained within the target range and was not indicative of N limited cane/sugar yields, something that was also consistent with the yield observations.

Farm : Greensil

Crop performance/N response

Yields varied non-significantly from 172 to 179 tonnes/ha in response to variation in N rates from 80 to 160 kgN/ha (Figure 6a). CCS also varied non-significantly from 14.1 to 14.2 (Figure 6b), and corresponding sugar yields ranged from 24.2 to 25.4 tonnes/ha (Figure 6c). Amino-N levels were low to moderate (106 - 141 ugN/ml juice) for all three N treatments (Figure 6d).

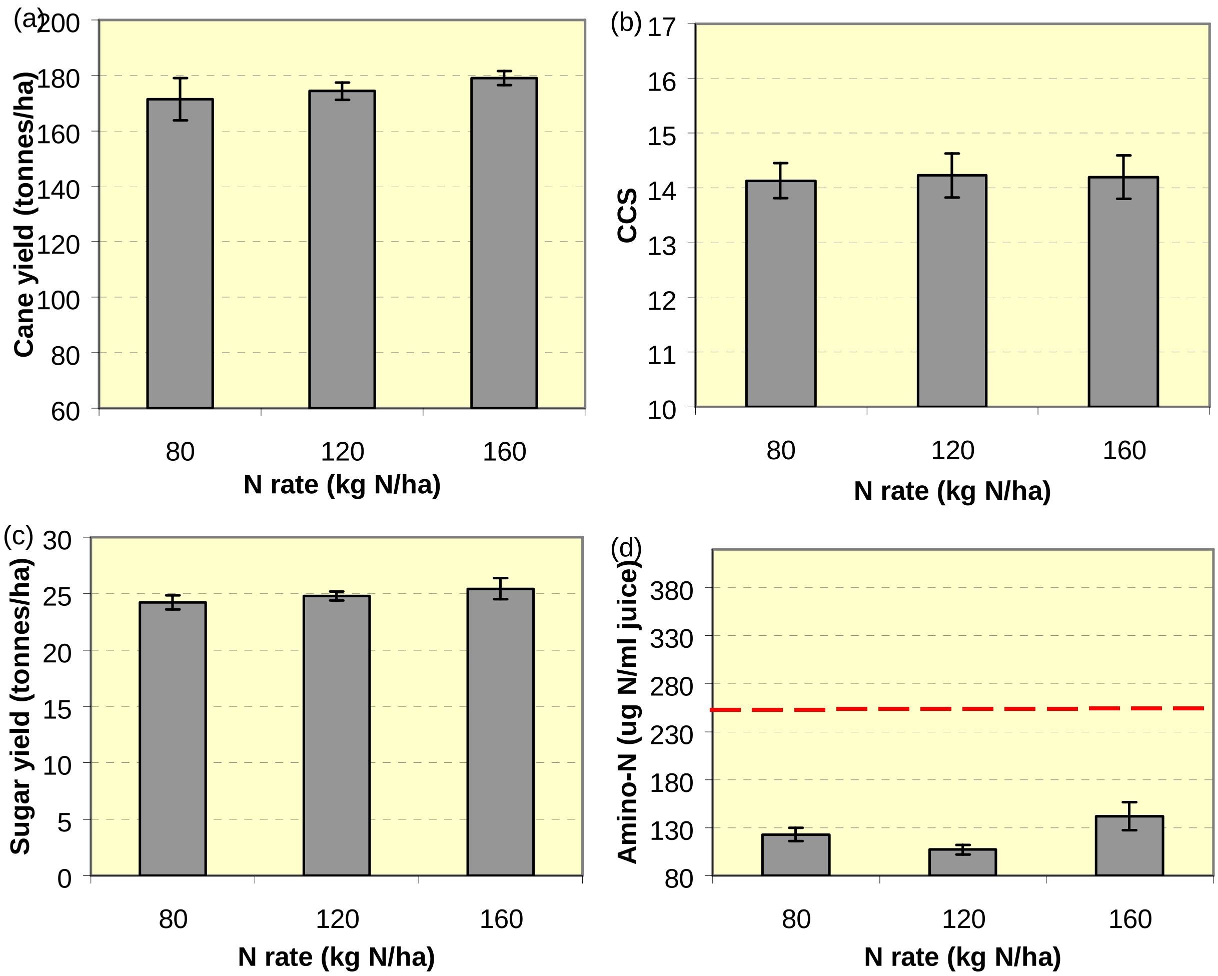

Figure 6. Results from the N strip trial at the farm of Greensil in the 1998/99 season. (a) Fresh cane yield (tonnes/ha), (b) CCS, (c) Sugar yield (tonnes/ha), (d) Amino-N (ugN/ml juice). (amino-N levels above dashed line are indicative of excess N supply)

Initial soil conditions

The profile contained on average 271 kg mineral-N (dominantly in the nitrate form) at the time of soil sampling (Figure 7a). In terms of organic N sources, this soil had the highest total N and C levels, and the lowest C:N ratio of all the sites sampled in these trials. (Figure 7b, c, and d).

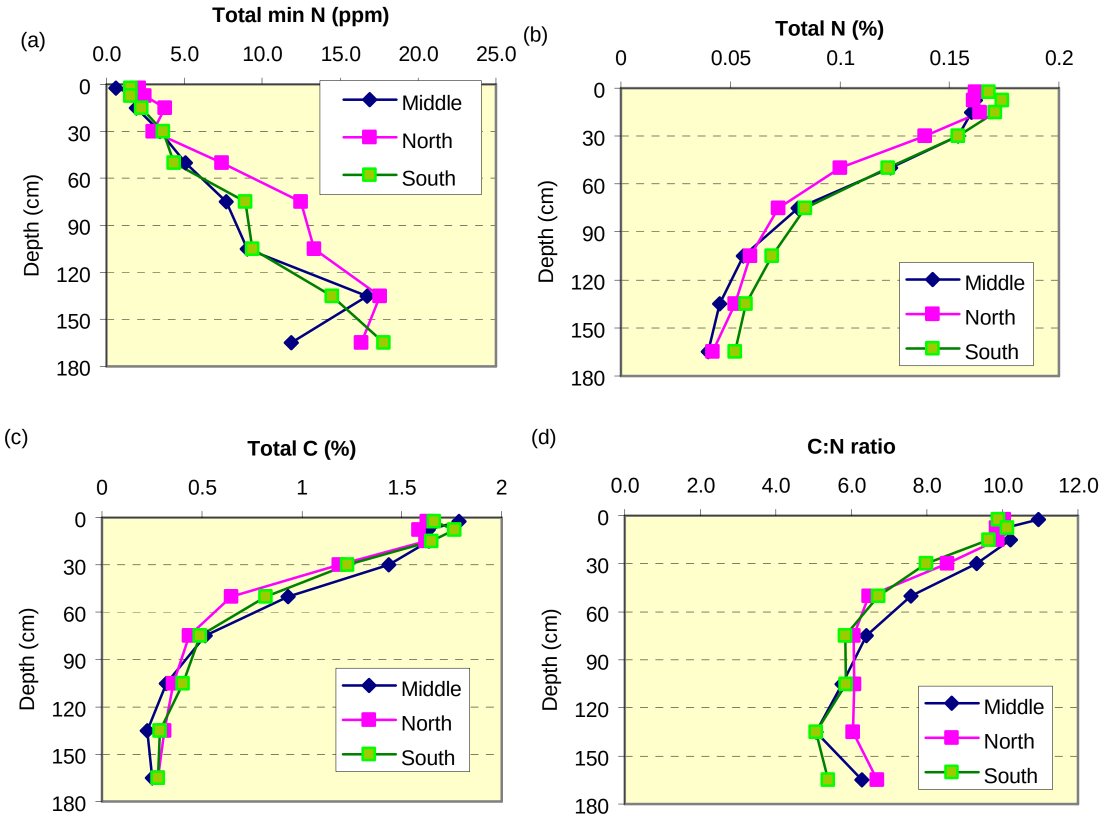

Figure 7. Initial soil nitrogen status in block used for N strip trial on the farm of Greensil. Soil sampled in Oct 1998. (a) total mineral N (ppm), (b) total N %, (c) total carbon %, (d) C:N ratio.

Interpretation

Varying N rates from 80 to 160 kgN/ha had no significant effect on yields in this exceptionally high yielding first ratoon crop. The crop N uptake levels were not measured, but experience elsewhere would suggest could be of the order of 200 to 250 kgN/ha (Muchow et al 1996). The fact that this level of yield was achieved with an N application as low as 80 kgN/ha is testament to the very high levels of mineral N in the profile at ratooning (approximately 270 kgN/ha). Clearly some of this initial soil N (perhaps in the order of half) was used by these crops. Further soil sampling is planned to confirm this. The high level of mineral N in the profile at ratooning suggests an even higher level was likely to have been present at the establishment of the plant crop, because fertiliser N application to the plant crop was modest. These high levels of soil mineral N have been observed before in the Bundaberg district as following small crops, (KLWeier and BA Keating uppubl data), as was also the case on this occasion.

The amino-N levels observed under all N fertiliser rates were in the low to moderate range (106 – 141 ugN/ml juice). These suggest that these well grown crops had adequate levels of N supply. In other words, even though the soil mineral N levels were very high, the moderate fertiliser regime (even at the +20% treatment) and the very large crops grown meant that N supply was well matched to demand. We would expect the crop receiving the –20% N rate to have depleted the soil mineral N reserves and to be more likely to respond to N fertiliser inputs in the current second ratoon crop. This prediction is tempered somewhat by indications of a “rich” soil organic N supply situation, evident in the high total N levels and low C:N ratios.

Farm : Jensen

Crop performance/N response

Yields varied non-significantly from 125 to 131 tonnes/ha in response to variation in N rates from 126 to 210 kgN/ha (Figure 8a). CCS also varied non-significantly from 13.5 to 13.9 (Figure 8b), and corresponding sugar yields ranged from 16.8 to 18.2 tonnes/ha (Figure 8c). Amino-N levels were moderate to high (245 - 270 ugN/ml juice) for all three N treatments (Figure 8d).

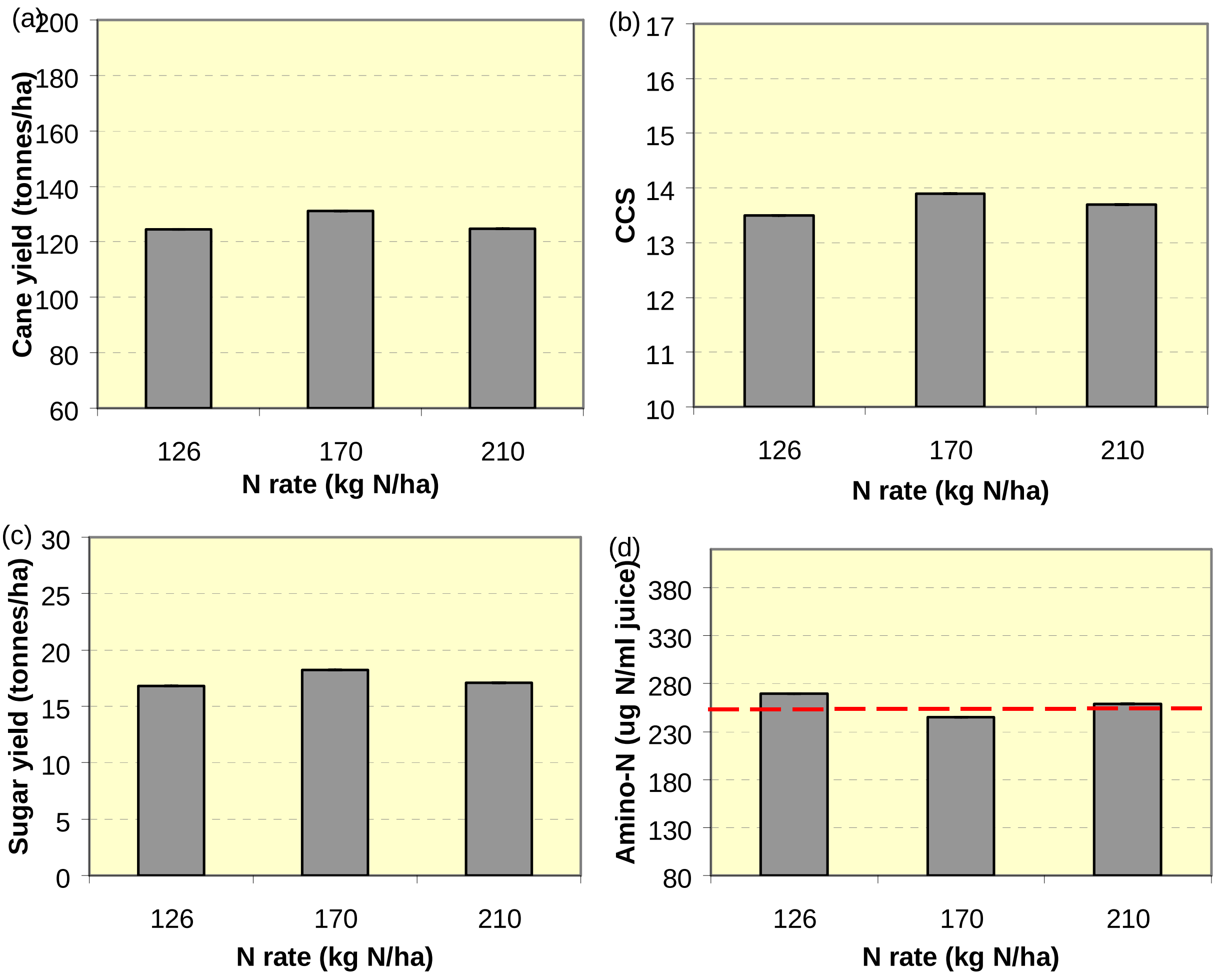

Figure 8. Results from the N strip trial at the farm of Jensen in the 1998/99 season. (a) Fresh cane yield (tonnes/ha), (b) CCS, (c) Sugar yield (tonnes/ha), (d) Amino-N (ugN/ml juice). (amino-N levels above dashed line are indicative of excess N supply)

Initial soil conditions

The profile contained on average 110 kg mineral-N (dominantly in the nitrate form located below 90cm) at the time of soil sampling (Figure 9a). In terms of organic N sources, this soil contained moderate to low total N and C levels, and exhibited a relatively low C:N ratio. (Figure 9b, c, and d).

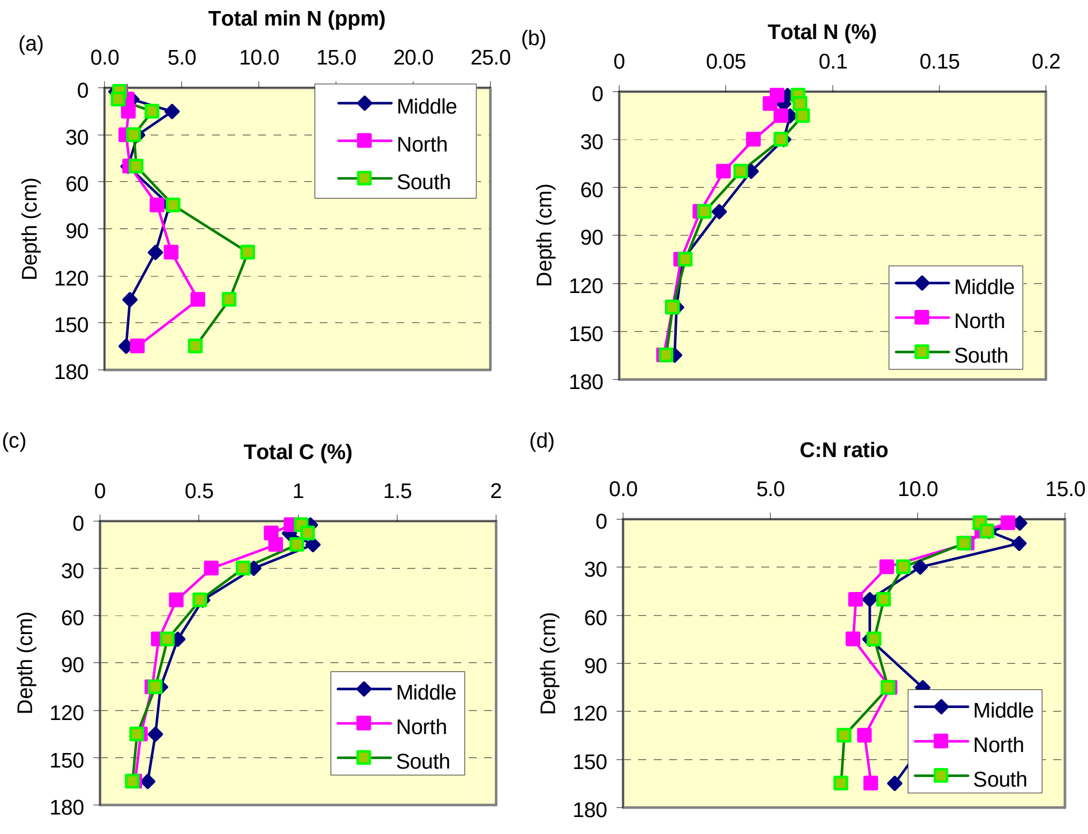

Figure 9. Initial soil nitrogen status in block used for N strip trial on the farm of Jensen. Soil sampled in Oct 1998. (a) total mineral N (ppm), (b) total N %, (c) total carbon %, (d) C:N ratio.

Interpretation

Cane and sugar yields were highest at the grower's standard rate of N fertiliser (170 kg/N ha), although the differences between all N treatments were small and given past experience with within field variability, unlikely to be significant (this trial was unreplicated and hence we cannot determine likely significance of these small yield differences). Yield levels were moderate to good (approx 130 tonnes cane/ha) and the lower fertiliser rate (126 kgN/ha), together with the modest level of N supply from the soil (110 kgN/ha in profile at ratooning plus within crop mineralisation activity) was sufficient to supply crop N needs.

Amino-N levels in cane were moderate to high, something that is consistent with the lack of clear response to altered N rates. The lack of response in amino N to the changed N rates (e.g., as N rates were increased from 126 to 210 kg/ha) was unexpected. Amino-N level measured on hand-cut stalks collected and laboratory processed just prior to the machine harvest and mill processing, did show a 10% increase in amino-N levels at the highest N rate. This effect was still small and not evident in the mill processed samples. It is possible that within field variation in soil N supply was masking the response in amino-N to fertiliser N additions. This unexpected result will be further investigated in the continuation of the trial over the 1999/2000 season.

Farm : Penningh

Crop performance/N response

Yields varied non-significantly from 122.3 to 122.7 tonnes/ha in response to variation in N rates from 81 to 159 kgN/ha (Figure 10a). CCS also varied non-significantly from 14.4 to 14.6 (Figure 10b), and corresponding sugar yields ranged from 17.6 to 17.8 tonnes/ha (Figure 10c). Amino-N levels were moderate at low N rates (180 ugN/ml juice) rising to high (260 ugN/ml juice) at the highest N rate (Figure 10d). (Note at the time of writing, the high level of variability in amino-N in juice of the low N rate is the subject of re-analysis).

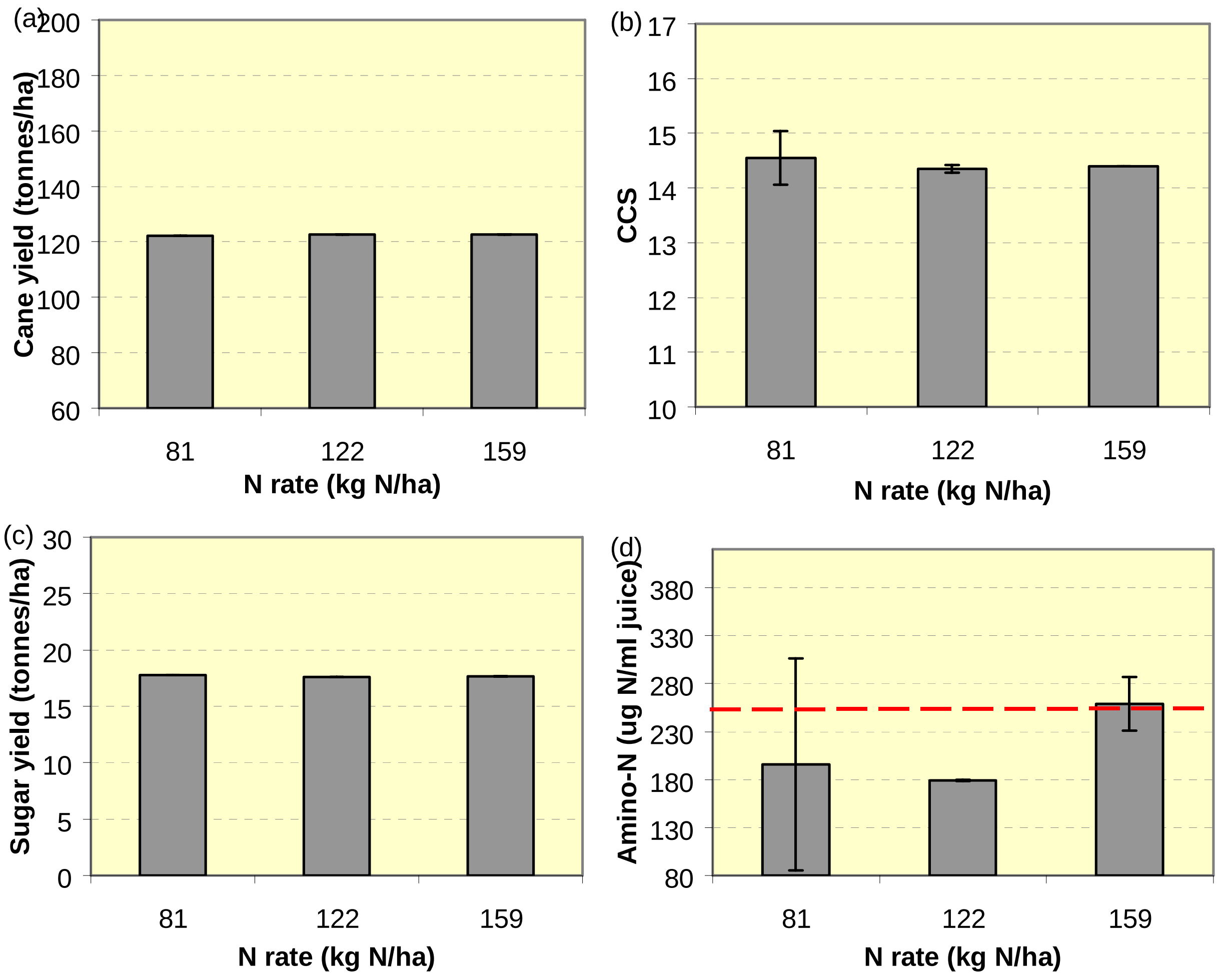

Figure 10. Results from the N strip trial at the farm of Penningh in the 1998/99 season. (a) Fresh cane yield (tonnes/ha), (b) CCS, (c) Sugar yield (tonnes/ha), (d) Amino-N (ugN/ml juice). (amino-N levels above dashed line are indicative of excess N supply)

Initial soil conditions

The profile contained on average 164 kg mineral-N (dominantly in the nitrate form located in the top 90cm) at the time of soil sampling (Figure 11a). A planting dose of 47 kgN/ha was applied a short time prior to this soil sampling and is still evident in the top 30 cm of the soil profile. In terms of organic N sources, this soil contained low total N and C levels, and exhibited a relatively high C:N ratio. (Figure 11b, c, and d).

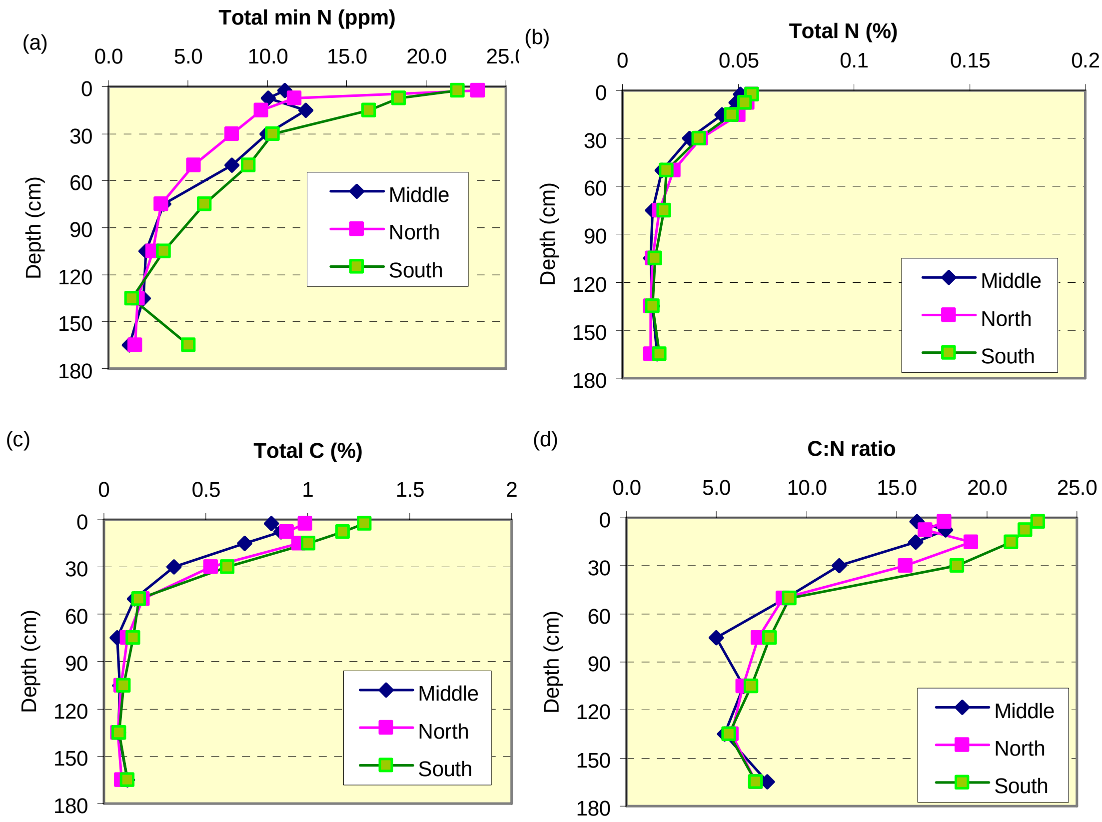

Figure 11. Initial soil nitrogen status in block used for N strip trial on the farm of Penningh. Soil sampled in Oct 1998. (a) total mineral N (ppm), (b) total N %, (c) total carbon %, (d) C:N ratio.

Interpretation

Cane and sugar yields were moderately good (>120 tonnes cane/ha) and did not respond to N fertiliser rates, suggesting none of the treatments were limited by N supply. Clearly the combination of the lowest N rate (81 kgN/ha) together with the N supply from soil sources (at least 117 kgN/ha mineral N ignoring the plant N application, plus in-season mineralisation) was sufficient to meet crop needs.

Amino-N levels were within the target range for the grower's standard N fertiliser practice. These levels rose to moderate to excessive levels in the treatment receiving the +20% N rate (159 kgN/ha), signaling this was in excess of the crops needs in this situation. There is some evidence of in-field variability in amino-N levels in the cane that will be further investigated in the 1999/2000 season.

Farm : Spyrou

Crop performance/N response

Yields increased from 94 to 106 tonnes/ha in response to variation in N rates from 106 to 210 kgN/ha (Figure 12a). CCS was very high, but varied non-significantly from 16.7 to 16.5 (Figure 12b). Corresponding sugar yields ranged from 15.6 to 17.5 tonnes/ha (Figure 12c). The difference between the sugar yields in the lowest N rate and the highest N was likely to be statistically significant.

Amino-N levels were moderate and within target range (180 ugN/ml juice) at the grower's standard N rate at the highest N rate (Figure 10d). These levels rose slightly at the +20% N fertiliser rate and fell slightly at the –20% fertiliser rate.

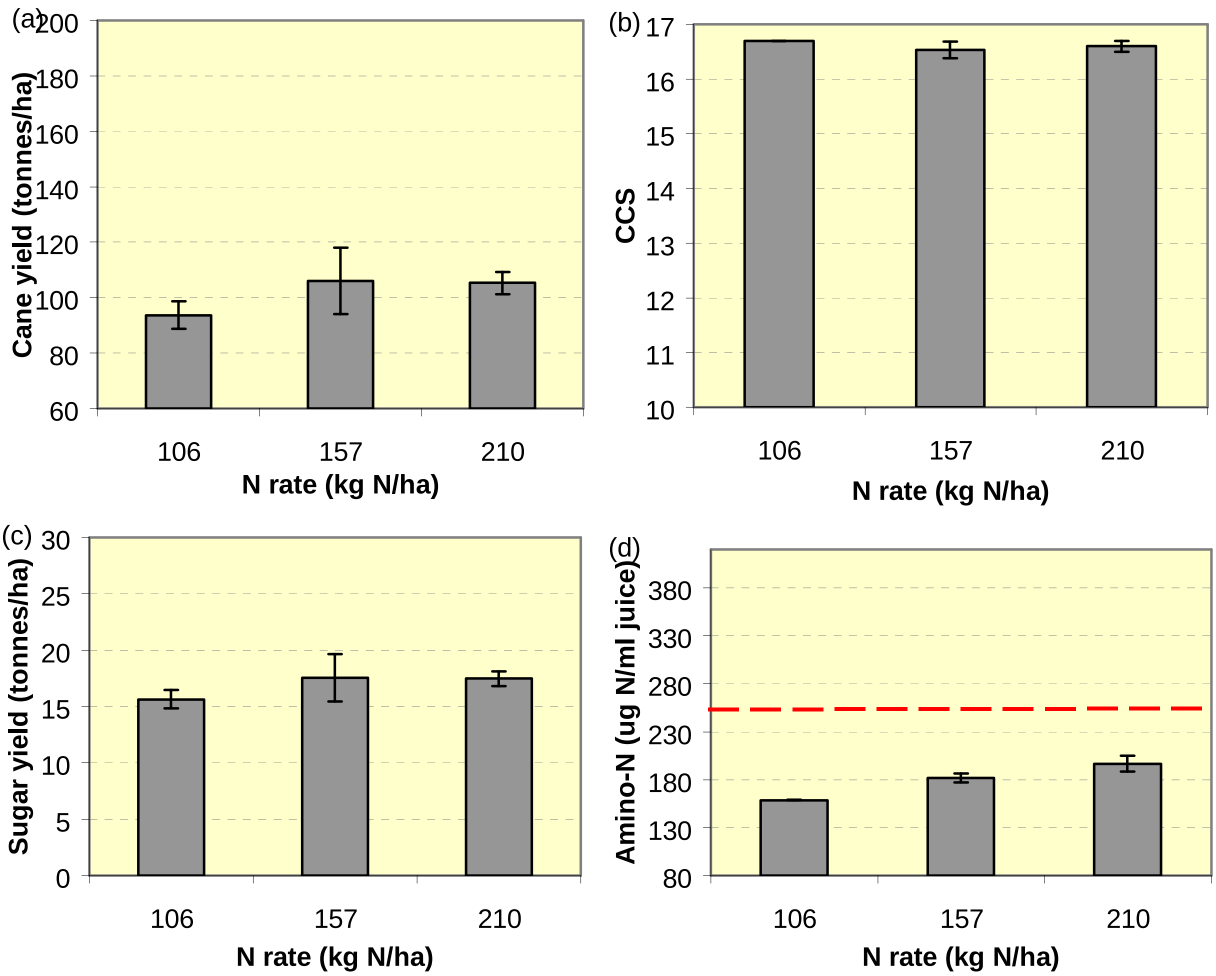

Figure 12. Results from the N strip trial at the farm of Spyrou in the 1998/99 season. (a) Fresh cane yield (tonnes/ha), (b) CCS, (c) Sugar yield (tonnes/ha), (d) Amino-N (ugN/ml juice). (amino-N levels above dashed line are indicative of excess N supply)

Initial soil conditions

The profile contained on average 52 kg mineral-N (dominantly in the nitrate form located in the top 90cm) at the time of soil sampling (Figure 13a). A proportion of this mineral N can be traced back to the application of 18 kgN/ha in the planing mix some weeks prior to soil sampling. In terms of organic N sources, this soil contained very low total N and C levels, and exhibited a relatively high C:N ratio. (Figure 13b, c, and d).

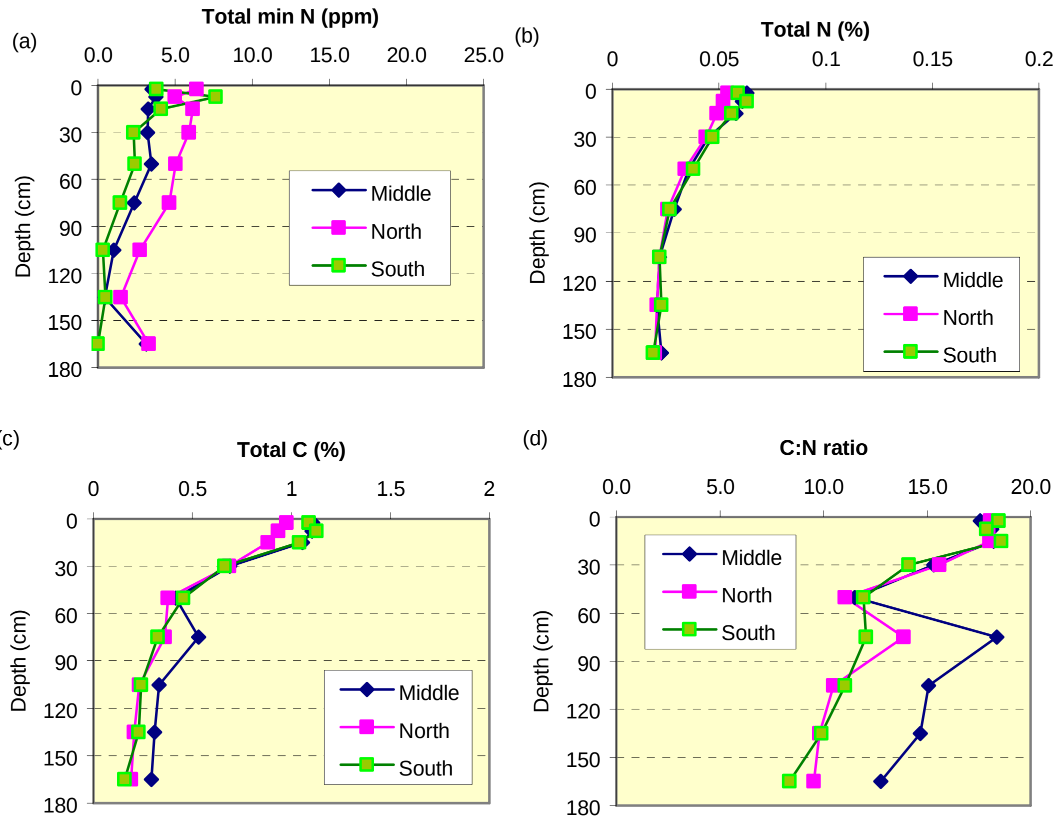

Figure 13. Initial soil nitrogen status in block used for N strip trial on the farm of Spyrou. Soil sampled in Oct 1998. (a) total mineral N (ppm), (b) total N %, (c) total carbon %, (d) C:N ratio.

Interpretation

Cane and sugar yields were at lower third of the range observed in these trials (approximately 100 tonnes cane/ha). This was the only site where a significant response to N fertiliser was observed in cane or sugar yields. The response was in the order of a 15% yield reduction at the lowest N rate (106 kgN/ha) relative to the two higher rates. Yields at the two higher rates did not differ. The low initial mineral-N and the low soil organic N offer some explanation of the reason a small response to fertiliser N was observed at this site.

Amino-N levels varied in response to N fertiliser rates, but stayed within the target range in all treatments. We had tentatively considered an amino-N level of less than 100 ugN/ml juice as indicative of low N supply conditions that could be associated with a depressed yield (see Figure 1 for example). In this trial, we have seen a 15% yield depression associated with an amino-N level of 158 ugN/ml juice, a level higher than we would have expected on past experience. The treatments have been repeated in 1999/2000 and if anything, the response should be stronger that in 1998/99. This will provide an opportunity to reevaluate this result.

General Discussion

In five out of six trials, cane and sugar yields have not responded significantly to the different N rates applied. In the sixth trial, a 15% yield reduction was observed at the lowest N rate. This result illustrates the extent to which N supply in cane crops is “buffered” by N supplied from soil sources (mineral N at planting or ratooning and within-crop organic N mineralisation). The soil sampling and analysis reported here provides some insight into the magnitude of the soil mineral-N levels that can be present. This is not a new result. Catchpoole and Keating (1995) report similar phenomena for a sequence of N trials at a single site in the Bundaberg district. Keating et al (1993) and Vallis and Keating (1994) provide further evidence for the relatively small proportion of a sugarcane crop’s N uptake that generally comes from current N fertiliser sources. Hence it is important to monitor these trials for another year or two. We would increasingly expect crop response to reflect the current N fertiliser treatments and to be less influenced by past cropping and fertiliser history.

The amino-N levels observed in these six trials represent much of the range that has been previously observed for cane supply to Bundaberg mills. This is illustrated in Figure 14, in which amino-N levels from all treatments in the six trials processed in the 1999 crushing season, are compared with data collected from 598 rakes samples collected and analysed under comparable conditions in 1997.

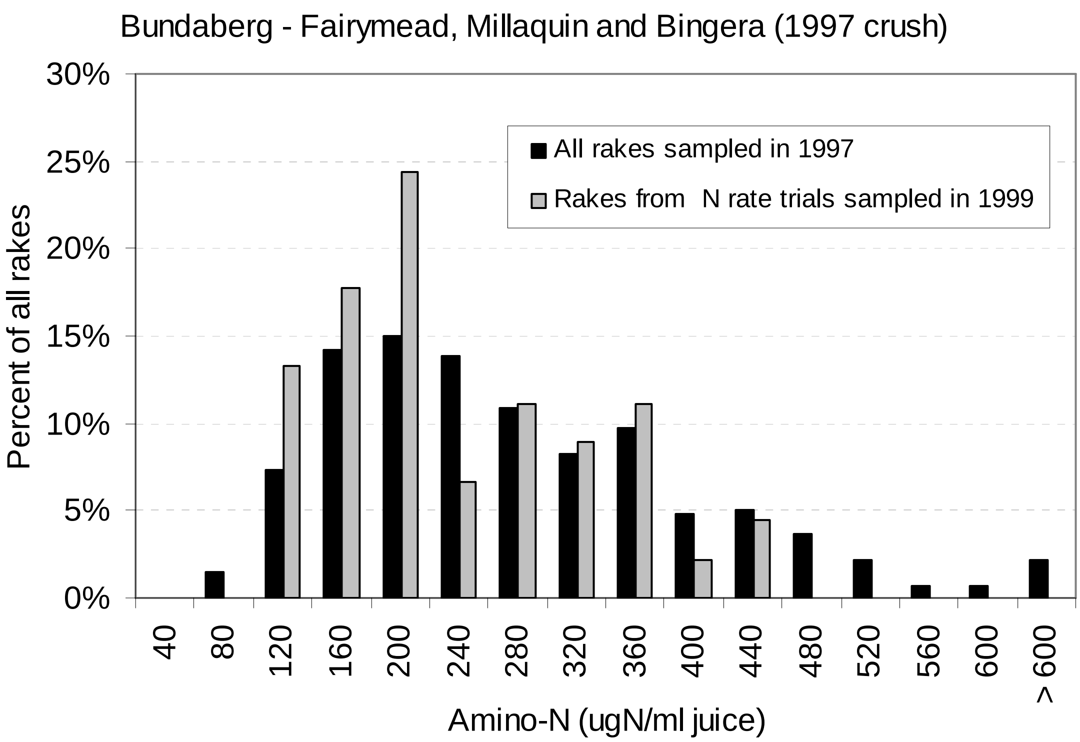

Figure 14. Frequency plot of amino-N levels measured in juice collected from rakes of cane supplied to the 3 Bundaberg mills during the 1997 crushing season in comparison to the levels measured in cane from the 3 treatments and 6 farms harvested in 1999.

The value of the amino-N monitoring information was mixed (Table 2). In general when N supply was greatest (either from soil or current fertiliser sources), the amino-N levels in cane at harvest were also greatest. However, in one case we saw a situation where N supply was very high, but so too was cane growth and yield (e.g., the 180 tonne/ha crop at the Greensil farm). In this case the amino N assessment confirmed optimal N management for this crop. In another case, the amino-N monitoring did not identify a treatment as likely to be N limited, while the yield data suggested a 15% yield depression due to low N fertiliser application.

Table 2. Summary of N rate trials

Farm	**Crop class**	**Significant N response**	**Amino N assessment of N supply under standard N fertiliser management**	**Value of information provided by amino-N monitoring**
Borg #22699	Plant	No	Excessive	Indicated that some reductions in fertiliser N rates may be appropriate for blocks/crops with a similar history
Dingle #3172	1R	No	Within target range	Indicated that the +20% fertiliser rate was excessive, something confirmed by trial results
Greensil #25056	1R	No	On the low side of target range	Even though low N rates were used on very large crops, these rates were sufficient for optimal N nutrition given the large supply of N from soil reserves.
Jensen #10268	1R	No	On the high side of target range	Indicated that crops were well supplied with N but not excessively so.
Penningh #10057	Plant	No	Within target range	Indicated that the grower's standard N fertiliser practice was appropriate and the higher N rate (+20%) was excessive.
Spyrou #537	Plant	Yes (approx 15%) (12 tonnes cane, 1.9 tonnes sugar)	Within target range	Indicated that N supply was not excessive and that current N practice was appropriate. Amino-N did not "detect" the small yield reduction observed in the –20% N rate.

The results presented here represent the first year of a 2-3 year trial. The soil sampling has proven useful in aiding interpretation of the results and will be repeated in mid 2000. In particular the results show it is critical to sample to some depth to fully assess the carry over of mineral N residues from one crop to the next. The amino-N results are generally consistent with past experience and indicative of a useful future role, but more results are needed before this can be confirmed. We expect N responses to be more prevalent in the second year of the trial and we await with interest an on-going assessment of the amino-N monitoring technique.

Acknowledgements

We are grateful for the support provided by the six growers in the Bundaberg district who have hosted these trials on their farms. We also acknowledge the efforts of the harvesting contractors and staff from the three Bundaberg mills who have assisted in the harvesting, sample collection and processing of these trials.

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Appendix 8.2 : Report on on-farm trials to evaluate "Amino-N monitoring in cane supply at the mill" conducted in the 1999/2000 season in the Bundaberg district.

Background

Nitrogen management in sugarcane has been problematical because growers have had little means of assessing their N management practices. The risks of inadequate N supply (in terms of reduced cane yields) are perceived to be high, and at least when sugar prices are good, the relative costs of N fertilisers are considered small in comparison to the value of the crop. There has been some evidence that growers have tended to over supply nitrogen fertiliser and pay inadequate attention to other sources of N supply such as N residues from prior small crops, N supplied from mill muds or N accumulated in the soil profile over fallow periods.

This research project aims to provide growers with a way of monitoring the adequacy of the N supply their crops are experiencing. Earlier work has shown that the nitrogen found in cane stems at harvest time is sensitive to the N supply the crop has experienced (see Keating et al 1999, 2001). In particular, the amino-N levels in stems or juice have proved to be a reasonably sensitive indicator of N supply. The monitoring technique appears particularly promising in identifying cane blocks that are exhibiting excessive levels of N supply (Figure 1). While cane that is deficient in N (leading to reduced yields) will exhibit low amino-N levels in stems or juice, the project team do not consider that the amino-N test will uniquely identify N deficiency, a rare condition in any case in the sugar industry. The strength of the approach will not be in the precision of estimation and interpretation of stem/juice amino-N levels, but in the "universal sampling" opportunity afforded by a test on the harvested cane at the mill. By monitoring amino-N levels in cane supply from all blocks on a farm, a grower will be able to develop a picture of block to block variation in N supply. Over time, with knowledge of variation in soils and management history on their farm, a grower should be able to use the amino-N information to "fine tune" their N management practices.

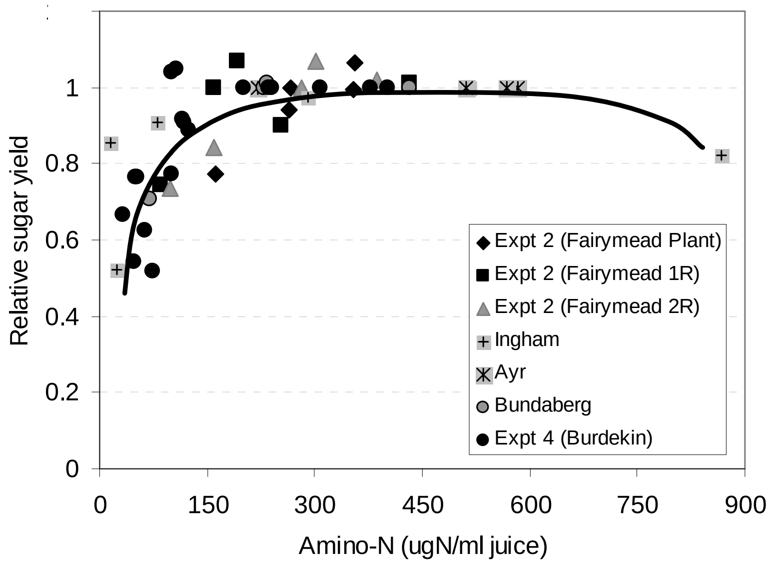


Figure 1. Sugar yield in relation to amino-N in cane juice (from Keating et al 2001). Lines indicate an idealised diagnostic response and a "target" region is identified as 150 to 300 ug N/ml juice (further refined from Milestone 6 report)

The trials reported here were aimed at exploring how the amino-N information might be used by growers. We have used the "strip trial" approach to focus these investigations. Taking the growers current practice as the "standard treatment", we have asked the question "what would happen to cane yields and CCS if N rates were 20% higher or lower?" We have asked this question with the growers in the context of the additional information provided by the amino-N monitoring technique. Specifically, what would we conclude based on the amino-N levels in cane grown under the grower's standard practice ? What does the amino-N test tell us about N supply in the plus or minus 20% N rate treatments ? Overall, can we interpret why growers are getting the responses or lack of responses we observe and how does the amino-N test help in this interpretation ?

General Methods

N rate trials were established in the Bundaberg district over the 1998/99 season and continued over the 1999/2000. Two trials were set up in each of the Bingera, Millaquin and Fairymead mill districts. At the outset, one trial in each mill district was on a plant crop and the other a first ratoon crop. Hence in 1999/2000 we had one 1st ratoon and one *2nd ratoon in each mill district. Three N rates were investigated in both seasons, based around the growers "standard" practice (T2) together with a reduction of approximately 20% (T1) and an increase of approximately 20% (T3). Other fertilisation practices were based on growers' standard practices, and in all cases trials received what amounts to standard industry rates of K, P and S.

The plots were large, typically based on 6 to 16 rows, 200 to 300 m long. A number of trials were formally replicated based on randomised complete block designs (Table 1) while others did not contain formal replication in the field, but had multiple sampling take place within a treatment. Hand cut samples (based on 9 stalks per plot) were cut prior to machine harvesting. These samples were processed via a Jeffco cutter/grinder and juice extraction in a Carver Press. Machine harvests were consigned to the mill as separate rakes for replications and treatments and yields and CCS obtained from mill data. Juice samples (first expressed juice after No. 1 mill) were collected for all samples at the mill and frozen immediately for subsequent amino-N analysis (using standard methods outlines by Keating et al 1999).

Other details of the trials are provided in Table 1.

Soil was sampled from all trial sites at the start of the experiment to a depth of 1.8m at the start of the trials in 1998. This sampling was repeated in each N rate treatment soon after the crops were harvested in 2000. Three positions in each block were sampled, each sample being made up of 3 bulked cores. Samples were extracted (fresh) with KCl and mineral nitrogen (NO3 and NH4) determined using standard colorimetric methods (Catchpoole and Keating 1995). Total N and total C were determined on dried samples via mass spectroscopy.

Table 1. Experimental details for N strip trials conducted in Bundaberg. (a) 1998/1999 and (b) 1999/2000 seasons.

(a)

Farm	Mill+	Soil type	Crop class	Variety	Low N rate (kgN/ha)	"Standard" N rate (kgN/ha)	High N rate (kgN/ha)	Reps	Soil sampling date	Side dress date	Mill harvest date
Borg #22699	MQN	Yellow podzolic	Plant (10/98)	Q151	101	138	204	3	14/10/98	20/11/98	20/08/99
Dingle #3172	FMD	Gleyed podzolic	1R (06/98)	Q151	123	161	207	*	10/98	30/10/98	22/06/99
Greensil #25056	MQN	Kraznozem	1R (10/98)	Q124	80	120	160	3	13/10/98	27/11/98	12/11/99
Jensen #10268	BIN	Red podzolic	1R	Q124	126	170	210	*	03/11/98	06/11/98	05/09/99
Penningh #10057	BIN		Spring Plant	Q124	81	122	159	*	04/11/98	07/11/98	01/09/99
Spyrou #537	FMD	Red earth	Ploughout & replant (10/98)	Q141	106	157	210	*	03/11/98	11/98 14/12/98	16/10/99

(b)

Farm	Mill+	Soil type	Crop class	Variety	Low N rate (kgN/ha)	"Standard" N rate (kgN/ha)	High N rate (kgN/ha)	Reps	Soil sampling date	Side dress date	Mill harvest date
Borg #22699	MQN	Yellow podzolic	1R	Q151	102	140	187	3	31/07/00		5/7/00
Dingle #3172	FMD	Gleyed podzolic	2R	Q151	123	161	207	*	02/08/00	11/10/99	4/7/00
Greensil #25056	MQN	Kraznozem	2R	Q124	80	120	160	3	16/10/00		12/9/00
Jensen #10268	BIN	Red podzolic	2R	Q124	126	170	210	*	24/10/00		11/10/00
Penningh #10057	BIN		1R	Q124	81	122	159	*	23/10/00	#	22/8/00
Spyrou #537	FMD	Red earth	1R	Q141	87	131	191	*	17/10/00	9/12/99	30/10/00

* No formal replication, 3 internal samples taken for yield and amino-N estimates.
+ MQN = Millaquin, FMD = Fairymead, BIN= Bingera
#Farmer already applied "standard" fertiliser rate to **all** treatments at time of soil sampling, but there had been no rain or irrigation since application.

Farm specific methods and results (2000 harvests)

Farm: Borg

Crop performance/N response :

Yields varied non-significantly from 97 to 110 tonnes/ha (compared to 107 to 117 tonnes/ha in 1999), in response to variation in N rates from 102 to 187 kgN/ha (Figure 2a). CCS was approximately 13.4 at the two lower N rates but dropped to 13.0 at the highest N rate (Figure 2b). Corresponding sugar yields ranged from 13.0 to 14.8 tonnes/ha (Figure 2c). Amino-N levels were on the high side of the target range (230 to 306 ugN/ml juice) (Figure 2d), with some evidence lower levels under the –20% N rate. The amino-N levels in this treatment were approximately 30% lower than those recorded for the same treatment in 1999.

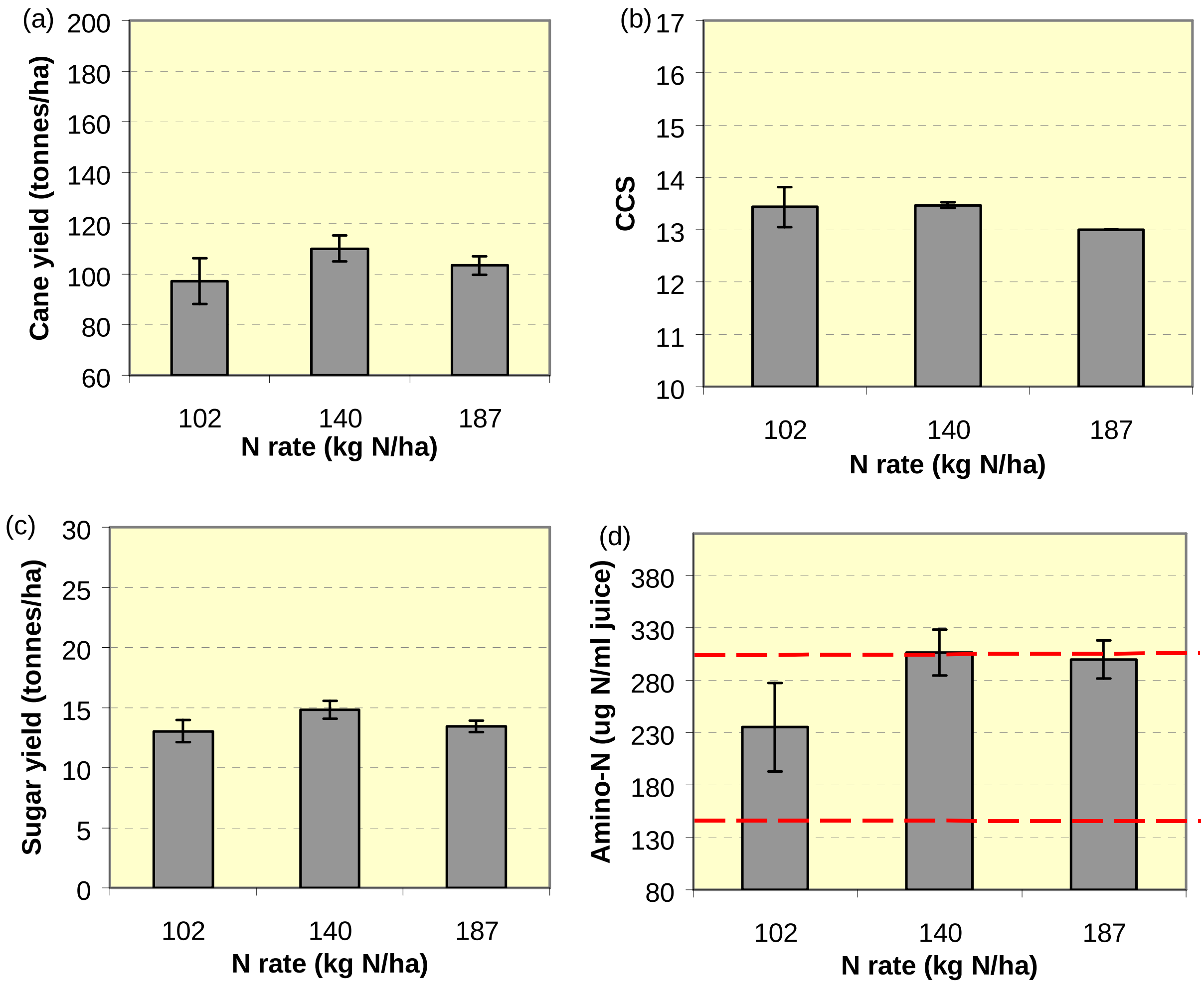


Figure 2. Results from the N strip trial at the farm of J Borg in the 1999/00 season. (a) Fresh cane yield (tonnes/ha), (b) CCS, (c) Sugar yield (tonnes/ha), (d) Amino-N (ugN/ml juice) (dashed lines on amino-N graph indicate target range)

N in the soil profile

When sampled at cane at plant crop establishment, the profile contained on average 262 kg mineral-N (dominantly in the nitrate from) (Figure 3a). In terms of organic N sources, this soil had relatively low total N and C levels, and moderately high C:N ratios (Figure 3b, c, and d). Mineral N levels had dropped to between 65 and 110 kgN/ha depending on N fertilisation history (Figure 3e) after the harvest of the 1999/2000 crop.

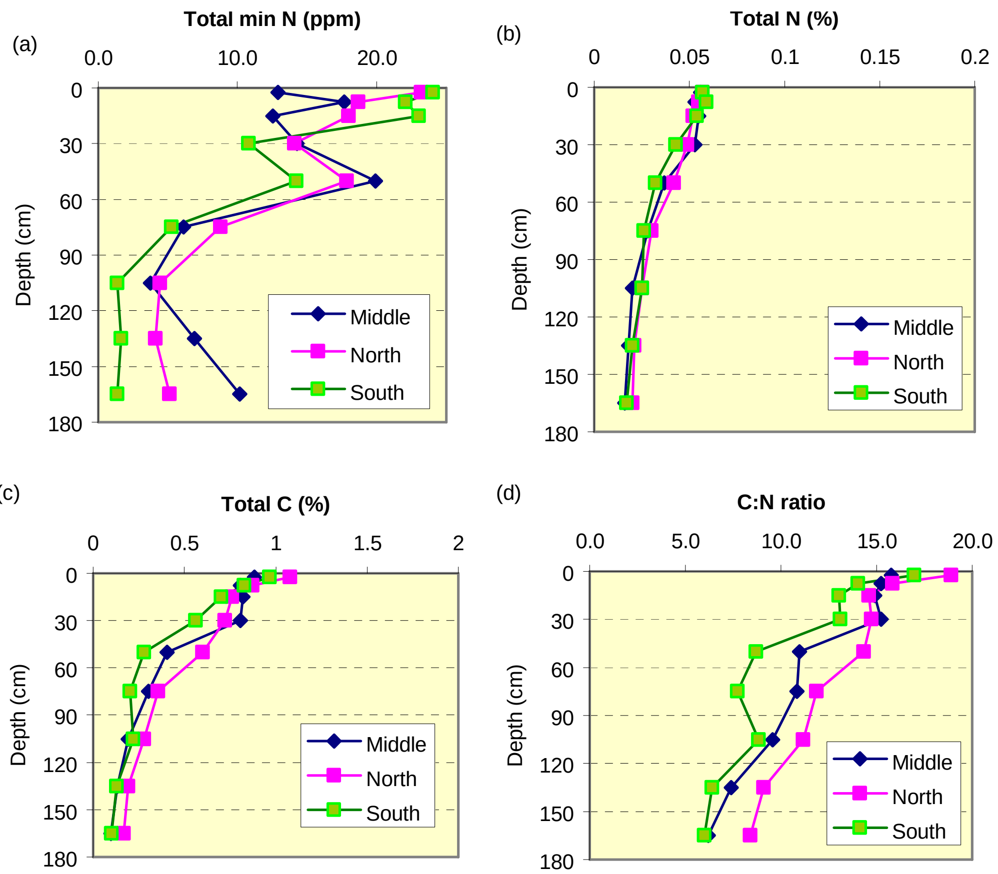


Figure 3. (a-d) Initial soil nitrogen status in block used for N strip trial on the farm of J. Borg. Soil sampled in Oct 1998. (a) total mineral N (ppm), (b) total N %, (c) total carbon %, (d) C:N ratio

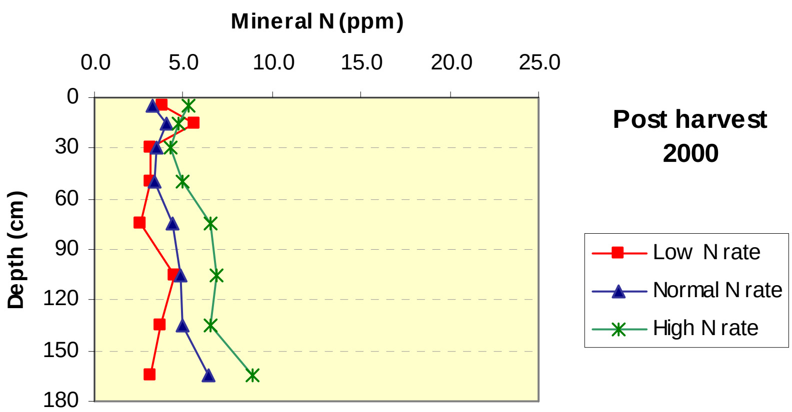


Figure 3. (e) Mineral N status (nitrate + ammonium) in block used for N strip trial on the farm of J Borg. Soil sampled after harvest in 2000.

Interpretation

Varying N rates from 100 to 204 kgN/ha had no significant effect on yields in the plant crop. The high levels of mineral N in the profile at planting (in excess of 200 kgN/ha) was thought to be responsible for this lack of response. In the first ratoon, there was some evidence that the lowest N rate was limiting yields (97 tonnes cane/ha compared to 103 to 110 tonnes cane/ha) but this difference was not significant. CCS was depressed 0.5 units by the highest N rate.

The amino-N levels under the grower's standard fertiliser practice were high (> 300 ugN/ml juice) in the plant crop. These had dropped slightly in the 1st ratoon, most significantly in the plots receiving the lowest N rate (eg., to 235 ugN/ml juice). In the plant crop we concluded that the amino-N information was indicative of excess N supply. In the 1st ratoon, the small reductions in amino-N levels suggest N supply was more restricted, but still adequate for N non-limited yield. Soil sampling results indicate that the 2 crops had substantially reduced the mineral N levels in the soil, eg. from in excess of 200 kg N/ha in 1998 to 64 - 110 kgN/ha after harvest in 2000. Interestingly, there was evidence that this reduction was greater in the low N rate (eg to 64 kg N/ha) than in the highest N rate (to 110 kg N/ha).

Farm : Dingle

Crop performance/N response

Yields ranged from 69 to 75 tonnes/ha in this 2nd ratoon crop and were unaffected by N rates ranging from 123 to 207 kg N/ha (Figure 4a). Yields were also low (86 to 90 tonnes/ha) and not responsive to N rate in the 1st ratoon. CCS varied non-significantly from 13.5 to 13.2 (Figure 4b), and corresponding sugar yields ranged from 9.0 to 9.9 tonnes/ha (Figure 4c).

In 1998/99, amino-N levels were moderate (201 ugN/ml juice) under the grower's standard practice, dropping somewhat at the –20% N rate and rising significantly (>300 ugN/ml juice) under the +20% N rate. A similar result was recorded in 1999/2000 (Figure 4d). Levels were within the provisional target range, although there was strong evidence that the enhanced N supply under the higher N rate was causing elevated amino-N levels in the juice (eg., Amino N levels of 300 ugN/ml juice in the highest N rate compared to 171 ugN/ml juice in the lowest N rate).

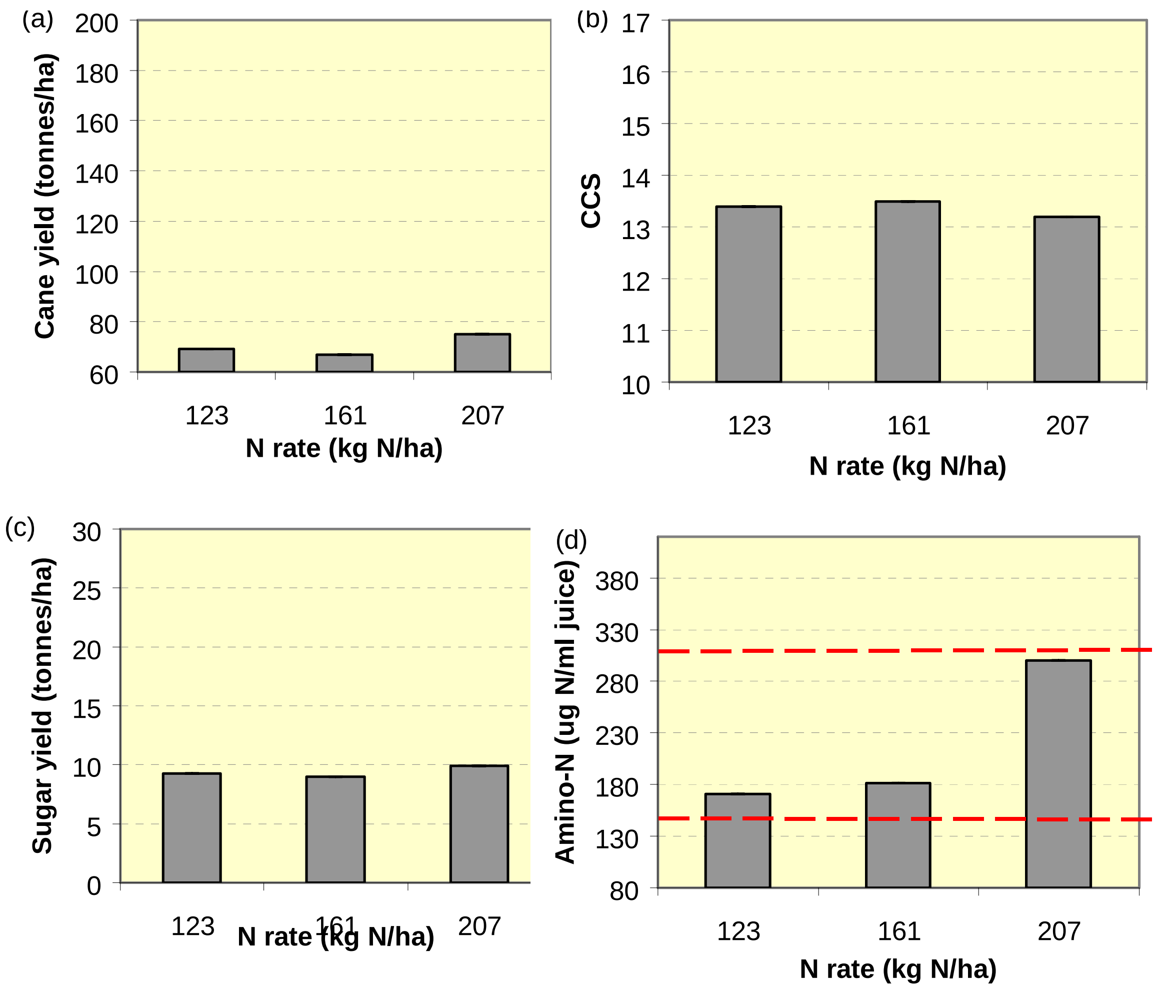


Figure 4. Results from the N strip trial at the farm of Dingle in the 1999/2000 season. (a) Fresh cane yield (tonnes/ha), (b) CCS, (c) Sugar yield (tonnes/ha), (d) Amino-N (ugN/ml juice). (dashed lines on amino-N graph indicate target range)

N in the soil profile

The profile contained on average 19 kg mineral-N (dominantly in the ammonium form) at the time of initial soil sampling (Figure 5a). In terms of organic N sources, this soil had moderate to high total N and C levels, and moderately high C:N ratios (Figure 5b, c, and d). When sampled after the harvest of the 2nd ratoon crop in 2000, the profile contained 90-110 kgN/ha, of which approximately 70% was in the a

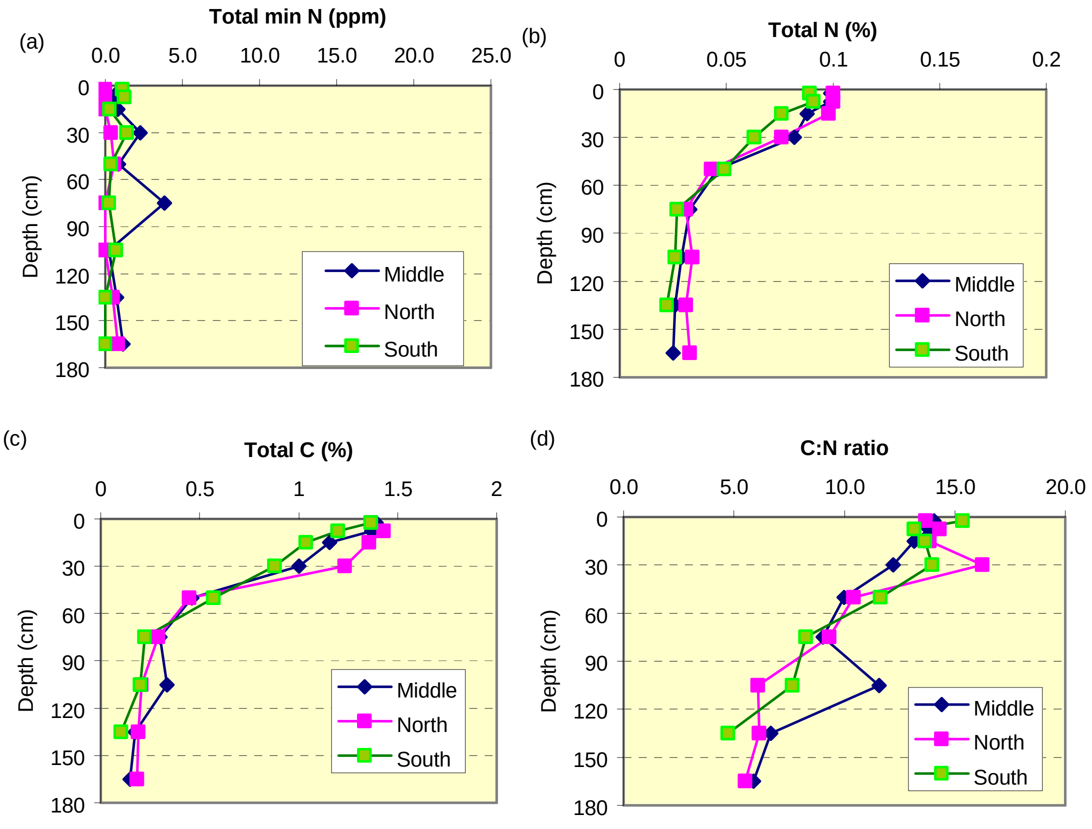


Figure 5.(a-d) Initial soil nitrogen status in block used for N strip trial on the farm of Dingle. Soil sampled in Oct 1998. (a) total mineral N (ppm), (b) total N %, (c) total carbon %, (d) C:N ratio.

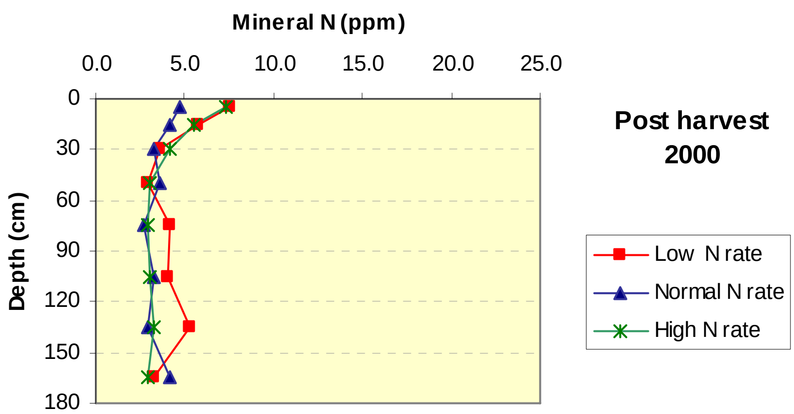


Figure 5. (e) Mineral N status (nitrate + ammonium) in block used for N strip trial on the farm of Dingle. Soil sampled after harvest in 2000.

Interpretation

Varying N rates from 123 to 207 kgN/ha had no significant effect on yields in either the 1st or 2nd ratoons. The levels of mineral N in the profile at ratooning in 1998/99 were very low when the trial started but somewhat surprisingly were higher after the harvest of the 2nd ratoon. The crop yields being recorded on this block are very low (60-90 tonnes ha) and the trial is unresponsive to the different N fertiliser rates being used. The soil plus fertiliser N supplied was still sufficient to produce N non-limited crop performance at even the lowest N rate used (123 kg N/ha) in both years. The low yield levels would have contributed to the lower crop demand for N.

The amino-N results were similar in both ratoon crops. The amino-N levels in juice from the two lower N rates were moderate (171-201 ugN/ml juice), suggesting the N supply status of these crops was also within the target range. The amino-N levels in cane increased into the excessive range (300 ugN/ml juice and above) under the +20% fertiliser treatment, suggesting this was an excessive level of fertiliser input for the yield levels achieved in these crops. The yield data which show no significant response to variation in N rates support this interpretation.

Farm : Greensil

Crop performance/N response

Yields ranged from 95 to 110 tonnes/ha over N rates ranging from 80 to 160 kg N/ha. Whilst not statistically significant, this 10-15% yield difference was in all probability due to limited N supply in the low N rate treatments (Figure 6a). These crops produced very high yields in their first year (172 to 179 tonnes/ha), but did not respond significantly to N rate at that time. CCS was depressed in the higher N treatments (from 15.8 to 14.8) (Figure 6b). Sugar yields ranged from 14.8 to 16.4 tonnes/ha (Figure 6c), compared to 24.2 to 25.4 tonnes/ha in the plant crop.

Amino-N levels were in the target range for the 2 higher N rate treatments (158 – 197 ugN/ml juice) but was below this range for the lowest N rate (120 ugN/ml).The range in amino-N recorded in 1999/2000 (120 to 197 ugN/ml juice) was a little larger that that recorded in 1998/99 (106 - 141 ugN/ml juice).

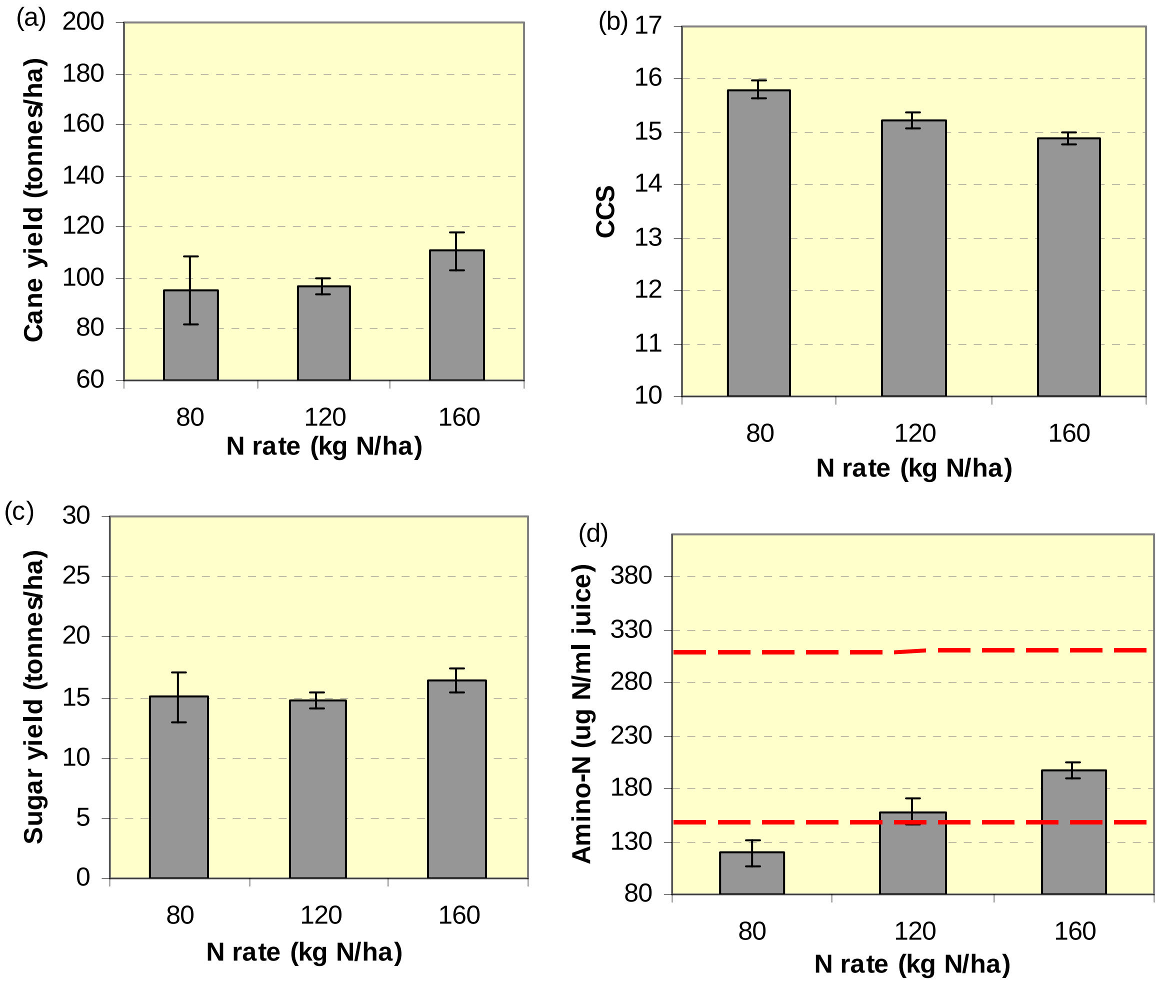


Figure 6. Results from the N strip trial at the farm of Greensil in the 1998/99 season. (a) Fresh cane yield (tonnes/ha), (b) CCS, (c) Sugar yield (tonnes/ha), (d) Amino-N (ugN/ml juice). (dashed lines on amino-N graph indicate target range)

N in soil profile

The profile contained between 59 and 96 kg N/ha as mineral-N when sampled after the harvest of the 1999/2000 crop (Figure 7e). This contrasts strongly with the situation when the plant crop was sampled in 1998. At that time, an average of 271 kg mineral-N (dominantly in the nitrate form) was observed (Figure 7a). Most of this N was at depth and was thought to have been residues from prior small crops. In terms of organic N sources, this soil had the highest total N and C levels, and the lowest C:N ratio of all the sites sampled in these trials. (Figure 7b, c, and d).

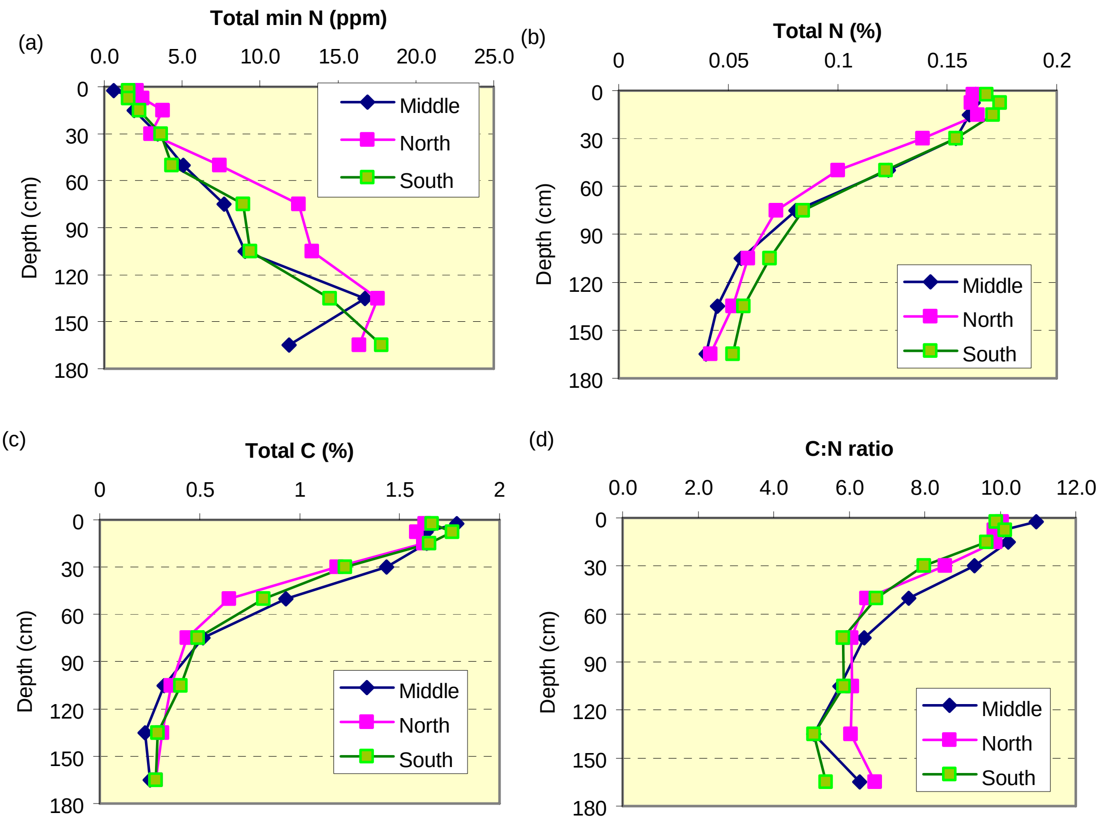


Figure 7(a-d). Initial soil nitrogen status in block used for N strip trial on the farm of Greensil. Soil sampled in Oct 1998. (a) total mineral N (ppm), (b) total N %, (c) total carbon %, (d) C:N ratio.

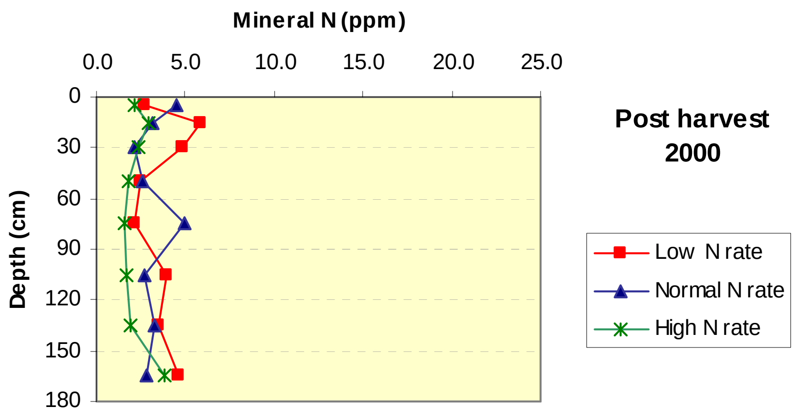


Figure 7. (e) Mineral N status (nitrate + ammonium) in block used for N strip trial on the farm of Greensil. Soil sampled after harvest in 2000.

Interpretation

This site produced an exceptionally high yielding plant crop (>170 tonnes/ha) irrespective of N rates applied. This suggests a substantial N supply from other than the current fertiliser, and the high levels of mineral-N in the profile after the small crops was believed to be the major source. A somewhat different story emerges in the first ratoon. Yields are much lower (for reasons that are not known at the time of writing – possibly limitations in water for irrigation) and there is clear evidence that the lowest N treatment (which received only 80 kg N/ha each year and which has now produced approximately 270 tonnes cane/ha) is becoming limited by N supply. A 12% sugar yield reduction was observed in this treatment in 1999/2000. The soil sampling taken after the harvest of the 1^{st} ratoon confirms most of the mineral N that was observed at depth in 1998 is no longer there. Given the crop production that has taken place on relatively low N rates, we hypothesize that much of this subsoil N has been recovered by the cane crop, although we can't completely discount the possibility that some of this sub-soil N may have been leached deeper below the reach of the crop root systems. This site is irrigated from groundwater in a region known to have groundwaters with elevated nitrate levels. The extent to which the irrigation water is contributing to N supply at this site is being investigated at the time of writing.

The amino-N levels observed in the juice collected in 1999/2000 provide further evidence that the low N treatment (80 kg N/ha) was running short of N. An amino-N level of 119 ugN/ml juice in this treatment is in the range that have been associated with yield limitations in other experimental studies (see Figure 1 for a provisional response surface). Amino-N levels in the other two treatments were in the target range. Unlike many other sites studied, no evidence of excess N supply has been found in the cane crops at this site. The combination of modest N rates and moderate to high yielding crops appears to result in effective N utilisation. The very high soil mineral-N levels following small crops is a different story and there may be some need for greater N use efficiency in the small crop phase of the rotation.

Farm : Jensen

Crop performance/N response

Yields varied from 116 to 129 tonnes/ha in response to variation in N rates from 126 to 210 kgN/ha (Figure 8a) in the 2nd ratoon harvested in 1999/2000. The intermediate N rate produced the higher yield, although lack of replication on this site means it is not possible to assess the statistical significance of these small yield difference. These yields compare with 125 to 131 tonnes/ha in the 1st ratoon in 1998/99. CCS was higher in 1999/2000 (15.1 to 15.4) compared to 1998/99 (13.5 to 13.9) with little indication of an effect of N treatments (Figure 8b). Corresponding sugar yields ranged from 17.5 to 19.9 tonnes/ha (Figure 8c). Amino-N levels were moderate to high (290 – 326 ugN/ml juice) for all three N treatments (Figure 8d), a similar result to that recorded in 1998/99 (245 - 270 ugN/ml juice).

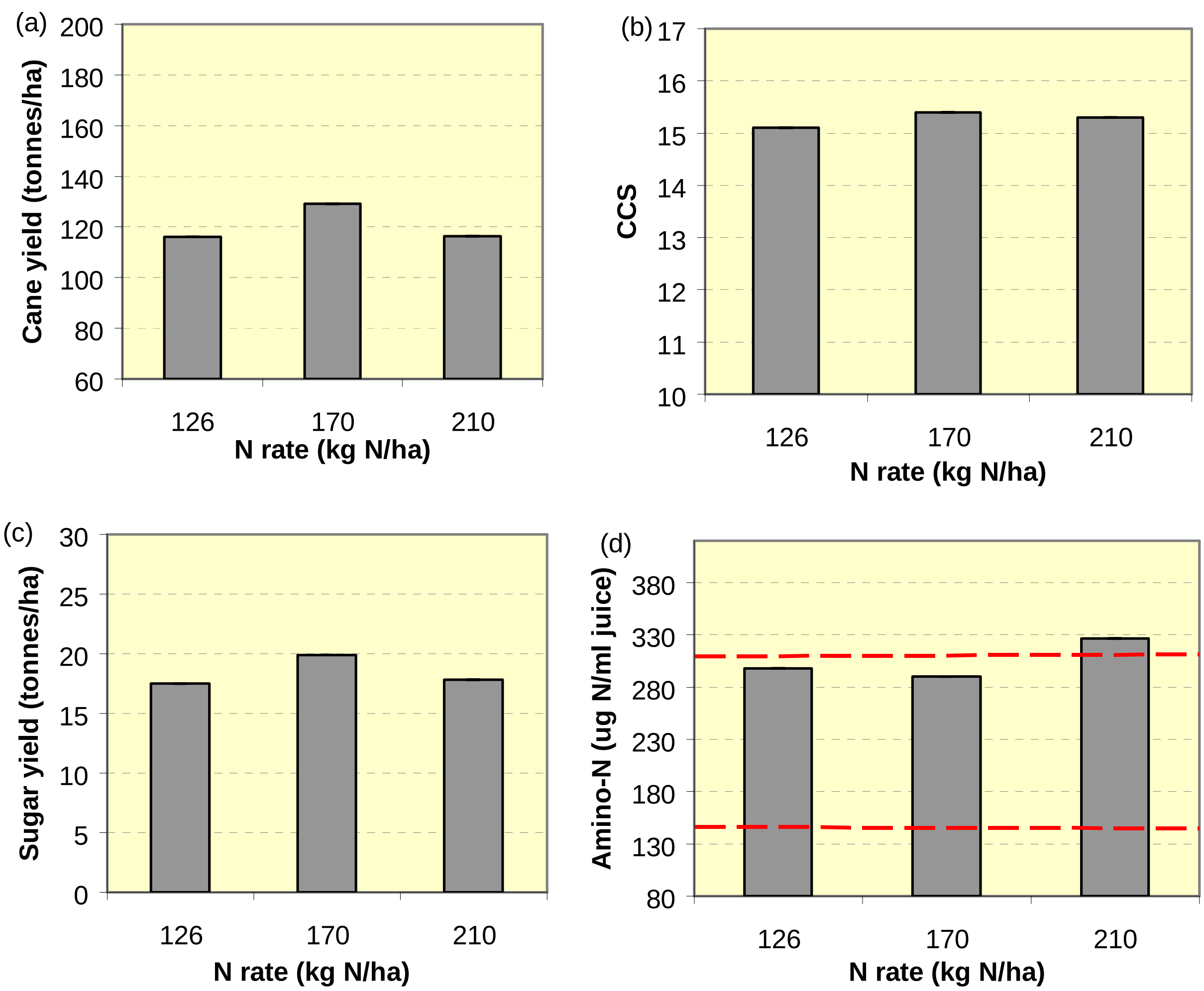


Figure 8. Results from the N strip trial at the farm of Jensen in the 1999/2000 season. (a) Fresh cane yield (tonnes/ha), (b) CCS, (c) Sugar yield (tonnes/ha), (d) Amino-N (ugN/ml juice (dashed lines on amino-N graph indicate target range)

N in soil profile

The profile contained between 54-91 kg mineral-N/ha when sampled after the harvest of the 2nd ratoon crop in 2000 (approximately half in the nitrate form) (Figure 9 e). This compares with an average of 110 kg mineral-N/ha in 1998 prior to the first year of the trial. (Figure 9a). In terms of organic N sources, this soil contained moderate to low total N and C levels, and exhibited a relatively low C:N ratio. (Figure 9b, c, and d).

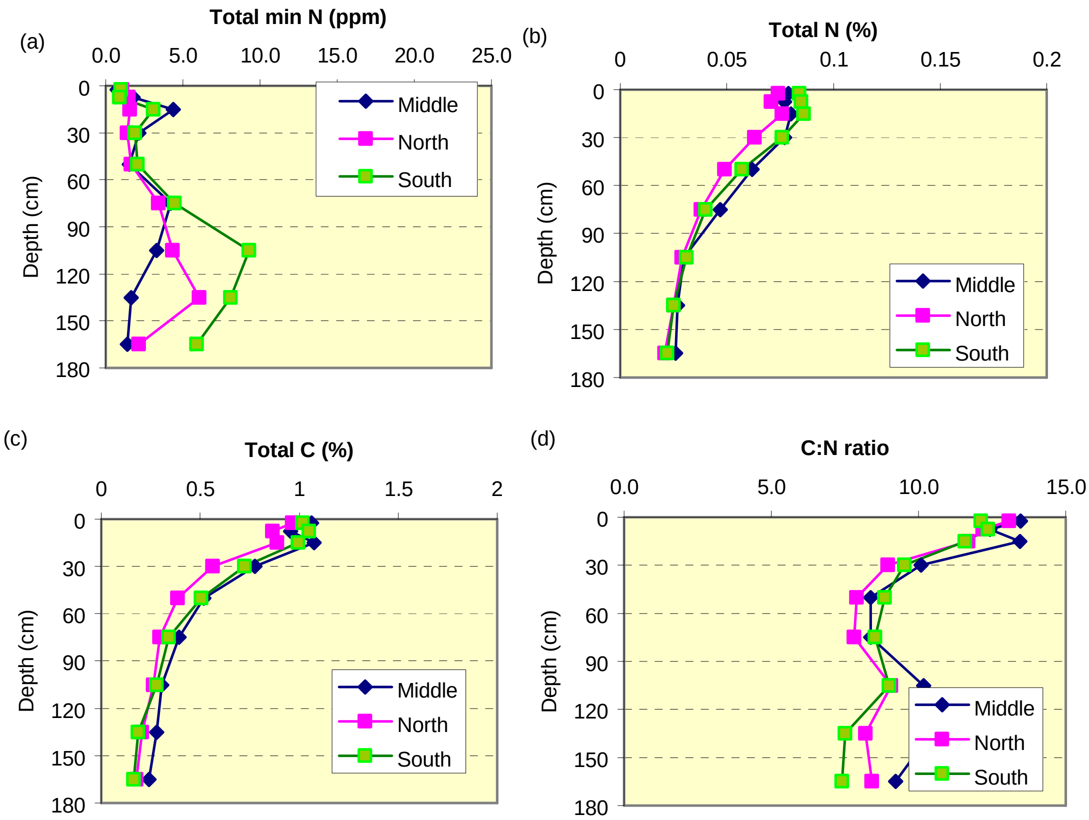


Figure 9 (a-d). Initial soil nitrogen status in block used for N strip trial on the farm of Jensen. Soil sampled in Oct 1998. (a) total mineral N (ppm), (b) total N %, (c) total carbon %, (d) C:N ratio.

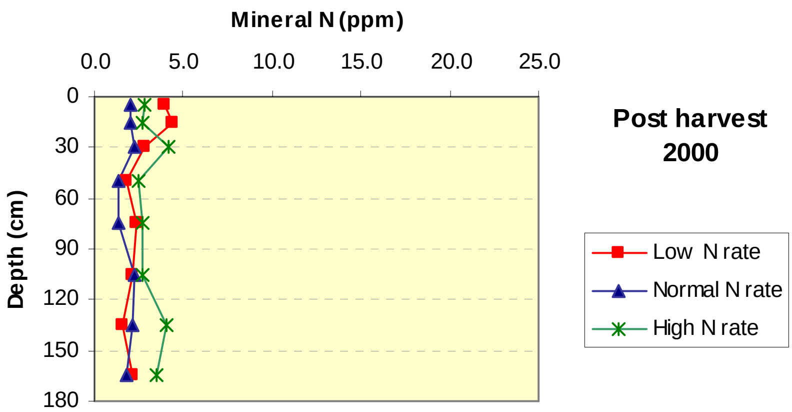


Figure 9. (e) Mineral N status (nitrate + ammonium) in block used for N strip trial on the farm of Jensen. Soil sampled after harvest in 2000.

Interpretation

In both the first and second ratoons, cane and sugar yields were highest at the grower's standard rate of N fertiliser (170 kg/N ha). The differences between all N treatments were small and given past experience with within field variability, unlikely to be significant (this trial was unreplicated and hence we cannot determine likely significance of these small yield differences). Yield levels were moderate to good (in the 120 to 130 tonnes cane/ha range) but the lower fertiliser rate (126 kgN/ha), together with the modest level of N supply from the soil (110 kgN/ha in profile at ratooning plus within crop mineralisation activity) appears to have been sufficient to supply crop N needs.

Amino-N levels in cane were moderate to high in both years, at the upper end of the provisional target range (300 ug N/ml juice). This is consistent with the lack of clear response to altered N rates. There was only a small response in amino-N in response to increasing N rates from 126 to 210 kg N/ha. A similar result was observed in the previous year. The result for this site was regarded as "unexpected" in the 1998/99 season, mainly because amino-N levels did not increase as N rates increased. Field variability was seen as a factor influencing this result. The 1999/2000 results are basically consistent with the previous year. It appears the site has a moderately high rate of N supply (e.g., from soil organic matter) and the crops are unresponsive to changing N rate. Consistent with this high level of N supply, we see a high level of amino-N in the juice at harvest time.

Farm : Penningh

Crop performance/N response

Yields were lower in the 1st ratoon crop (82 to 97 tonnes/ha) compared to the plant crop (122.3 to 122.7 tonnes/ha). Cane yield was 20% higher in the highest N rate (Figure 10a) while CCS was 0.6 units lower (Figure 10b), and corresponding sugar yields ranged from 12.3 to 14.0 tonnes/ha (Figure 10c). Amino-N levels followed similar patterns to those observed in the previous year's plant crop (Figure 10d). At approximately 130 ugN/ml juice, they were below the target range at the two lower N rates (cf., 180 ugN/ml juice in the 1998/99 plant crop). At 287 ugN/ml juice, amino-N was in the high end of the target range for the high N rate treatment (cf., 260 ugN/ml juice in this treatment in the plant crop in 1998/99).

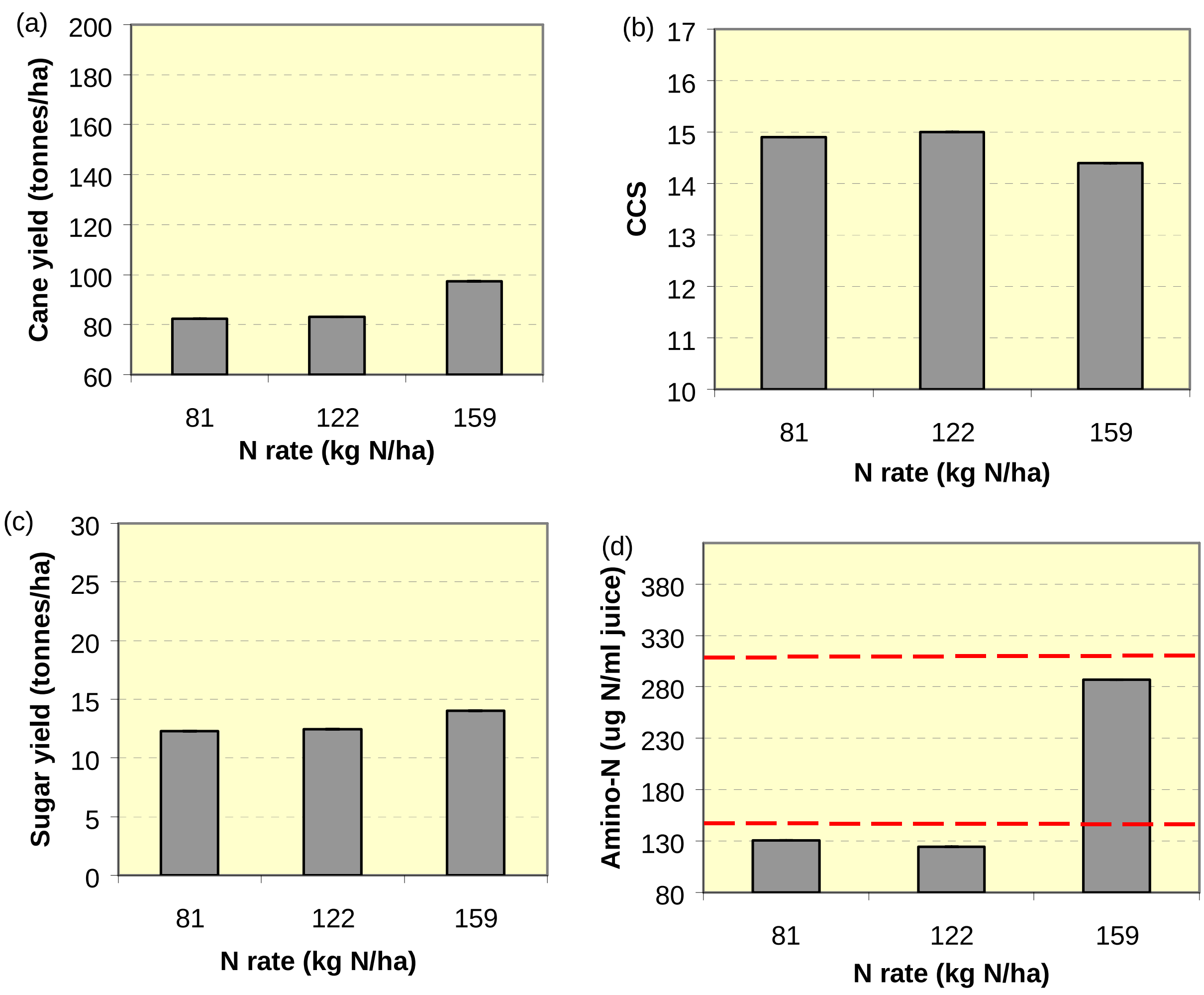


Figure 10. Results from the N strip trial at the farm of Penningh in the 1998/99 season. (a) Fresh cane yield (tonnes/ha), (b) CCS, (c) Sugar yield (tonnes/ha), (d) Amino-N (ugN/ml juice). (dashed lines on amino-N graph indicate target range)

N in soil profile

Low levels of mineral N (39-54 kg N/ha) were observed in the soil profile after harvest of the 1st ratoon crop in 2000 (Figure 11e). In contrast, the profile contained an average of 164 kg mineral-N (dominantly in the nitrate form located in the top 90cm) at the time of establishment of the plant crop in 1998 (Figure 11a). In terms of organic N sources, this soil contained low total N and C levels, and exhibited a relatively high C:N ratio. (Figure 11b, c, and d).

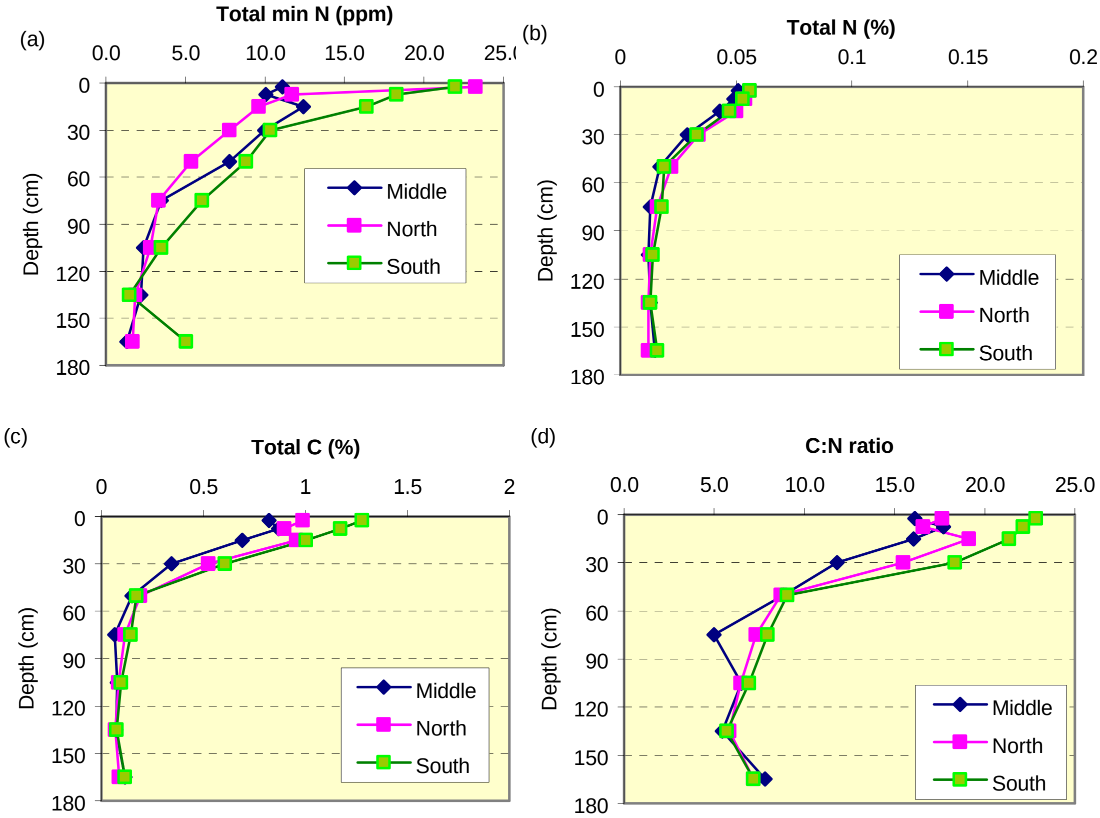


Figure 11. (a-d). Initial soil nitrogen status in block used for N strip trial on the farm of Penningh. Soil sampled in Oct 1998. (a) total mineral N (ppm), (b) total N %, (c) total carbon %, (d) C:N ratio.

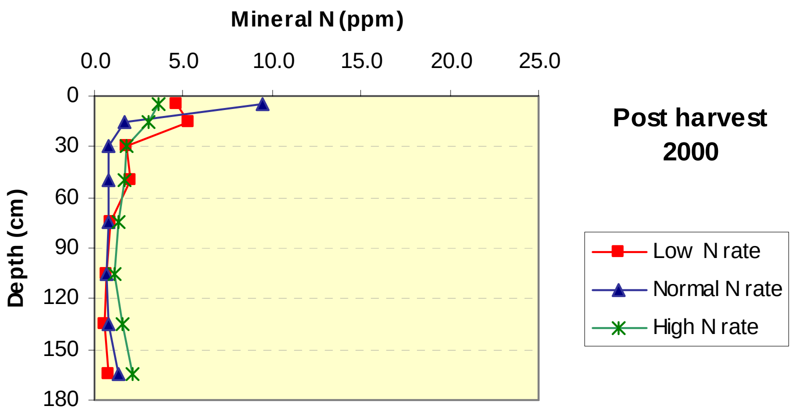


Figure 11 (e) Mineral N status (nitrate + ammonium) in block used for N strip trial on the farm of Penningh. Soil sampled after harvest in 2000.

Interpretation

Amino-N levels in the highest N rate treatment (159 kgN/ha) were over twice those of the other two N rate treatments. This response is greater than might be normally expected from the difference in N rates alone, and may in addition reflect field variability in N supply. A similar discontinuity between the two higher N rate treatments was observed in the plant crop. The higher N status of this treatment was translated to 20 to 15% higher cane and sugar yields respectively. The amino-N levels in the two lower N rate treatments were below the provisional target range suggesting the possibility of some mild N limitation to yield and consisted with the lower yields observed in these treatments. Overall the yield levels (82-97 tonnes cane/ha) were lower than those recorded in the plant crop in 1998/99 (>120 tonnes cane/ha).

There was general evidence that the N supply to the 1st ratoon was lower than that observed in the plant crop in 1998/99. No yield response to N fertiliser rates were recorded in the plant crop and amino-N levels ranged from 179 to 259 ugN/ml juice. Despite the 40% lower yield in the 1st ratoon, amino-N in the two lower N rate treatments was approximately one third lower than in the plant crop. The soil sampling indicates the two cane crops had drawn down the soil mineral N levels to the full depth of sampling (180 cm), further indication of a “tightening” in N supply.

Farm : Spyrou

Crop performance/N response

Yields increased from 90 to 96 tonnes/ha as N rates were raised from 87 to 191 kgN/ha (Figure 12a). These yield levels were 5-10% less than those recorded in the plant crop of 1998/99 (94 to 106 tonnes/ha). CCS ranged from 15.8 to15.4 (Figure 12b) and corresponding sugar yields ranged from 14.3 to 15.1 tonnes/ha (Figure 12c). Unlike the 1998/99 crop, this difference between the sugar yields in the lowest N rate and the highest N was not statistically significant in the 1st ratoon of 1999/2000.

Amino-N levels were moderate and within target range (230 - 270 ugN/ml juice) with only a small drop in amino_N levels observed at the lowest N rate (Figure 10d).

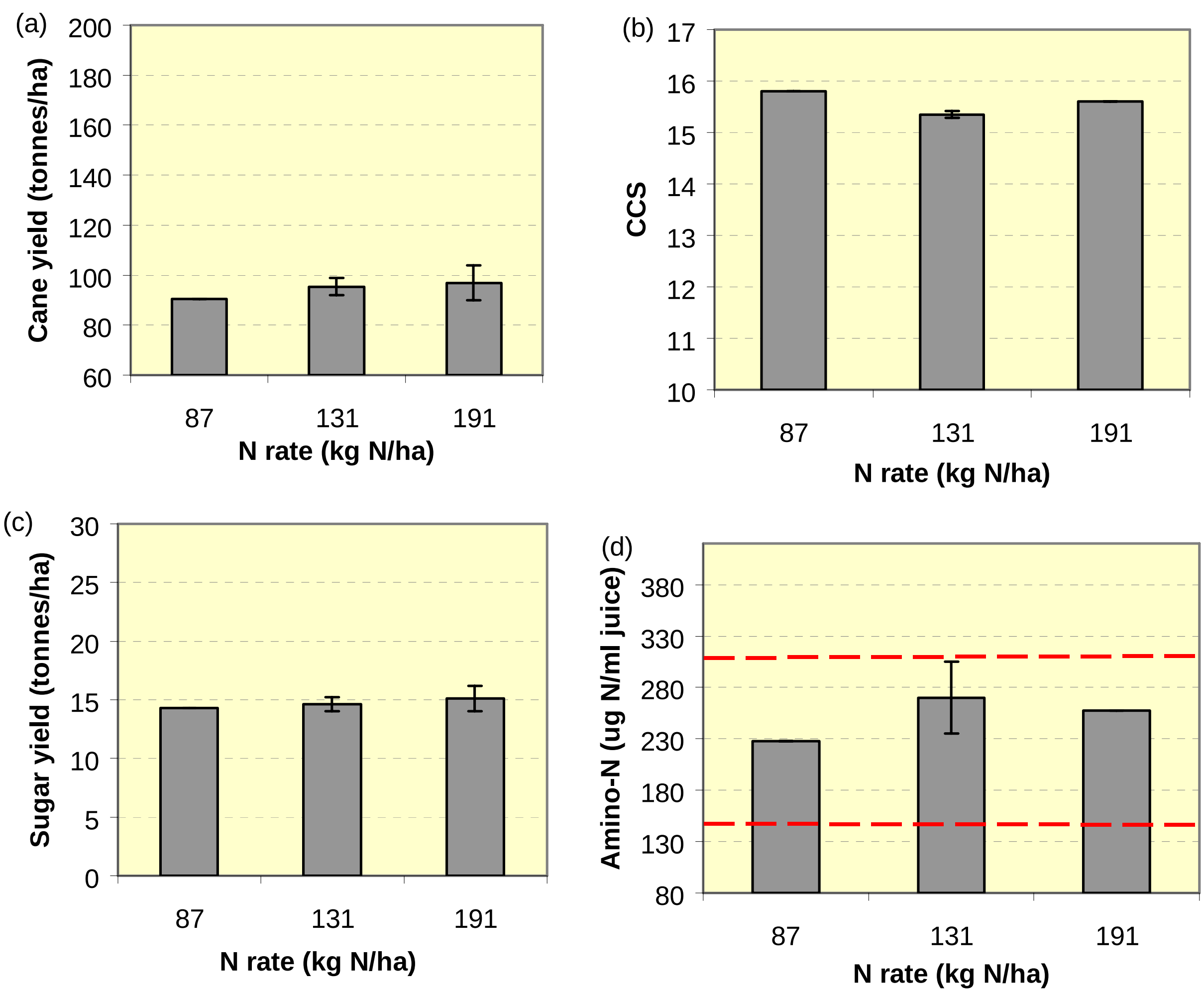


Figure 12. Results from the N strip trial at the farm of Spyrou in the 1998/99 season. (a) Fresh cane yield (tonnes/ha), (b) CCS, (c) Sugar yield (tonnes/ha), (d) Amino-N (ugN/ml juice). (dashed lines on amino-N graph indicate target range)

N in soil profile

The profile contained between 71 and 91 kg mineral N to 180cm depth when sampled after harvest in 2000 (Figure 13e). This compares with an average 52 kg mineral-N (dominantly in the nitrate form located in the top 90cm) at the time of initial soil sampling in 1998 (Figure 13a). In terms of organic N sources, this soil contained very low total N and C levels, and exhibited a relatively high C:N ratio. (Figure 13b, c, and d).

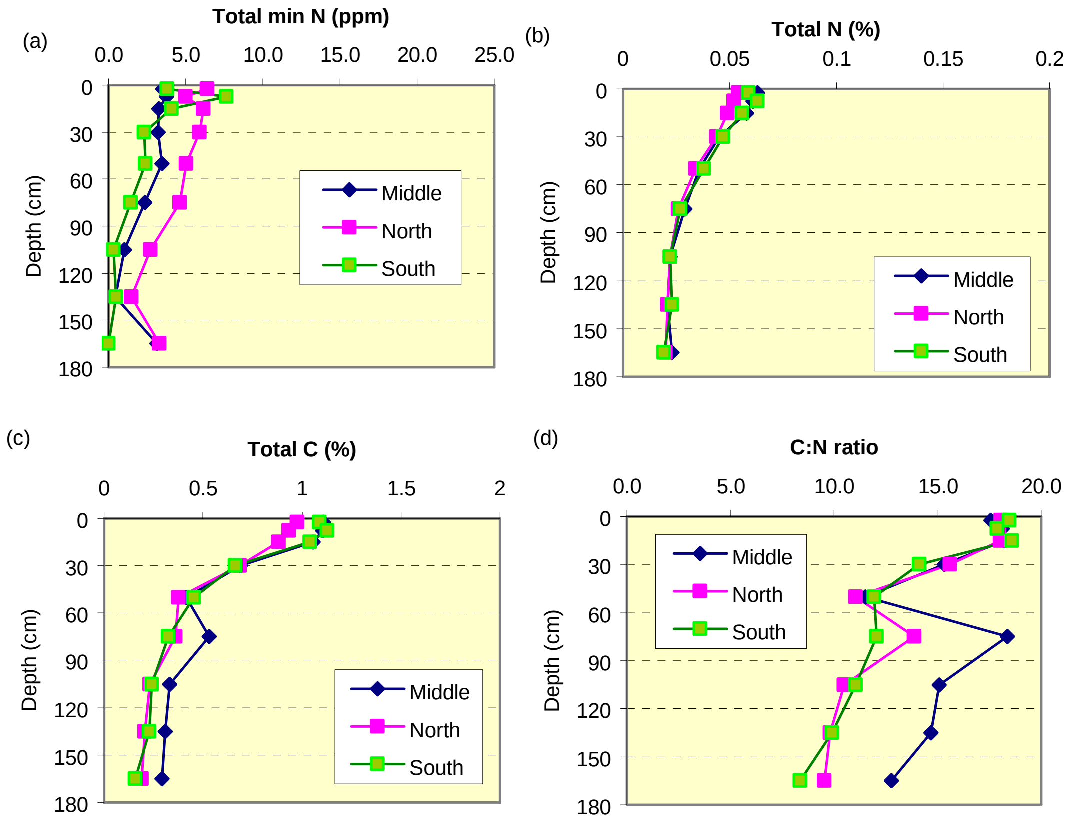


Figure 13. (a-d) Initial soil nitrogen status in block used for N strip trial on the farm of Spyrou. Soil sampled in Oct 1998. (a) total mineral N (ppm), (b) total N %, (c) total carbon %, (d) C:N ratio.

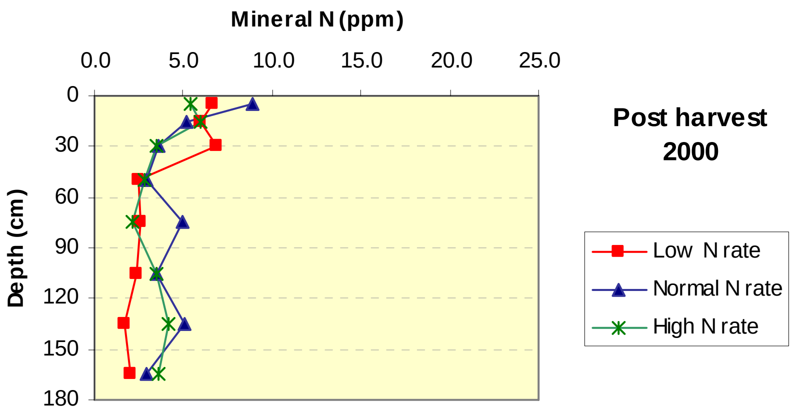


Figure 13. (e) Mineral N status (nitrate + ammonium) in block used for N strip trial on the farm of Spyrou. Soil sampled after harvest in 2000.

Interpretation

This was the only site where a significant response to N fertiliser was observed in cane or sugar yields in the first year of these trials in 1998/99. The response was in the order of a 15% yield reduction at the lowest N rate (106 kgN/ha) relative to the two higher rates. While cane and sugar yields were of the same order of magnitude in the 1999/2000 1st ratoon, the small yield increase associated with increasing the N rate was not of statistical significance. The low initial mineral-N and the low soil organic N were thought to offer some explanation of the observed response in 1998/99, but somewhat surprisingly, the response was not repeated in 1999/2000.

Amino-N levels varied little in response to N fertiliser rates, but stayed within the target range in all treatments. In 1998/99 the low N rate treatment exhibited an amino-N level of 158 ugN/ml juice and a yield depression of 15% relative to the two higher N rates. In 1999/2000 our expectation that this N limitation would intensify was not realized. Instead, amino-N levels were 228 ugN/ml juice and yield was within 7% of the higher N rate treatments. Both these results suggest a relatively better N supply status in 1999/2000, but the source of this N is unknown at this stage.

General Discussion

Expectations for more frequent and larger yield responses to the changes in N rates in the second year if these trials were not realized. While small yield differences were observed between treatments in 1999/2000, none were statistically significant (where replication allowed for this assessment). By way of comparison, a significant yield response (15% difference) was observed in only one of the six trials in 1998/99.

As pointed out in a previous report, this result illustrates the extent to which N supply in cane crops is "buffered" by N supplied from soil sources (mineral N at planting or ratooning and within-crop organic N mineralisation). The results of the soil sampling show that the crops were generally effective in utilising the large accumulation of mineral N at depth observed at a number of farms at the start of the trial (eg., at Borg, Greensil, Jensen and Penningh farms)

The degree to which sugar yields are "buffered" from current N fertiliser management is illustrated in Figure 14. Here, sugar yields at the higher and lower rates are expressed as a percent difference from the sugar yield at the intermediate N rate (i.e., the farmer's standard rate). Positive values indicate a higher yield than the farmer's standard and negative values a lower yield.

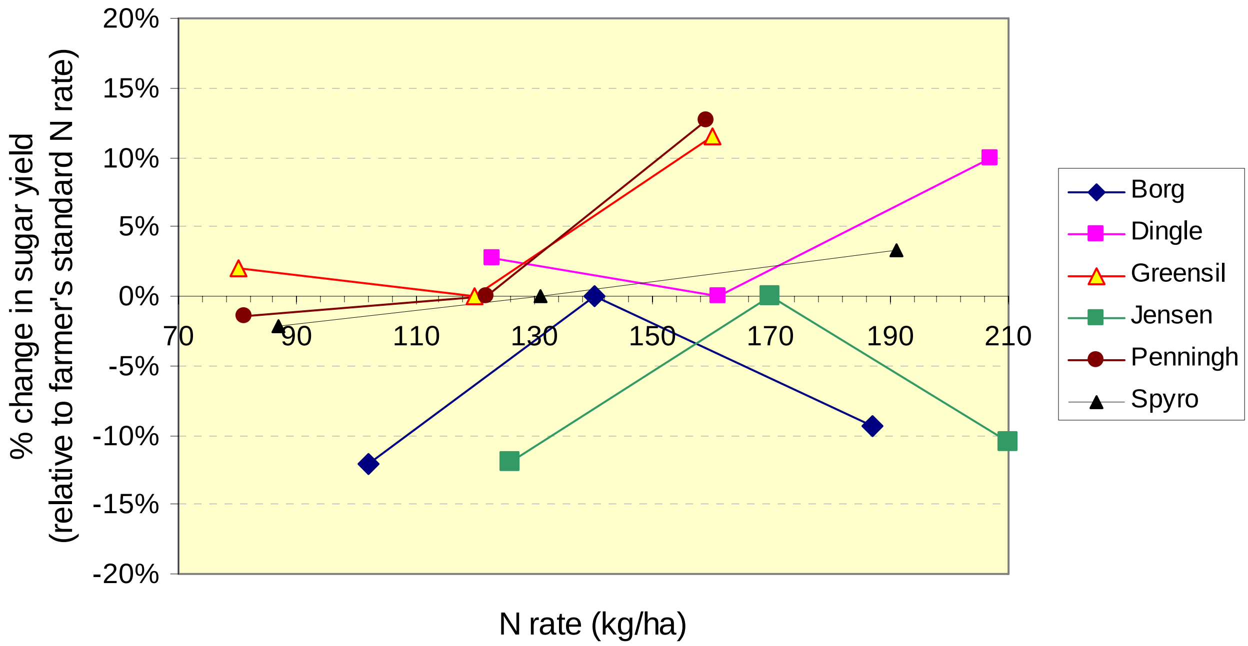


Figure 14. Percent change in sugar yield as a result of changing N rates. (expressed relative to sugar yield at the farmer's standard N rate).

Figure 14 shows that approximately half of the sugar yields arising from changes in N rate are within 3% of the sugar yield recorded at the farmers's standard rate. The remainder are within 12% of this yield. As yield differences of less than 15% are difficult to identify in replicated trials on cane farms, we are faced with considerable difficulty gathering conclusive data in these studies. In this study, not all the trials were replicated, further adding to the difficulty of assessing the significance or otherwise of very small yield differences.

The truly remarkable feature of the results presented in Figure 14 is that such large differences in N rate make such little difference in crop yield. The physiological mechanisms by which up to 100 kg N/ha can make only a 6% yield difference are uncertain. Strong relationships between N uptake and crop yield cannot apply in such circumstances. One hypothesis is that the higher N rates promote early tillering, which, after extensive self thinning of tillers, leads to very small differences in final stalk number and subsequently to very small differences in yield.

The value of the amino-N monitoring information was again mixed (Table 2). The lack of strong N responses is hampering evaluation of the amino-N monitoring for detection and interpretation of N limiting situations. Likewise the absence of situations when N supply is clearly excessive is also placing limits on the benefits that can accrue from this monitoring. The majority of the amino-N assays are located within the target zone (150 to 300 ugN/ml juice). The full range of amino-N levels recorded at the three Bundaberg mills in an earlier time is shown in Figure 15. This mill scale monitoring suggest that there are blocks of cane with much higher and much lower levels of amino-N being harvested than we have experienced in these experiments.

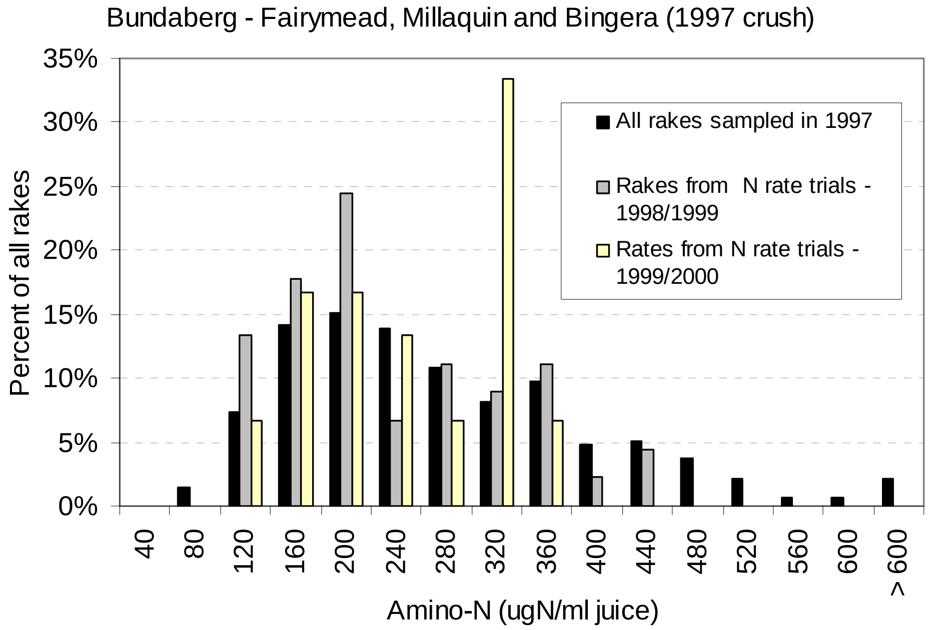


Figure 15. Frequency plot of amino-N levels measured in juice collected from rakes of cane supplied to the 3 Bundaberg mills during the 1997 crushing season in comparison to the levels measured in cane from the 3 treatments and 6 farms harvested in 1999 and 2000.

Another way of obtaining an overview of this years's results is to locate the data on the response surface presented earlier relating relative sugar yield to amino-N level in juice at harvest (Figure 1). This is done below in Figure 16. While it can be seen that the data collected in the N rate trials are generally consistent with this response surface, the range in the data is too small to really test the relationship, given the inherent variability that exists in field trials.

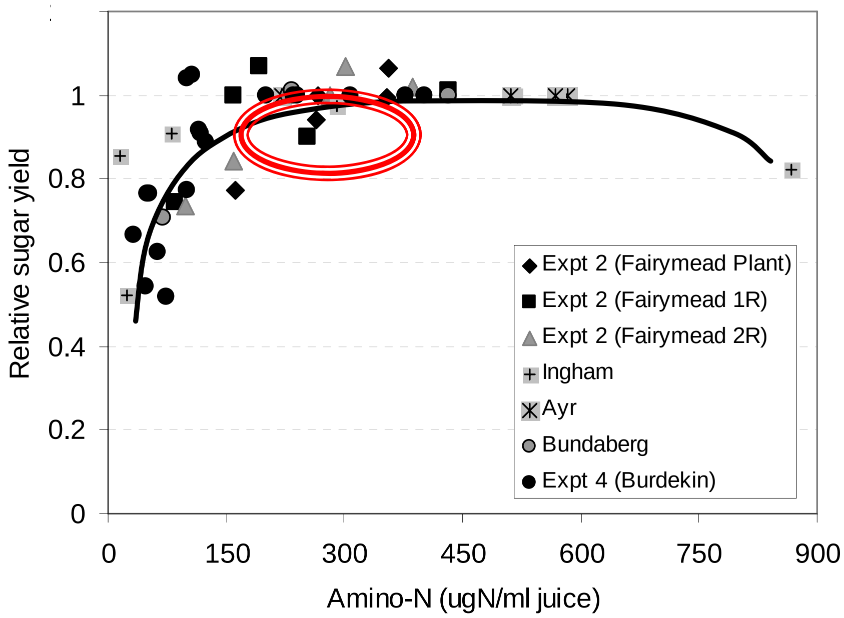


Figure 16. Response surface relating relative sugar yield to amino-N (reproduced from Figure 1). The oval shape indicates the location of data from the second year of the 6 N rate trials in the Bundaberg district.

Table 2. Summary of N rate trials : 1999/2000

Farm	Crop class	Significant N response	Amino N assessment of N supply under standard N fertiliser management	Value of information provided by amino-N monitoring
Borg #22699	1R	No	Upper boundary of target range	Indicated that the –20% treatment may be starting to be limited by N supply, although all treatments remain in the target zone.
Dingle #3172	2R	No	Within target range	Indicated that the +20% fertiliser rate was approaching an excessive N supply, something confirmed by yield results
Greensil #25056	2R	No	Lower boundary of target range	Two years of usage of low rates (particularly after a large plant crop) is running soil N supply down and N supply to crops is potentially limiting, particularly at the –20% N rate.
Jensen #10268	2R	No	High side of target range	Indicated that crops were well supplied with N at all 3 N rates. The +20% N rate was verging on the excessive.
Penningh #10057	1R	No	Below target range	N supply likely to be limiting yields at the two lower N rates and adequate at the +20% Nrate.
Spyrou #537	1R	No	Within target range	Indicated that N supply was not excessive and that current N practice was appropriate.

Acknowledgements

We are grateful for the support provided by the six growers in the Bundaberg district who have hosted these trials on their farms. We also acknowledge the efforts of the harvesting contractors and staff from the three Bundaberg mills who have assisted in the harvesting, sample collection and processing of these trials.

References

Keating, B.A. Kingston, G., Wood, A.W., Berding, N. and Muchow, R.C. (1999) Monitoring nitrogen at the mill to guide N fertilisation practice on farm. Proceedings of the Australian Society of Sugar Cane Technologists 21, 10-19.

BA Keating, G Kingston, RC Muchow AW Wood and MA Smith (2001) A monitoring system based on amino-N at harvest time to improve nitrogen management in sugarcane systems. Australian Agronomy Conference Hobart 2001.

Muchow, R.C., Robertson, M.J., Wood, A.W. and Keating, B.A. (1996) Effect of nitrogen on the time-course of sucrose accumulation in sugarcane. Field Crops Research, 47, 143-153.

Appendix 8.3: Report on Bundaberg on-farm trials in the 2000/2001 season

General Methods

N rate trials were established in the Bundaberg district over the 1998/99 season and continued over the 1999/2000 and 2000/2001 seasons. Two trials were set up in each of the Bingera, Millaquin and Fairymead mill districts. At the outset, one trial in each mill district was on a plant crop and the other a first ratoon crop. Hence in 2000/2001 we had one 2nd ratoon and one 3rd ratoon in each mill district. Three N rates were investigated in both seasons, based around the growers "standard" practice (T2) together with a reduction of approximately 20% (T1) and an increase of approximately 20% (T3). Other fertilisation practices were based on growers' standard practices, and in all cases trials received what amounts to standard industry rates of K, P and S.

The plots were large, typically based on 6 to 16 rows, 200 to 300 m long. A number of trials were formally replicated based on randomised complete block designs (Table 1) while others did not contain formal replication in the field, but had multiple sampling take place within a treatment. Hand cut samples (based on 9 stalks per plot) were cut prior to machine harvesting. These samples were processed via a Jeffco cutter/grinder and juice extraction in a Carver Press. Machine harvests were consigned to the mill as separate rakes for replications and treatments and yields and CCS obtained from mill data. Juice samples (first expressed juice after No. 1 mill) were collected for all samples at the mill and frozen immediately for subsequent amino-N analysis (using standard methods outlines by Keating et al 1999).

Further details of these trials are provided in the reports prepared for the first and second seasons (Appendix 8.1 and 8.2 respectively) and will not be reported here.

Results

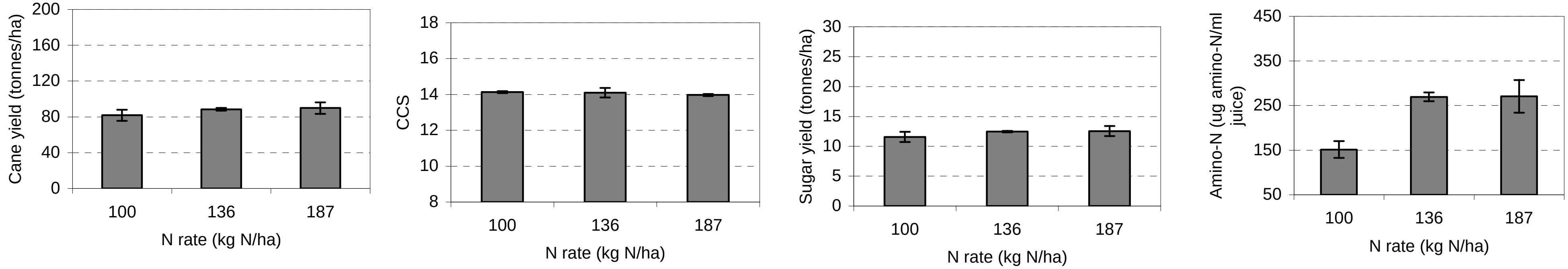
The results for the third year of these trials are presented in Figures 1 to 6 in terms of cane yield, CCS, sugar yield and amino-N response to the variation in N fertiliser rate. Also shown for comparison is the same set of measurements for the first and second years of the trial.

These results are discussed in full in the main body of this report (section 5.4)

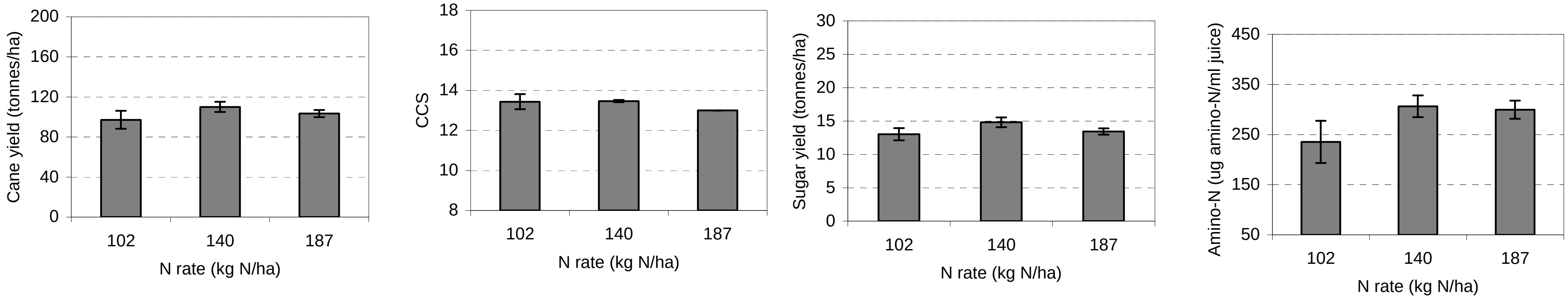
Borg J

Figure 1. Responses observed on the Borg farm to variation in N fertiliser rate over three seasons.

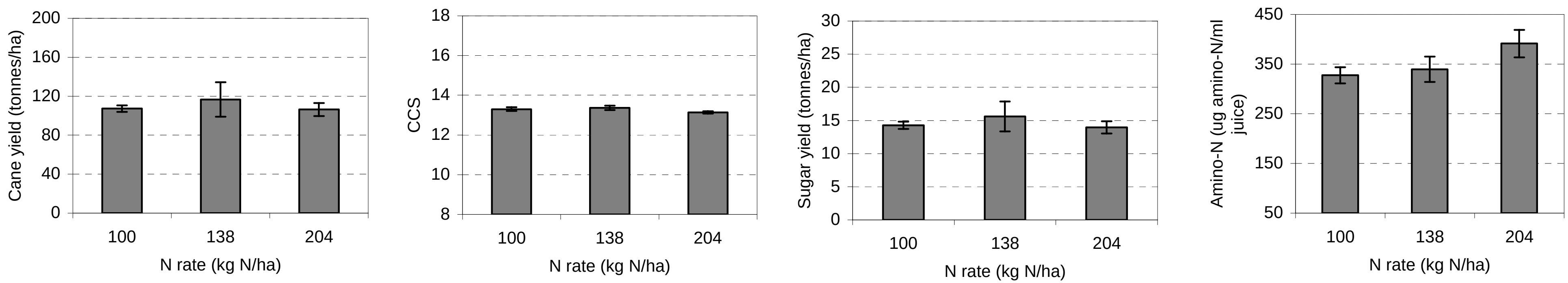
2000/2001



1999/2000



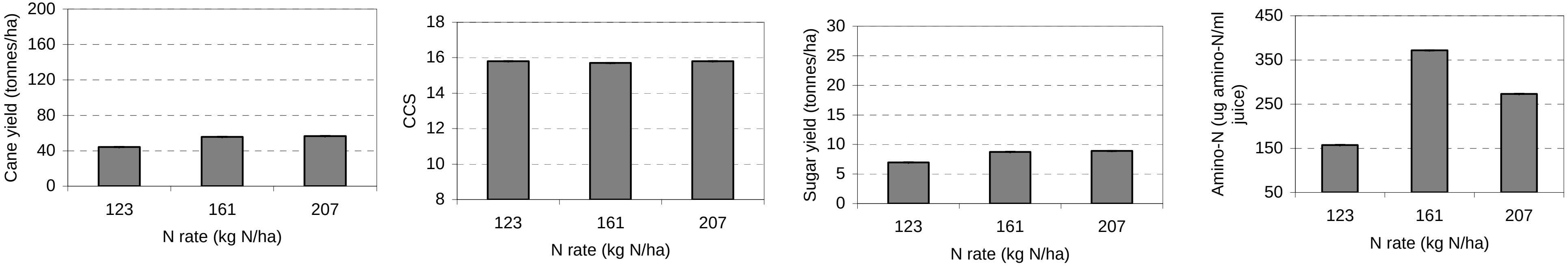
1998/1999



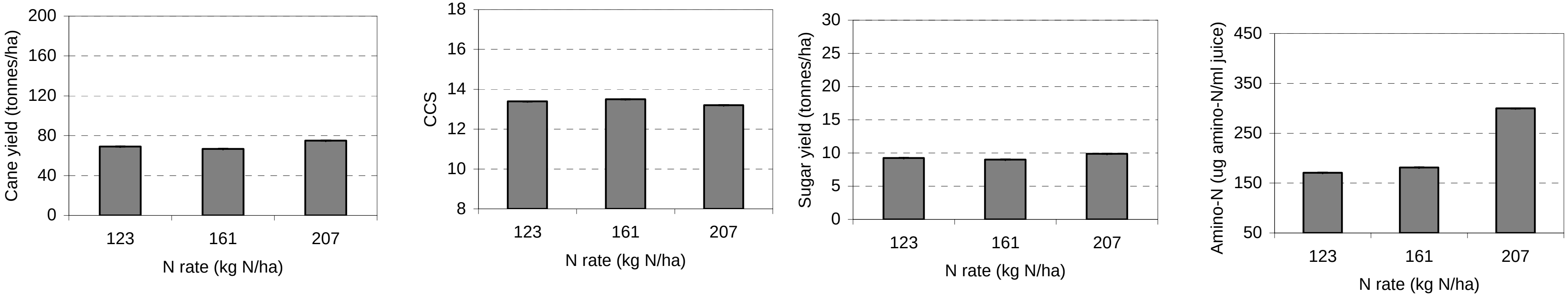
Dingle A

Figure 2. Responses observed on the Dingle farm to variation in N fertiliser rate over three seasons.

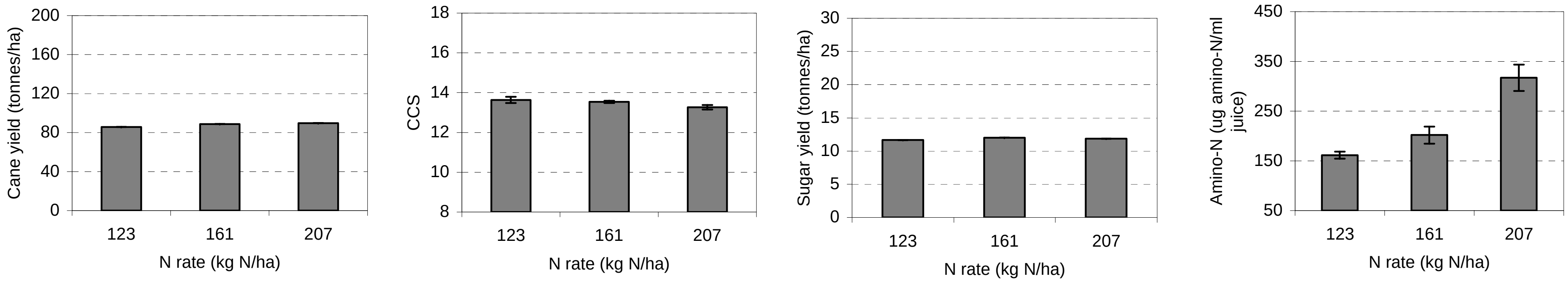
2000/2001



1999/2000



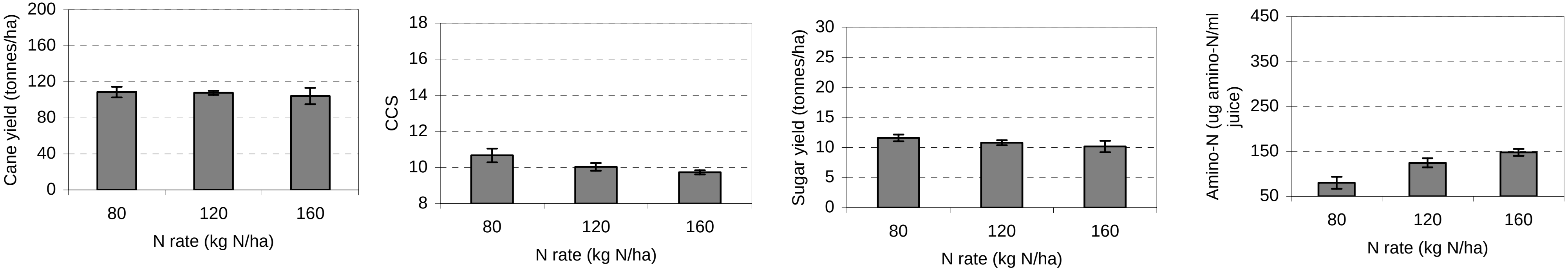
1998/1999



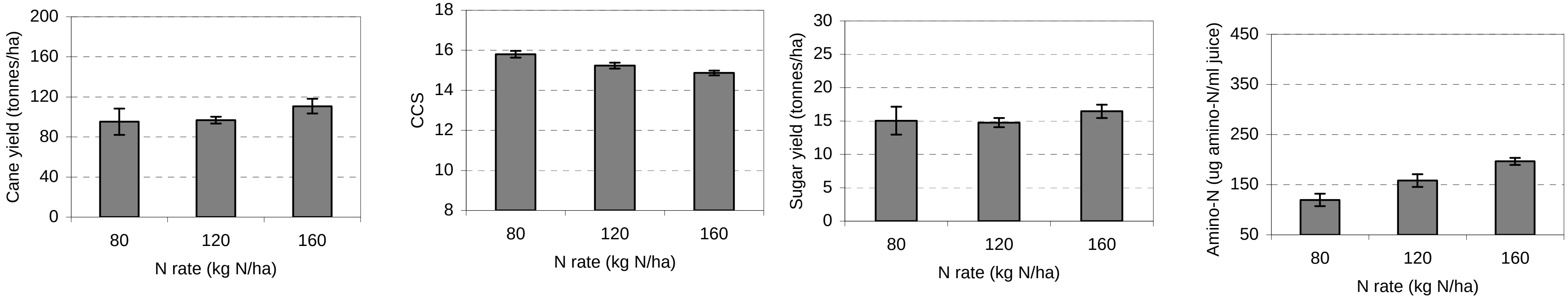
Greensil L

Figure 3. Responses observed on the Greensil farm to variation in N fertiliser rate over three seasons.

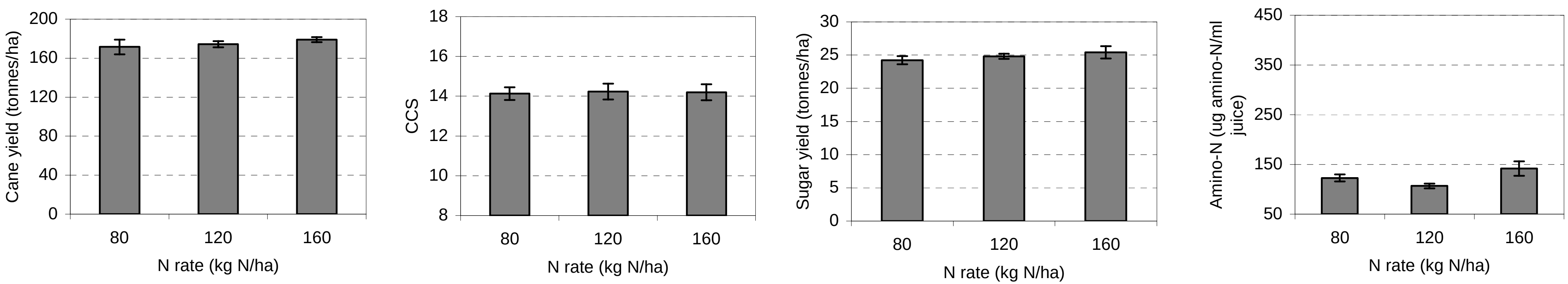
2000/2001



1999/2000



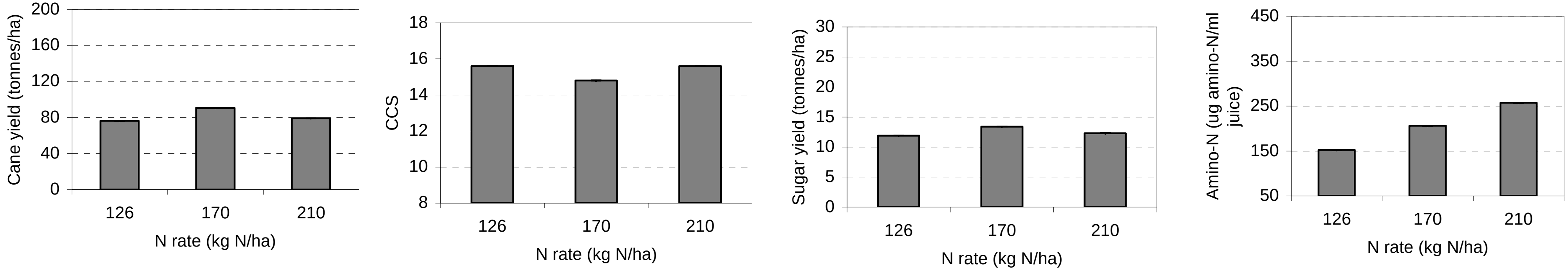
1998/1999



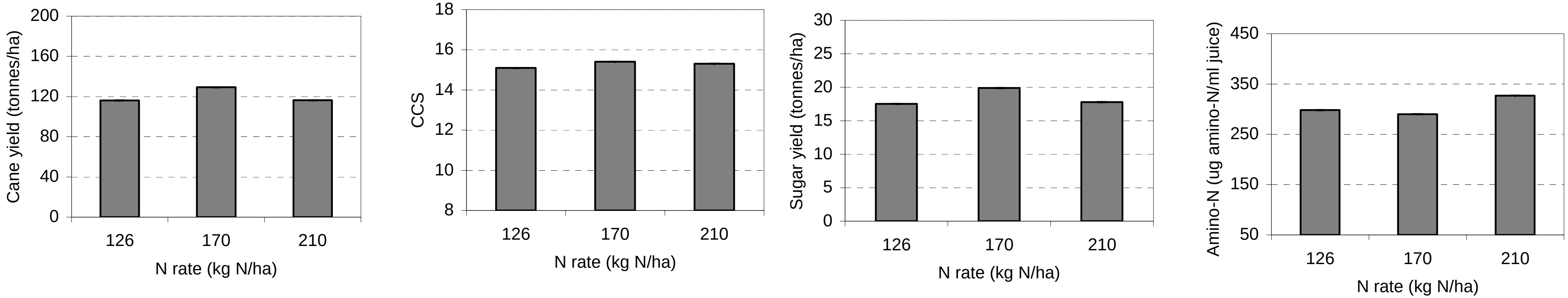
Jensen R

Figure 4. Responses observed on the Jensen farm to variation in N fertiliser rate over three seasons.

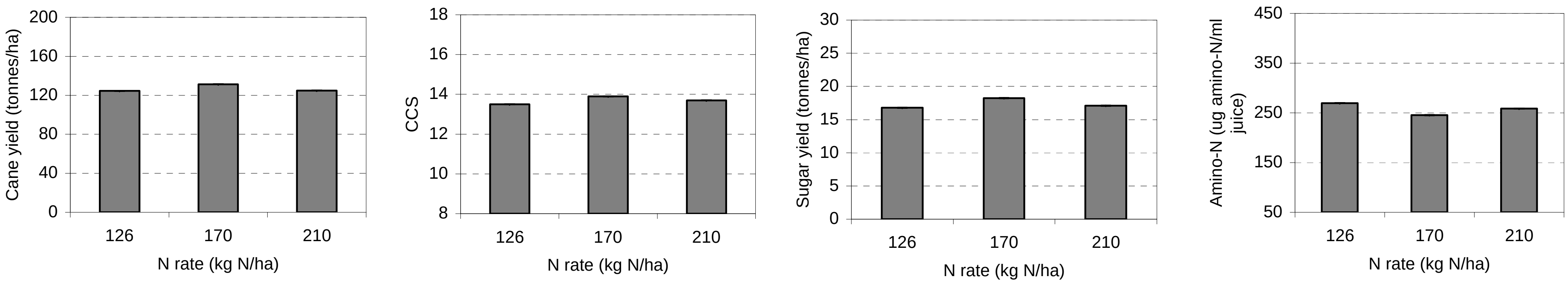
2000/2001



1999/2000



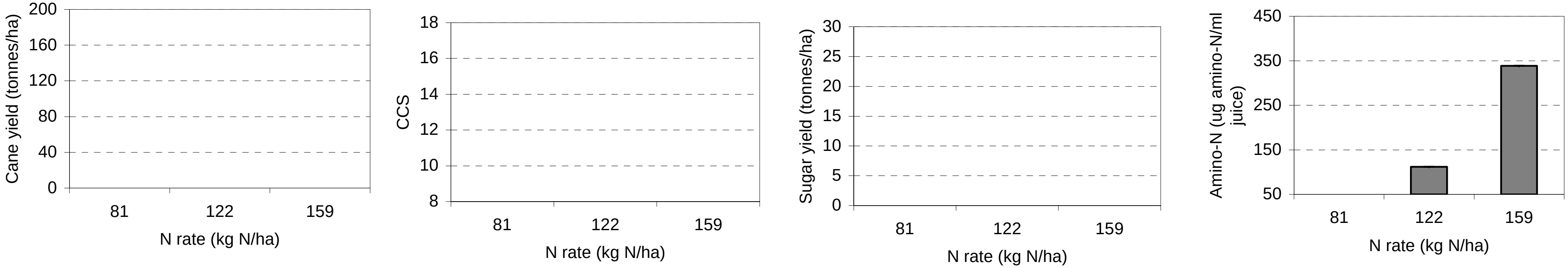
1998/1999



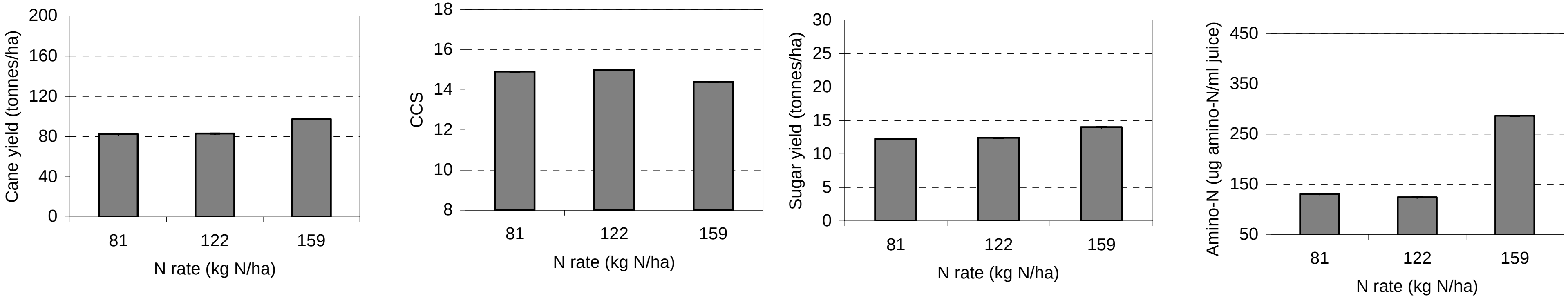
Penningh R

Figure 5. Responses observed on the Penningh farm to variation in N fertiliser rate over three seasons.

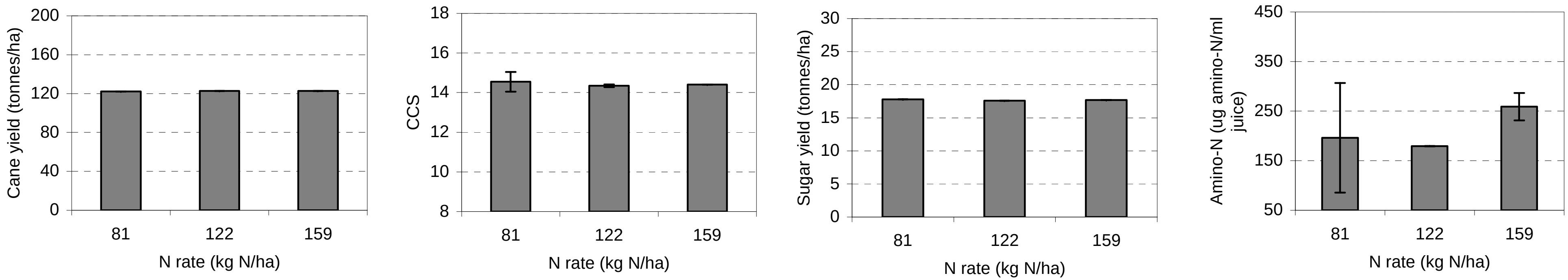
2000/2001



1999/2000



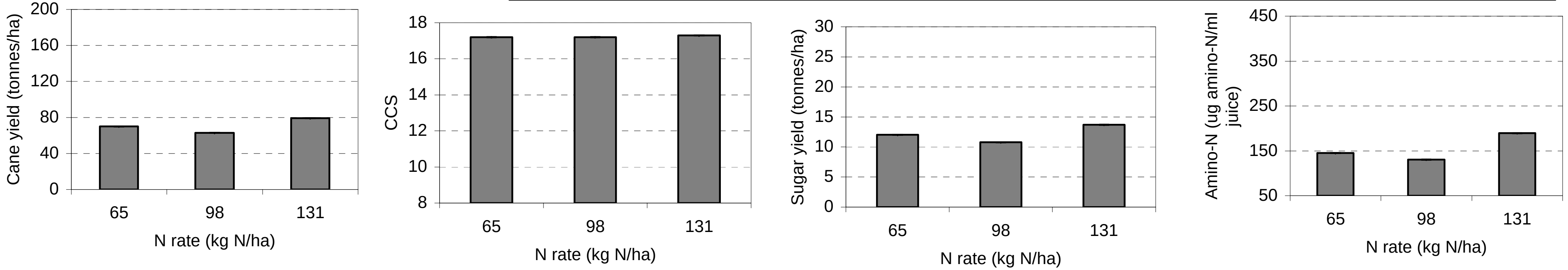
1998/1999



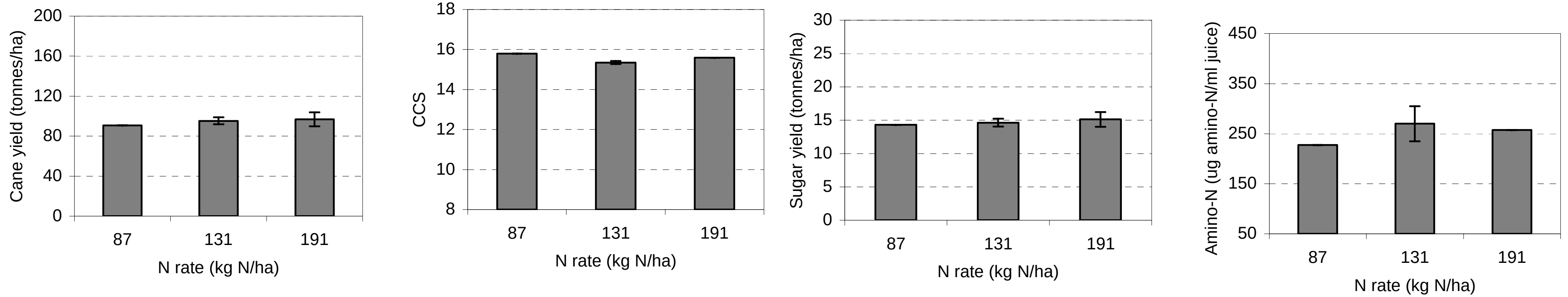
Spyrou E

Figure 6. Responses observed on the Spyrou farm to variation in N fertiliser rate over three seasons.

2000/2001



1999/2000



1998/1999