ALTERNATIVE NITROGEN MANAGEMENT STRATEGIES FOR SUGARCANE PRODUCTION IN AUSTRALIA: THE ESSENCE OF WHAT THEY MEAN

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Abstract

THE Australian sugar industry currently faces a combination of escalating input costs, moderately low sugar prices, decreasing cane supply and the requirement to illustrate its commitment to being environmentally responsible. This paper provides a summary of the different nitrogen (N) management strategies (grower-developed, traditional, SIX EASY STEPS and N Replacement) for sugarcane production, and reports on an assessment of the effectiveness of these different approaches using trial data from Macknade and Tully. It is important to ensure that on-farm strategies enable growers to remain profitable and sustainable, particularly in terms of the current circumstances. This can only be achieved if they select management options that allow maintenance of yields (cane and sugar) in combination with inputs that are both cost effective and environmentally responsible. These objectives are achievable when the SIX EASY STEPS approach is used. Alternative approaches, that are either wasteful of nutrient inputs (and are therefore environmentally unacceptable) or are likely to lead to productivity losses (and are therefore likely to affect industry viability) should not be regarded as appropriate N input strategies for sugarcane production.

Introduction

The Australian sugar industry currently faces a combination of different circumstances that has the potential to affect its longer-term viability. Each of these, escalating input costs, continuing low sugar prices, decreasing crop size and the requirement to illustrate its commitment to being environmentally responsible, is a reason for concern on its own. However, the combination of these circumstances puts additional pressure on the industry and there is a need to deal with this combination of issues at various levels within the sugarcane production and processing cycle.

Strategies need to be assessed and/or developed and then implemented to ensure that they have a positive effect on the industry's future productivity, profitability and long-term sustainability.

In particular, nutrient management strategies need to be assessed in terms of the background scenario described above. The assessment of the different nitrogen (N) management strategies is especially relevant because of the widespread use of this essential plant nutrient across the Australian sugarcane industry and the different views regarding N application rates (Schroeder *et al*., 2008). These strategies cover both the recommended application rates (guidelines) and the amounts of N actually applied on-farm.

Several N application rate strategies occur within the industry: the so-called traditional (see below), the grower-developed, the SIX EASY STEPS and the N-replacement strategies. These approaches have developed with time and are aimed at different overall objectives and are based on different N input criteria.

This paper provides a summary of these different strategies and reports on an assessment of the effectiveness of the four N input strategies in terms of productivity (maintenance of yield), profitability (calculated industry net returns) and environmental implications (estimated potential off-site losses).

Summary of different N management strategies

The fundamental objectives and the criteria of the N management strategies are shown in Table 1.

Table 1—Different N management strategies used within the Australian sugar industry.

N strategy	Objectives	N input criteria	Reference
Traditional	Maximising productivity and linking N application rates to sugar price	Averaged industry regional production functions	Chapman (1994), Schroeder *et al.* (1998)
Grower-developed	Minimising risk of yield losses	In excess of 'traditional' rate or personal preferences	Johnson (1995), Wegener (1990)
SIX EASY STEPS	Sustaining sugarcane production; profitability in combination with environmental responsibility	District yield potentials and soil specific N mineralisation index	Schroeder *et al.*. (2005), Wood *et al.* (2003)
N Replacement	Minimising N application rates. Focus on the environment and N-use efficiency	N input based on yield and N off-take of previous crop	Thorburn *et al.*. (2007, 2008)

The 'traditional' approach formed the basis of the N guidelines that were promoted by the Bureau of Sugar Experiment Stations (now BSES Limited). These guidelines were conservative in nature with suggested N rates probably being higher than needed in most cases. Their general nature (average recommendations across non-Burdekin regions and soils) also made them vulnerable to doubt by growers who were not convinced they were appropriate for use on their own farms. They were also questioned by environmentalists and government agencies who were concerned about off-site effects. Being risk adverse, growers often reacted to the traditional guidelines by developing their own N management strategies that were aimed at minimising the risk of yield losses. This kind of approach (the 'grower-developed' strategy) often meant that even more N was applied to sugarcane than recommended by the 'traditional' guidelines.

During the 1990s, attention was focused on the need for nutrient management to aim at sustainable sugarcane production rather than being based almost entirely for productivity (Kingston and Lawn, 2003). This meant that alternative nutrient (especially N) strategies were needed to enable profitable sugarcane production in combination with minimal on- or off-site effects (Wood *et al.*, 1997; Schroeder *et al.*, 1998). As a result, the SIX EASY STEPS program was developed. It is based on the underlying principles that sustainable nutrient management is only possible if soils are managed according to their intrinsic properties, the nutrient processes that occur in soils and the interaction of applied nutrients with soils (Schroeder *et al.*, 2006).

In addition to this development, researchers working within the Commonwealth Scientific and Industrial Research Organisation (CSIRO) developed another strategy to refine N inputs. Their approach (N replacement concept) aims at minimising N inputs by using the yield of the previous sugarcane crop and a relatively low multiplier for determining the N input rate per crop (Thorburn *et al*., 2008).

Selection of appropriate N input strategies on-farm is important, especially with current high input costs and moderately low sugar prices. These strategies become even more critical when viewed in combination with the need for environmental responsibility (especially in terms of the Great Barrier Reef and the Reef Rescue strategy) and the security of cane supply (to ensure viability of sugar mills). It is therefore important that growers make informed decisions about fertiliser (and especially N) application rates.

Procedure

The four N input approaches were assessed using data from replicated N-rate trials conducted at Macknade and Tully over a crop cycle (Table 2). Soil samples were collected prior to the treatment applications. Selected site data and brief descriptions of the different crop management strategies that were in place at the trial locations prior to commencement of the trial are shown in Table 3.

Cumulative response curves for both cane and sugar yields were then produced by summing yields from successive crops within the crop cycle and plotting these yields against cumulative N rates. These curves were used to calculate industry partial net returns for each of the N management strategies highlighted in Table 1 according to the following equation:

Industry partial net return = (sugar yield x price of sugar) – (fertiliser cost x application rate (kg/ha) – (cane yield x estimated harvesting costs plus levies) …….. (1)

This equation was chosen because it reflects the total net return (grower and miller components). An alternative was to use a generalised commercial cane sugar content (CCS) based cane payment formula, but this would have reflected only the net return to the grower.

Table 2—Details of trials and N treatments used.

Site	Crop cycle	Crops	Treatments (kg N/ha)
Macknade	Plant crop and four ratoons	Plant crop	0, 75, 150, 225
		Ratoon crops	0, 75, 150, 225
Tully	Plant crop and three ratoons	Plant crop	0, 50, 100, 150
		Ratoon crops	0, 80, 160, 240

Table 3—Selected site data and details of crop management prior to the trials.

Site	Soil type[1]	Crop management prior to trial	$pH_{(water)}$	Org C (%)	ECEC (me%)
Macknade	Chernic Tenosol (River Bank[2])	Two seasons of cane grown without N fertiliser	5.30	0.7	9.3
Tully	Redoxic Hydrosol (Coom[3])	Green cane trash blanketed cane, with a bare fallow prior to planting. Previous crop produced 117 t cane/ha	5.28	1.2	4.0

[1]Australian Soil Classification (Isbell, 1996), with local soil name in brackets
[2] CSR Technical Field Department soil name (Wood *et al.,* 2003))
[3] Soil series (Murtha, 1986)

Results and discussion

All cumulative cane and sugar responses to applied N (Macknade: Figures 1 and 2, respectively, and Tully: Figures 3 and 4, respectively), obtained by progressively summing the yields from harvested crops, were significant ($P < 0.05$), except the sugar yield of the plant crop at Tully.

These responses to applied N are interesting, as the two trials were conducted on different soil types and followed different cropping histories prior to planting (Table 3).

The Macknade site had been 'run down' in terms of residual N in the soil by growing cane for two seasons without applied N.

As the soil at this site had a soil organic carbon (C) content of 0.7%, the potential for mineralising N during the unfertilised period was low (Schroeder and Wood, 2001).

The trial was planted as replant cane (cane established without a fallow period). The Tully site had been fertilised according to normal practices within a green cane trash blanked system prior to the trial being planted after a bare fallow period.

The final ratoon in the previous crop cycle yielded 117 t cane/ha. The soil at this site had a soil organic C content of 1.2% with a moderate to moderately low potential to mineralise N.

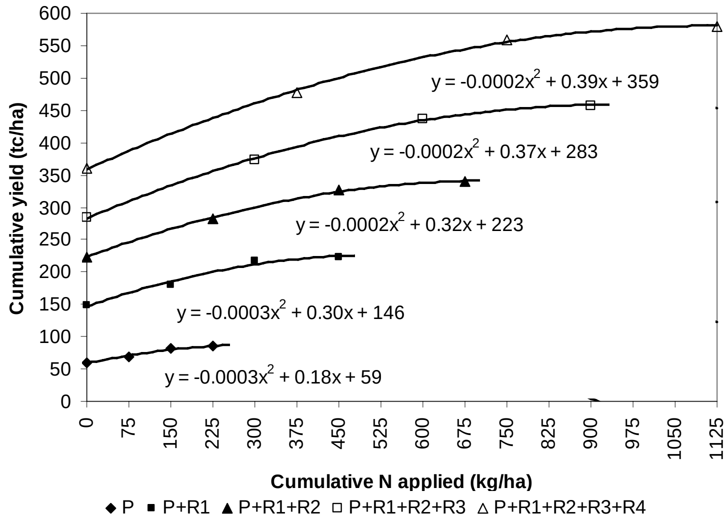
The responses to applied N at both sites, particularly in ratoon crops, suggested that large reserves of N (in mineral and /or organic forms) were not present in the soils at these sites.

Therefore, the soils did not have the capacity to act as a buffer to enable reduced amounts of N to be applied as fertiliser, if sugarcane productivity were to be maintained.

The cumulative cane and sugar yield response curves (relationships shown within Figures 1, 2, 3 and 4) enabled yields to be determined for any N input strategy by progressively moving from one response curve to the next (as the crop cycle advanced).

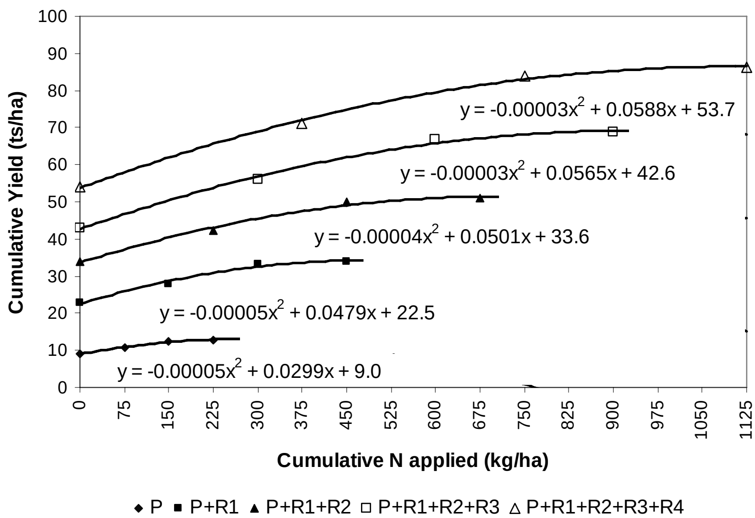
The estimated yields (cane and sugar) for the grower-developed, traditional, SIX EASY STEPS and N Replacement approaches that were tested using the Macknade data are shown in Tables 4 and 5.

In a similar manner, the estimated yields (cane and sugar) for the different approaches that were tested using Tully data are shown in Tables 6 and 7.



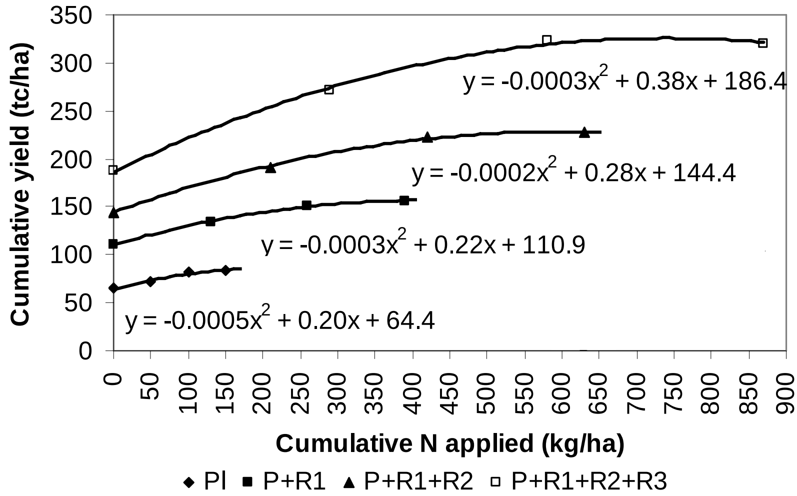
P: SE = 2.65; LSD(0.05) = 7.86
P+R1: SE = 4.80; LSD(0.05) = 14.26
P+R1+R2: SE = 7.85; LSD(0.05) = 23.33
P+R1+R2+R3: SE = 9.60; LSD(0.05) = 28.53
P+R1+R2+R3+R4: SE = 11.54; LSD(0.05) = 34.28

Fig. 1—Macknade trial: cumulative cane yield responses to N applied over a crop cycle (plant crop (P) and four ratoons (R), with SE and LSD values from the analysis of variance (after Schroeder *et al.*, 2008).



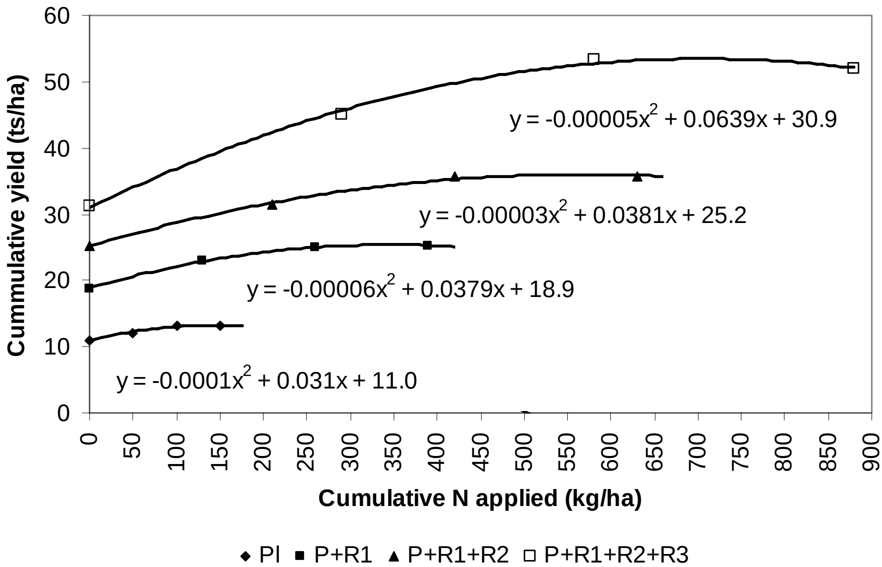
P: SE = 0.46; LSD(0.05) = 1.37
P+R1: SE = 0.83; LSD(0.05) = 2.47
P+R1+R2: SE = 1.23; LSD(0.05) = 3.65
P+R1+R2+R3: SE = 1.42; LSD(0.05) = 4.21
P+R1+R2+R3+R4: SE = 1.76; LSD(0.05) = 5.16

Fig. 2—Macknade trial: cumulative sugar yield responses to N applied over a crop cycle (plant crop (P) and four ratoons (R), with SE and LSD values from the analysis of variance.



P: SE = 2.57; LSD(0.05) = 8.90
P+R1: SE = 4.38; LSD(0.05) = 15.17
P+R1+R2: SE = 5.41; LSD(0.05) = 18.73
P+R1+R2+R3: SE = 7.47; LSD(0.05) = 25.83

Fig. 3—Tully trial: cumulative cane yield responses to N applied over a crop cycle (plant crop (P) and three ratoons (R), with SE and LSD values from the analysis of variance.



P: SE = 0.50; LSD(0.05): NS
P+R1: SE = 0.84; LSD(0.05) = 2.89
P+R1+R2: SE = 0.89; LSD(0.05) = 3.10
P+R1+R2+R3: SE = 1.23; LSD(0.05) = 4.27

Fig. 4—Tully trial: cumulative sugar yield responses to N applied over a crop cycle (plant crop (P) and three ratoons (R), with SE and LSD values from the analysis of variance.

Table 4—Macknade trial: N inputs and cumulative cane yields for each of the N management strategies (after Schroeder *et al.*, 2008).

	Grower-developed			Traditional			SIX EASY STEPS			N Replacement		
	N applied per Crop	Cumulative values		N applied per crop	Cumulative values		N applied per crop	Cumulative values		*N applied per crop	Cumulative values	
		N applied	Yield		N applied	Yield		N applied	Yield		N applied	Yield
	(kg/ha)	(kg/ha)	(tc/ha)	(kg N/ha)		(tc/ha)	(kg N/ha)		(tc/ha)	(kg N/ha)		(tc/ha)
Plant	180	180	81	160	160	80	150	150	79	**90	90	72
R1	180	360	217	160	320	213	150	300	211	72	162	188
R2	180	540	340	160	480	333	150	450	328	116	278	298
R3	180	720	444	160	640	436	150	600	432	110	388	395
R4	180	900	550	160	800	545	150	750	541	98	485	502

* 1 kg N/t cane in previous crop (Thorburn *et al.*, 2007)
** Cane yield of 90 t/ha assumed for the last ratoon of the previous crop cycle. No allowance was made for N removal in the penultimate ratoon.

Table 5—Cumulative sugar yields (t sugar/ha) and calculated industry partial net returns for the Macknade trial.

Cumulative crop	Grower-developed	Traditional	SIX EASY STEPS	N Replacement
	Cumulative yield (t sugar/ha)			
P	12.7	12.5	12.3	11.3
P+R1	33.3	32.8	32.4	29.0
P+R1+ R2	49.0	48.5	48.1	44.5
P+R1+R2+R3	67.8	66.5	65.7	60.0
P+R1+R2+R3+R4	82.3	81.5	80.9	75.2
*Industry net return ($/ha)	20832	20864	20825	19916
Average industry net return ($/ha/year)	4166	4173	4165	3993
Difference in industry net return from SIX EASY STEPS approach ($/ha/year)	1	8	–	–182

* Assumptions: Sugar price = $330/tonne, cost of N = $2.60/kg, harvesting costs = $7.25/tonne of cane,

At Macknade, the ‘grower-developed’ approach (180 kg N/ha/crop) yielded 550 t cane/ha (Table 4) and 82.3 t sugar/ha (Table 5) over the crop cycle. This resulted in an industry net return of $20832/ha over 5 years or an average of $4166/ha/year (Table 5).

The ‘traditional’ approach (160 kg N/ha/crop) resulted in a total crop cycle yield of 545 t cane/ha and 81 t sugar/ha, with an average industry net return of $4173/ha/year. The SIX EASY STEPS N input rate (150 kg N/ha/crop) produced an estimated crop of 541 t cane/ha and 80.9 t sugar/ha for the crop cycle, with a calculated industry net return of $4165/ha/year. The N Replacement strategy, with N inputs varying according to the yield of the previous crop (Table 4), resulted in a total crop cycle yield of 502 t cane/ha and 75.2 t sugar/ha. The calculated industry net return in this case was $3993/ha/year.

Table 6—Tully trial: N inputs and cumulative cane yields for each of the N management strategies.

	Grower-developed			Traditional			SIX EASY STEPS			N Replacement		
	N applied per Crop	Cumulative values		N applied per crop	Cumulative values		N applied per crop	Cumulative values		*N applied per crop	Cumulative values	
		N applied	Yield		N applied	Yield		N applied	Yield		N applied	Yield
	(kg/ha)		(tc/ha)	(kg N/ha)		(tc/ha)	(kg N/ha)		(tc/ha)	(kg N/ha)		(tc/ha)
Plant	150	150	84	120	120	82	120	120	82	**117	117	81
R1	180	330	151	160	280	150	140	260	148	81	198	143
R2	180	510	236	160	440	229	140	400	225	62	260	204
R3	180	690	304	160	600	305	140	540	303	61	321	277

* 1 kg N/t cane in previous crop (Thorburn *et al.*, 2007)
** Cane yield of 117 t/ha for the last ratoon of the previous crop cycle

Table 7—Cumulative sugar yields (t sugar/ha) and calculated industry partial net returns for the Tully trial.

Cumulative crop	Grower-developed	Traditional	SIX EASY STEPS	N Replacement
	Cumulative yield (t sugar/ha)			
Plant	13.4	13.2	13.2	13.2
Plant + R1	24.8	24.8	24.8	24.7
Plant + R1 + R2	36.4	36.2	35.6	33.1
Plant + R1 + R2 + R3	51.2	51.3	50.9	46.3
*Industry net return ($/ha)	12386	12645	12687	11973
Average industry net return ($/ha/year)	3114	3184	3198	3027
Difference in industry net return from SIX EASY STEPS approach ($/ha/year)	–75	– 10	–	–190

* Assumptions: Sugar price = $330/t, cost of N = $2.60/kg, harvesting costs = $7.25/t of cane,

At Tully, the 'grower-developed' approach (150 kg N/ha for the plant crop and 180 kg N/ha/ratoon crop) yielded 304 t cane/ha (Table 6) and 51.2 t sugar/ha (Table 7) over the crop cycle. The industry net return in this case was $4114/ha/year (Table 7). The 'traditional' approach (120 kg N/ha for the plant crop, and 160 kg N/ha for each of the ratoons) resulted in a total crop cycle yield of 305 t cane/ha and 51.3 t sugar/ha. The average industry net return was $3184/ha/year.

The SIX EASY STEPS approach (120 kg N/ha for the plant crop and 140 kg N/ha for each ratoons) yielded 303 t cane/ha and 50.9 t sugar/ha for the crop cycle, with an average industry net return of $3198/ha/year. The N Replacement strategy (N inputs rates as shown in Table 6 and calculated according to the size of the previous crop), resulted in a total crop cycle yield of 277 t cane/ha and 46.3 t sugar/ha. The calculated industry net return was $3027/ha/year.

An alternative economic approach using partial budgets was used to check the validity of the 'industry partial net return' calculation. The Tully data used in this alternative approach gave identical results to those above.

Conclusions

The four N input strategies described and assessed within two different circumstances resulted in different levels of productivity (cane and sugar yield) and profitability (as measured by the industry net return in each case and crop size). The higher overall industry net returns that were obtained for the Macknade trial were a reflection of the higher yields that were achieved compared to those at Tully. Nonetheless, the different strategies that were assessed gave rise to different productivity and profitability outcomes both within and across sites.

At Macknade, the grower-developed, traditional and SIX EASY STEPS approaches resulted in similar average industry net returns (Table 5). The difference in industry net return from the SIX EASY STEPS approach was slightly in favour of the 'traditional' approach ($8/ha/crop). However, the N replacement resulted in a net industry return $182/ha/crop less than the SIX EASY STEPS strategy. In this case the SIX EASY STEPS approach is the more appropriate than the grower-developed and the traditional approaches, as yields were generally maintained, but inputs were lower, with less chance of off-site movement. In relation to the N replacement strategy, N fertiliser inputs were considerably lower than that of the SIX EASY STEPS approach, but yield penalties (both cane and sugar) resulted in substantially lower profitability.

The Tully data (Table 7) showed that the SIX EASY STEPS approach was the most favourable in terms of the calculated industry net return. The 'grower-developed' approach resulted in a reduced profit of $75/ha/crop compared to the SIX EASY STEPS. The N Replacement strategy gave rise to the lowest industry net return ($190/ha lower than that of the SIX EASY STEPS approach). The higher N inputs associated with the 'grower-developed' approach were not warranted because they did not produce substantially higher yields compared with the SIX EASY STEPS strategy. As with the Macknade scenario, the N Replacement approach resulted in lower N inputs, but with resulting lower cane and sugar yields.

In terms of the current circumstances (escalating input costs, moderately low sugar prices, decreasing cane supply and environmental pressures), it is important to ensure that on-farm strategies enable growers to remain profitable and sustainable. This can only be achieved if they select management options that allow maintenance of yields (cane and sugar) in combination with inputs that are cost effective and are environmentally responsible.

Our assessment shows that these objectives are possible when the SIX EASY STEPS approach is used. Alternative approaches, that are either wasteful of nutrient inputs (and are therefore environmentally unacceptable) or that lead to productivity losses (and are therefore likely to affect industry viability) should not be seriously considered as appropriate N inputs strategies for sugarcane production.

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