FINAL REPORT – SRDC PROJECT GGIP050

IMPROVING SOYBEAN AND NITROGEN MANAGEMENT IN SUBTROPICAL NSW CANE SYSTEMS

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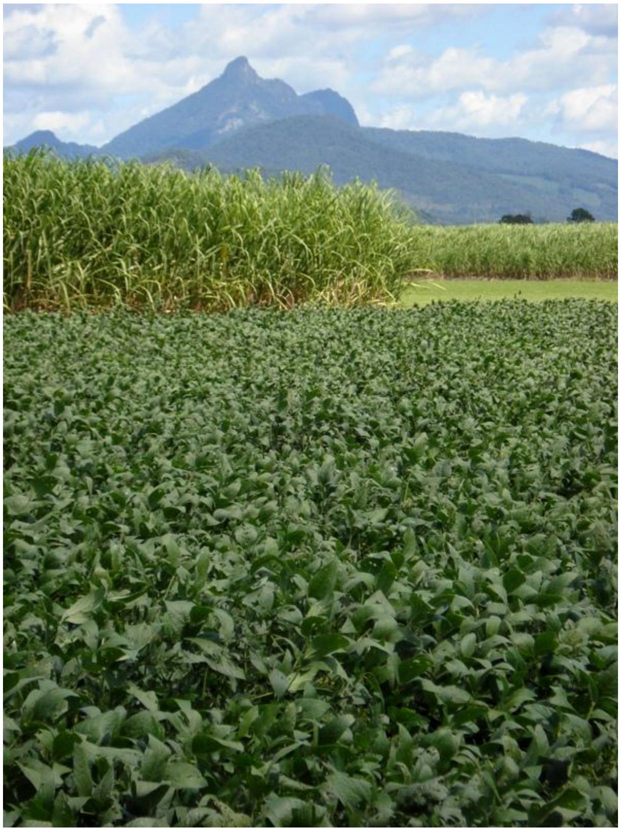

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NSW DEPARTMENT OF PRIMARY INDUSTRIES

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SRDC Grower Group Innovation Project
Final Report

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Australian Government
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Executive Summary

This project aimed to document nitrogen inputs from soybean crops grown in NSW cane lands, promote soil-specific fertiliser recommendations following soybean to achieve more efficient use of nitrogen fertiliser and to assess different methods for dealing with soybean crop residue. The project was a Grower Group Innovation Project undertaken from April 2009 to March 2012 by the NSW Farming Systems Group Inc. in association with staff from the NSW Department of Primary Industries, BSES Limited, NSW Sugar Milling Cooperative and the University of New England.

Whilst many sugar cane growers have adopted soybean rotations, the potential benefits of soybean are not being fully realised, particularly making use of residual nitrogen (N) in the following cane crop. Some growers continue to over-fertilise cane following a soybean crop, while on some soil types in NSW cane crops have shown nitrogen stress after a well grown soybean crop. Local data was required to fine-tune N fertiliser recommendations in sugar cane following soybean. Previous research on soybean as a rotation crop in cane-production systems was conducted in the tropical Qld environment through the Sugar Cane Yield Decline Joint Venture. However, the different rainfall, temperature and soil conditions in this subtropical region of NSW are likely to impact differently on N cycling.

The project team established seven trial sites across the Condong, Broadwater and Harwood mill areas, five during the 2008/09 summer (Group 1 sites) and two during the 2009/10 summer (Group 2 sites). Multiple flood events occurred in northern NSW followed by prolonged spring and summer rainfall throughout 2010 and 2011 which affected both the soybean and sugar cane phases at several of the trial sites. Weather conditions prevented completion the soybean crop residue experiments (2010). However, measurements of various soil parameters, soybean crops, and cane yield were able to be collected from enough sites to enable meaningful interpretation of the data. These measurements enabled economic assessments of ranges of fertiliser nitrogen rates applied to cane crops following soybean. Benchmarking of soybean crops across the region was also completed. This information was used to develop a simple method to assist growers to account for the nitrogen benefits of soybean-based rotations and, where appropriate, to reduce fertiliser nitrogen inputs for the following cane crop.

The key findings from the data collected in this project are:

- Soybean crops on the North Coast of NSW, including those at the trial sites and other benchmarking crops in the region, had %Ndfa values in the range 55–96% indicating that these soybean crops were fixing atmospheric N very well compared with country-wide estimates of 80% for Argentina and Brazil and 60% for the United States of America (Herridge *et al.*, 2008)
- The 7 benchmarked crops from the 2009/10 season had grain yields of 2.47–4.46 t/ha, shoot Ns of 130–420 kg/ha, %Ndfa values of 55–96% and crop N fixed values of 143–390 kg N/ha. The benchmarked crops covered showed similar variations as the experimental crops in Table 3.
- On average for each tonne of soybean grain produced, about 80 kg of N was fixed by the soybean crop
- On average for each tonne of soybean grain harvested, around 35 kg of N was left in the soil as N-rich residues
- Economic analysis of yield data from N rate trials on cane crops following soybean showed that some fertiliser N was required for the cane but that increasing rates of fertiliser N beyond 100 kg N/ha did not lead to proportionate economic benefits in cane or sugar yield.

Three key recommendations are made from the findings of this project:

1. Nitrogen fertiliser rate discounts for sugar cane following soybean crops have been determined and tabled in the BSES '6 Easy Steps' guidelines for nutrient management. The N rate discount

amounts are correlated with the size of the soybean crop which, for ease of assessment by the grower, is defined by grain yield. The ‘6 Easy Steps’ system of nutrient budgeting for a cane crop incorporates an understanding of the farm’s soil types, soil test analysis, consideration of the prevailing soil conditions and a projected yield for the cane crop. This method assists growers to account for the nitrogen from soybean when calculating a nutrient budget for following cane crops.

2. To realise the benefits of soybean rotations, soybean crops must be inoculated correctly.

3. Cane growers should access training in best practice nutrient management by attending a ‘6 Easy Steps’ workshop on nutrient management.

Project findings were presented to industry at the G.I.V.E. Conference held at Yamba in March 2012 (approx 250 growers). Project trial sites were included in several Cane Check meetings across the three mill areas of NSW during the course of the project (40–60 growers at each meeting). A paper ‘Improving soybean and nitrogen management in sugar cane systems in subtropical NSW’ was presented at the Summer Grains Conference held at the Gold Coast in June 2010 (see published paper, Appendix 1). Project findings were also conveyed to growers during several field tours, newsletters and cane productivity meetings delivered by BSES Limited and NSW Sugar Milling Cooperative staff.

Background

Local observations indicated that cane growers may not be fully capturing the benefits of soybean, grown as a rotation crop, in terms of reducing the nitrogen inputs to the following cane crops. Data from the subtropical NSW growing region was required to fine-tune nitrogen fertiliser recommendations for sugar cane following soybean and compare with research conducted in tropical Qld.

Aims

This project aimed to:

1. Provide information on N_2 fixation inputs by soybean grown in rotation with cane and residual N cycling following the soybean phase on different cane soil types in subtropical NSW

2. Use this information to produce soil-specific fertiliser recommendations for soybean-cane systems to achieve more efficient use of nitrogen fertiliser in NSW cane crops

3. Compare different methods for dealing with soybean crop residue in terms of cost in a subtropical environment.

We aimed to develop the skills of our group members through collaboration with technical staff in BSES Limited, NSW DPI and the University of New England and by focussing on the issue of nitrogen cycling in our farming systems and our environment. Through this we aimed to fine-tune our skills in nitrogen management.

Methodology

Conduct replicated field trials on growers’ farms (Table 1) to:

1. measure nitrogen fixation by soybean crops (including nodule assessment, shoot biomass, grain yield and protein and ^{15}N analysis)
2. measure soil nitrogen and organic carbon
3. assess the efficacy of different N fertiliser treatments in plant cane crops following the soybean crops (replicated N rate trials). Measurements included leaf analysis, stalk biomass of two-year crops at one year old, cane tonnage and sugar yield.
4. assess the economics of different treatments for the management of soybean crop residue
5. refine fertiliser recommendations for sugar cane following soybean.

Soybean crop measurements

Measurements on the soybean crops included visual assessment of nodulation, shoot biomass (i.e. the above ground component of crop biomass), shoot %N and ^{15}N, grain yield and grain protein. Nodulation of the roots was assessed at three points across each field site by digging up the plants with root system largely intact, gently removing soil from the roots and visually assessing the number of nodules and the colour inside the nodules.

Shoot biomass (kg/ha dry matter basis) was assessed by cutting all the plants at ground level in three 1.0 m^2 quadrats near to where nodulation had been assessed previously. Crops were sampled at the mid to late pod-fill stage of maturity. At the same time, three non-leguminous weeds were sampled from the vicinity of the quadrat cuts to be used as non N_2-fixing references for the ^{15}N estimation of soybean N_2 fixation. Weeds were chosen on the basis of being non-legumes and of similar age as the crop. All harvested plants (soybean and weeds) were then dried in a dehydrator at 50°C for 3–4 days until oven dry and ground. Grain yields for each site were provided by the harvesting contractors. Samples of grain (2 kg) were taken for oil and protein determinations at a NATA accredited grain testing laboratory (Futari Grain Technology, Narrabri, NSW).

Table 1 Field sites and collaborating growers for Grower Group Innovation Project GGIP050.

Sites 2008-2009	Collaborating grower	Location	NSW Sugar Milling Cooperative Mill area	Size of field site (ha)
1.	A. Stainlay	South Murwillumbah	Condong	1.82
2.	J. Sneesby	Broadwater	Broadwater	2.50
3.	A. Munro	Woodford Dale	Harwood	6.05
4.	A. Lawrence	Palmers Island	Harwood	3.28
5.	D. Small	Palmers Channel	Harwood	6.58
Sites 2009-2010				
6.	A. Brown	Condong	Condong	2.50
7.	A. Munro	Woodford Dale	Harwood	2.67

The % of soybean N derived from N_2 fixation (%Ndfa) was determined for each crop using the natural ^{15}N abundance method (Shearer and Kohl, 1986). The ground soybean and weed samples were sent to the University of Melbourne School of Land and Environment laboratories for analysis of ^{15}N and %N using an automated dry combustion N analyser linked to a mass spectrometer. The formulae used to determine N_2 fixation and shoot ^{15}N values are detailed in Appendix 1.

Soil measurements

Before the N fertiliser treatments were applied to the cane crops, soil samples were taken to 90 cm depth (intervals of 0–25 cm, 25–60 cm and 60–90 cm) at six points across each field site using a soil auger (Plate 1). The cane planting fertiliser zones were carefully avoided. The six replicate cores and the soil core depth intervals were kept separate for later analysis. Samples were kept in refrigerated storage and taken within 24 hours to the Diagnostic and Analytical Services (DAS) laboratory at the NSW Primary Industries Institute, Wollongbar, NSW. On arrival, the samples were immediately air dried at 40°C in dehydrators according to method 1B1 (Rayment and Higginson, 1992). Mineral N (KCl extractable ammonium-N and nitrate-N) was assessed using method 2M KCl R&H 7C2 (Rayment and Higginson, 1992).

Soil organic carbon was measured in the 0–25 cm depth using the Walkley and Black method R&H 6A1 (Rayment and Higginson, 1992). Soil organic carbon data were assessed in order to link final NSW fertiliser recommendations with the N management system known as 'Six Easy Steps', which has been adopted by the sugarcane industry in Queensland in preference to other N management systems (Schroeder, *et al.* 2009).

Plate 1. Soil at each trial site was sampled at six locations across the site and from three depth intervals: 0–25cm, 25–50cm and 50–90cm. Each depth interval was analysed separately. Photo: N. Moore NSW DPI

N rate trials on sugar cane

At each of the Group 1 sites and at one of the Group 2 sites, a replicated N rate trial was established in the plant cane crop following the soybean crop. Each trial was a randomised block design with the N rates shown in Table 2. Individual plots were at least 6 cane rows wide and the whole length of the field to facilitate the acquisition of cane yield using commercial harvesters.

Table 2. Nitgrogen rate trial designs at each site.

Site number[1]	Collaborating grower	Mill area	Total Nitrogen applied in planting mix and as side dressing of urea[2] (Total kg N/ha)	Replications
1.	A. Stainlay	Condong	17, 72, 102, 132	2
2.	J. Sneesby	Broadwater	20, 102, 196	2
3.	A. Munro	Harwood	18, 57, 86, 113	3
4.	A. Lawrence	Harwood	28, 102, 193	2
5.	D. Small	Harwood	0, 85, 113, 156, 115[2]	3
7.	A. & M. Brown	Condong	10, 60, 110, 155	2

Notes:
[1] Cane crop at Site 6 unable to be planted due to flooding
[2] Nitrogen was applied as side dressing of urea fertiliser except for one of the treatments at trial Site 5, which supplied nitrogen from ENTEC fertiliser

Sugar cane crop measurements

At sites where two year old cane was to be grown (Sites 3, 4 and 5), cane biomass measurements were undertaken when the cane crop was 9–10 months old. Biomass (tops + stalks) measurement at this time approximates the commercial cane yield were the cane to be harvested as 1 year old. In each replicate plot a 10 m length of row was marked out and the total number of cane shoots and millable stalks was recorded. The method of Hogarth and Skinner (1967) was used to determine cane biomass (Plate 2).

Commercial cane yield for individual trial plots was assessed using commercial harvesters and POL values were measured as per standard mill procedure.

Plate 2. Weighing cane biomass samples at trial site 4, Alan Lawrence, Palmers Island. Project staff from left to right: Wayne Davis (NSW Sugar Milling Cooperative), Dr Bob Aitken (BSES), Graeme Doust (NSW DPI) and Steve Lokes (NSW Sugar Milling Cooperative).

Photo: N. Moore NSW DPI

Soybean stubble treatments

At Site 7 (Alan Munro, Woodford Island), the soybean crop was grown on raised beds at 1.8 m (6 feet) centres using GPS guidance and controlled traffic. Three rows of soybean were sown on the top of each bed at 50-cm row spacing. After the soybean crop was harvested (May 2010), treatments were applied to the soybean crop stubble on the top of the beds as follows:

Treatment 1. Strip tillage utilising wavy coulters in June and again in August (Plate 3)

Treatment 2. Zonal power harrow, shallow (50mm) and early (June) (Plate 4)

Treatment 3. Zonal power harrow, deep (125mm) and late (end August).

The stubble treatments were intended to be followed by soil tests and then overlayed with two nitrogen rates once the cane crop was planted. Economic analysis was to be performed on the total cost and economic yield of each stubble and nitrogen rate treatment. Unfortunately, due to flooding and prolonged rainfall during 2010, cane planting was not possible and this experiment could not be completed. Results of soil analyses following the stubble treatments are presented below.

Photos: A. Munro

Plate 3. Strip tillage of the inter-row of soybean crop stubble using wavy coulters in June and August 2010. The objective is to encourage penetration of rainfall and create a zone conducive to the germination of dual row cane, whilst causing minimal disturbance to soil and bed structure. Soybean stubble is mostly retained on the surface with this treatment.

Photos A. Munro

Plate 4. Zonal tillage using a power harrow and crumbler roller was applied to the top of the beds at 50 mm depth in June 2010 only and at 125 mm depth in August only prior to planting cane in September. The objective is to incorporate soybean crop stubble and create a zone conducive to growth of a dual row of cane whilst retaining bed structure.

Results and Outputs

Summary of soybean crop results and interpretation of the data (Table 3)

- The soybean trial crops produced shoot biomasses of 5.7 to 8.3 t dry matter/ha
- Soybean grain yields ranged from 2.25 to 4.6 t/ha, compared to a regional average of 2.7t/ha
- Soybean grain protein ranged from 37.5 to 46% dry matter basis
- Soybean crops on the North Coast of NSW, including those at the trial sites and other benchmarking crops in the region, had %Ndfa values in the range 55–96% indicating that these soybean crops were fixing atmospheric N very well compared with country-wide estimates of 80% for Argentina and Brazil and 60% for the United States of America (Herridge *et al.*, 2008)
- The seven benchmarked crops from the 2009/10 season had grain yields of 2.47–4.46 t/ha, shoot N values of 130–420 kg/ha, %Ndfa values of 55–96% and crop N fixed values of 143–390 kg N/ha. The benchmarked crops showed similar variations as the experimental site crops in Table 3.
- On average for each tonne of soybean grain produced, about 80 kg of N was fixed by the soybean crop
- On average for each tonne of soybean grain harvested, around 35 kg of N was left in the soil as N-rich residues

Table 3. Grain yield and N values for soybean trial crops grown in subtropical NSW during the 2008/09 and 2009/10 summer seasons. Values are the mean of three replicate samples per crop.

Site number & collaborating grower	Shoot biomass (t dry matter/ha)	Total crop N incl. roots (kg/ha)	Grain yield (t/ha)	Grain protein (%)	Grain N (kg/ha)	Soybean %Ndfa	Total crop N fixed (kg/ha)	Estimated N in soybean crop residues (kg N/ha)
1. A. Stainlay	6.82	418	3.50	44.4	249	73	308	170
2. J. Sneesby	5.74	237	2.50	37.5[1]	150	79	187	87
3. A. Munro	7.00	354	4.03	43.3	279	74	263	75
4. A. Lawrence	8.27	467	2.65	ND[2]	ND	76	355	ND
5. D. Small	6.37	334	3.24	42.5	220	72	242	114
6. A. & M. Brown	4.74	289	2.25	46.0	166	91	263	112
7. A. Munro	6.23	325	4.60	44.9	330	88	287	16[3]

Notes:

1. The lower grain protein for Site 2 could not be explained and was not reflected by a correspondingly low estimate of %Ndfa. It was, however, also the lowest yielding crop.

2 ND – no data available

3 This very low value reflects the low estimate of total crop N, which may have been due to a premature sampling of the crop for maximum biomass and N

Summary of soil measurements

Soil nitrate ranged between 9–164 kg N/ha (Table 4) with soil mineral N levels ranging between 40 and 260 kg N/ha (Table 5). Nitrate-N as a percentage of total mineral N varied between 22 and 75%, with an median of 60%. The relatively high occurrence of ammonium-N may have reflected soil conditions and partially mineralised organic matter (residues plus native humus). Soil organic C levels were generally about 2%, except for Sites 1 and 6 at 2.9 and 2.6%, respectively (Table 6). Sites 1 and 6 are in the Condong mill area with soils of higher organic matter content and with peat soils comprising around 50% of the mill area.

We expected to see consistent relationships between soil carbon, residue-N (Table 7, final column) and soil mineral N. Indeed, for Sites 1–3, such a relationship was evident. However, the lower-than-expected mineral-N levels at Sites 5 and 6 (50 and 65 kg N/ha) were inconsistent with the soil organic carbons 1.9% and 2.6% and estimated residue-N values of 114 and 112 kg N/ha. Site 5 was more severely affected by local flooding during May and June 2009 than the other Group 1 trial sites (note that Site 2 was also affected by flooding) and mineral N may have been lost from the soil *via* denitrification. Denmead *et al.* (2007) reported nitrous oxide (N_2O) emissions of 46 kg N/ha for a period of just under 12 months from a sugar cane crop growing in the Tweed River valley of NSW. They did not measure the denitrified N emitted as N_2, so total N losses were likely to have been even higher. Thus, in developing final fertiliser recommendations for sugar cane, the conditions experienced after soybean harvest must be taken into account, particularly extended periods of flooding. In addition, study of the mineralisation potential of NSW cane soils in relation to soil organic carbon has shown that there are two broad soil groups that are defined by soil pH and organic C (Panitz *et al.*, 2012). One group, with generally higher organic C values but with low soil pH values, appears to have a lower nitrogen mineralisation potential with the amounts of N mineralised lower than would be expected for the levels of organic matter.

Table 4. Soil nitrate N (kg/ha) from all trial sites at three depth intervals following soybean crops and before the sugarcane crop received fertiliser N rate treatments. Data are mean values from six cores per site. Sites 1 – 5 were sampled in September 2009. Sites 6 and 7 were sampled in September 2010.

Site number And Grower:		**1** **Stainlay**[1]	**2** **Sneesby**	**3** **Munro**	**4** **Lawrence**	**5** **Small**	**6** **Brown**	**7** **Munro (2)**
Depth interval (cm)	Average depth (cm)							
0–25	12.5	88	48	72	53	17	24	40
25–50	42.5	56	10	20	23	9	15	23
50–90	75	20	2	4	6	3	2	5
	Total	**164**	**60**	**96**	**82**	**29**	**41**	**68**

Notes:

[1] Analysis results from Stainlay sampling sites AS1 & AS2 was not included in the mean valued for nitrate as these samples may have been taken too close to the location of the cane planting mixture.

Table 5. Soil mineral N (nitrate-N + ammonium-N) (kg/ha) from all trial sites at three depth intervals following soybean crops and before the sugarcane crop received fertiliser N rate treatments. Data are mean values from six cores per site.

Site number And Grower:		**1 Stainlay[1]**	**2 Sneesby**	**3 Munro**	**4 Lawrence**	**5 Small**	**6 Brown**	**7 Munro (2)**
Depth interval (cm)	Average depth (cm)							
0–25	12.5	153	69	88	66	27	33	49
25–50	42.5	70	32	30	38	18	24	36
50–90	75	36	14	10	9	5	8	16
	Total	**260**	**115**	**128**	**113**	**50**	**65**	**101**

Notes:
[1] Analysis results from Stainlay sampling sites AS1 & AS2 was not included in the mean valued for nitrate and ammonium as these samples may have been taken too close to the location of the cane planting mixture.

Table 6. Soil organic carbon (%) from the 0-25cm depth interval at each site. Data are the mean values of six cores per site, which were sampled after soybean crops and before N rate treatments were applied to the cane crop.

Site No & Grower	**1 Stainlay[1]**	**2 Sneesby**	**3 Munro**	**4 Lawrence**	**5 Small**	**6 Brown**	**7 Munro (2)**
Depth interval 0–25 cm	2.9	1.9	2.0	1.9	1.9	2.6	1.8

Table 7. Summary of soil analysis data for each site after the soybean crop and before N rate treatments were applied to the cane crop. Data are the mean values of six cores per site. Nitrate and total mineral N values are to 90 cm depth; soil organic carbon values are to 25 cm depth.

Site number	**Grower**	**Organic Carbon 0–25 cm**	**Nitrate-N total 0–90 cm**	**Mineral-N total 0–90 cm**
1	Stainlay	2.9	164	260
2	Sneesby	1.9	60	115
3	Munro	2.0	96	128
4	Lawrence	1.9	82	113
5	Small	1.9	29	50
6	Brown	2.6	41	65
7	Munro (2)	1.8	68	101

It was possible to conduct soil analyses on the Group 2 sites (Site 6 and 7) both before a soybean crop was planted (November 2009) and a number of months after the soybean crop was harvested (September 2010). A total of 126 soil samples from the two sites were analysed for soil nitrogen (nitrate and ammonium forms) for all depth intervals and soil organic carbon for the 0–25cm depth interval. These data are presented in Tables 8 and 9.

Pre-sowing soil nitrates and soil mineral N levels were low at both sites (Tables 8 and 9), which meant that the crops were highly reliant on N fixation (%Ndfa values of 88 and 91% (see Table 3). Post-harvest soil nitrates and mineral N levels were higher, reflecting the positive effect of the soybean crops on plant-available N (Tables 8 and 9). The post-harvest levels were consistent with the levels at the Group 1 sites (Table 7).

Table 8. Soil nitrate N (kg/ha) and soil organic carbon (%) levels for Sites 6 and 7 before (Nov 2009) and after (Sept 2010) the soybean crop and before N rate treatments were applied to the cane crop. Data are mean values of six cores per site. Only the 0–25cm depth interval was analysed for soil organic carbon.

Depth interval sampled (cm)	**Site 6 Brown**				**Site 7 Munro (2)**			
	Pre-soybean crop		**Post- soybean crop**		**Pre- soybean crop**		**Post- soybean crop**	
	Soil nitrate N (kg/ha)	Soil organic carbon (%)	Soil nitrate N (kg/ha)	Soil organic carbon (%)	Soil nitrate N (kg/ha)	Soil organic carbon (%)	Soil nitrate N (kg/ha)	Soil organic carbon (%)
0–25	6	2.4	24	2.6	25	1.7	40	1.8
25–60	2		15		12		23	
60–90	1		2		2		5	
Total	**9**		**41**		**39**		**68**	

Both sites showed a small increase in soil organic carbon in the surface 25 cm following the soybean crop although these changes may not be significant.

Table 9. Soil total mineral-N (nitrate-N + ammonium-N) (kg/ha) for Sites 6 and 7 before (Nov 2009) and after (Sept 2010) the soybean crop and before N rate treatments were applied to the cane crop. Data are mean values of six cores per site.

	Site 6 Brown		**Site 7 Munro (2)**	
Depth interval (cm)	**Pre-soybean crop**	**Post- soybean crop**	**Pre- soybean crop**	**Post- soybean crop**
0–25	23	33	34	49
25–60	10	24	22	36
60–90	8	8	9	16
Total	**41**	**65**	**65**	**101**

At Site 7, A. Munro (2), treatments were applied to the stubble of the soybean crop prior to planting the cane crop. Soil was sampled at three depth intervals from three sampling sites in four replicate plots of every stubble treatment. Results of soil analysis are shown in Table 10.

Table 10. Average soil nitrate N (kg/ha) at trial Site 7 following three soybean crop stubble treatments. Soil nitrate N data are the mean of three sampling sites per treatment x four replicates.

Soil depth interval (cm)	**Stubble Treatment 1** Strip tillage with wavy coulters June & early September	**Stubble Treatment 2** Zonal power harrow, shallow (50 mm) & early (June)	**Stubble Treatment 3** Zonal power harrow, deep (125 mm) & late (early September)
0–25	47	40	45
25–60	24	20	21
60–90	5	4	4
Total	76	64	70

There was little difference in soil nitrate-N levels for a given depth interval or when summed across all depths (Table 10). However, there was a slight trend for the stubble treatment 2 to have lower nitrate-N than the other treatments. This is as would be expected if early incorporation and breakdown of stubble with concomitant rainfall led to loss of mineral N from the 0–90 cm depth.

Economic analysis of nitrogen fertiliser rate trials on sugarcane following soybean
Flooding and prolonged wet weather affected trial results and removed N rate treatment effects in the 2-year cane crops at trial sites 2, 3, 4 and 5. The cane crop data that was able to be recorded at these sites and trends that were visible earlier in the trial are presented in Appendix 2. Cane crop results at the 1-year cane sites (Site numbers 1 and 6) were less affected by wet weather and economic analysis was completed for these sites in Tables 11 and 12 respectively.


Photos: N. Moore NSW DPI

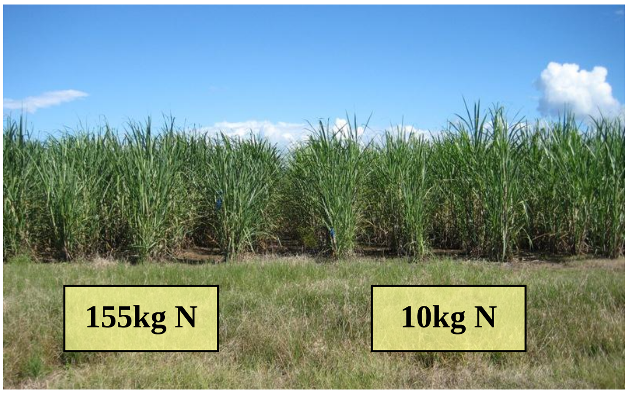
Plate 5. Trial Site 1, Angus Stainlay, Condong, NSW in the soybean phase (left) that was followed by 1-year cane crop (right) with different rates of nitrogen fertiliser. Soybean yield was 3.5t/ha with a grain protein of 44.4%.

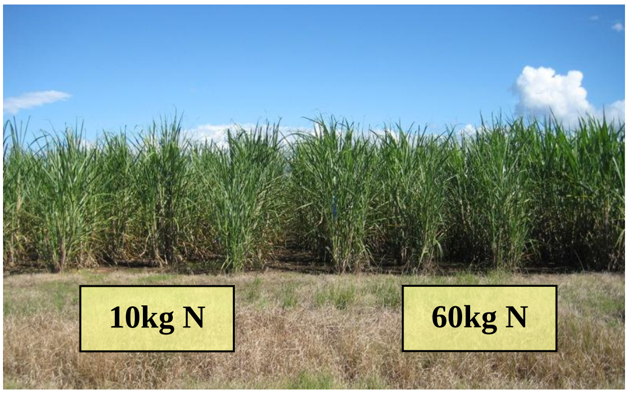
Table 11. Cane harvest results and economic analysis from Trial Site 1, Angus Stainlay, Condong, NSW. The sugarcane variety was Q200. Data analysis by Peter McGuire, BSES Condong.

	Treatment 1	**Treatment 2**	**Treatment 3**	**Treatment 4**
N applied in cane planting mix (kg/ha)	**17**	**17**	**17**	**17**
Additional N (kg/ha) applied to the cane as side dressing of urea	**0**	**55**	**85**	**115**
Leaf tissue analysis at 6mth (%N) Critical level is 1.8%	2.15	2.35	2.4	2.25
Av cane yield (t/ha)	112.0	126.2	122.4	125.5
Av cane pol	13.0	13.3	13.2	13.1
Av T pol/ha	14.6	16.7	16.2	16.4
Av response to N Tpol/ha	0.0	2.2	1.6	1.8
@ $300/ T pol		$645	$468	$528
Economic yield of additional N Net benefit $/ha relative to T1 (no additional N following soybean)	**- -**	**$446**	**$264**	**$258**

In this trial there was a clear benefit in applying some additional nitrogen to the cane crop following a soybean crop (i.e. 55 kg N/ha, Treatment 2) but little extra benefit in applying higher rates of additional N (85 or 115 kg N/ha).

Treatment 2 (additional 55kg of N applied as fertiliser following a soybean crop) provided the greatest response of POL to applied fertiliser and the best economic yield of the treatments used in this experiment.





Photos: P. McGuire BSES.

Plate 6. Trial Site 6, Alan & Malcolm Brown, Condong, NSW showing the cane crop and total rates of nitrogen fertiliser applied per hectare following the soybean crop. The cane was planted in September 2010 following a soybean crop that yielded 2.25 t/ha (+ approx 0.18t/ha grain left on ground) with a grain protein of 46% dry matter. The above photographs show visual comparisons between some of the Total N rate plots at 8 months after planting.

Table 12. Cane harvest results and economic analysis from Trial Site 6, Alan & Malcolm Brown, Condong, NSW. The sugarcane variety was Q208 (ex ASP). Data analysis by Peter McGuire, BSES Condong.

	Treatments Nitrogen added to cane after soybean			
	Treatment 1	**Treatment 2**	**Treatment 3**	**Treatment 4[1]**
N applied in cane planting mix (kg/ha) 163kg CK33/ha (10kgN, 11kgP, 54kgK)	**10**	**10**	**10**	**10**
Additional N applied as side dressing of urea (kg N/Ha)	**0**	**50**	**100**	**145**
Leaf tissue analysis at 6mth (%N) Critical level is 1.8%	1.8	1.95	2.25	2.35
Av yield (t/ha)	36.0	39.2	58.2	55.8
Av pol	13.39	12.84	11.80	11.38
Av T pol/ha	4.82	5.03	6.87	6.35
Av response Tpol/ha	0.00	0.21	2.05	1.53
$/ha return @ $300/ T pol		$64	$616	$458
Additional costs:				
Urea @ $1.30/kg N		65	130	189
Harvesting @ $9/tonne		29	200	178
Economic yield of additional N: Net benefit $/ha relative to T1 (no additional N following soybean)		**-$30**	**$286**	**$92**

Note:

[1] T4 is the current farmer practice equivalent rate of “2 ½ bags of urea per acre”

Treatment 3 (100 kg of N applied as fertiliser following a soybean crop) provided the greatest response of tonnes of POL to applied fertiliser and the best economic yield of the treatments used in this experiment. The current farmer practice of “2 ½ bags of urea to the acre” or 145 kg N/ha produced significantly less economic benefit in this crop.

These results confirm that plant cane crops following successful soy crops benefit from some additional nitrogen but could receive significantly less applied nitrogen than is the current practice of many farmers.

Intellectual Property and Confidentiality

There is no protected Project Technology associated with this project. There is nothing contained in this report that should be treated as confidential.

Capacity Building

The grower group have obtained experience in the conduct of R&D through working with researchers from other organisations, particularly in the design of replicated trials, interpretation of soil analyses and better understanding of nitrogen measurements in soybean and soil. The work was directly relevant to the coastal sugarcane farming systems of our region of New South Wales. A practical recommendation for nitrogen fertiliser application for plant cane following soybean was developed from the project.

Outcomes

- Nitrogen contributions from soybean crops confirmed for the local soil types and climate.
- This data has been incorporated into the Six Easy Steps 'Soil-specific nutrient management guidelines for sugarcane production in NSW' (Panitz *et al.*, 2012), and is already being extended to cane growers in all mill areas via a series of workshops.

Environmental Impact

No adverse environmental impacts were encountered in conducting this project. Potential environmental benefits may result due to reductions in fertiliser N applications to cane crops following soybean crops, where this is appropriate. The project findings have contributed to greater awareness of nitrogen management for cane growers and provided a guideline for the industry to use via its '6 Easy Steps' nutrient management program.

Communication and Adoption of Outputs

Communication of project outputs with acknowledgement of SRDC includes:

- Incorporation of project recommendations for nitrogen rate discounts for sugar cane following soybean in the BSES '6 Easy Steps' guidelines for nutrient management. Training workshops commenced in April 2011 with three completed for Condong, Broadwater and Harwood mill areas (approx 75 growers) to date
- Presentation at the G.I.V.E. Conference held at Yamba in March 2012 (approx 250 growers)
- Project trial sites were included in several Cane Check meetings across the three mill areas of NSW during the course of the project (40–60 growers at each series of meetings)
- A paper 'Improving soybean and nitrogen management in sugar cane systems in subtropical NSW' was given at the Summer Grains Conference, Gold Coast, June 2010 (Appendix 1)
- Mark North, a grower from the Condong Mill Area stood in for Alan Munro at the Summer Grains Conference and delivered an excellent presentation on the role of soybean in his cane farming system including economic benefits and improvements to soil and cane crops
- Project findings were conveyed to growers during several field tours, newsletters and cane productivity meetings delivered by BSES and NSW Sugar Milling Cooperative staff
- An overview of the project was provided to soybean growers at the North Coast Oilseed Growers Association annual seminar and AGM, Casino, September 2010
- Project aims and progress reported by Natalie Moore and other team members at the annual meeting of the NSW Farming Systems Group Inc at Broadwater in 2009, 2010 and 2011
- Project aims and progress was reported to growers in the Harwood Mill area at NORCO shed meetings in 2009 and 2011
- Project aims and progress were included in an article by Peter McGuire, "*How much Nitrogen do soys provide for cane?*"),in the Condong BSES Newsletter, Sept 2009
- A general information article "*Sowing soybean seeds – get the rate right*" was written by Bob Aitken & Natalie Moore for BSES Bulletin Issue 24 2009

Recommendations

Three recommendations stem from the findings of this project:

1. Nitrogen rate discounts for sugar cane following soybean crops have been determined and tabled in the BSES '6 Easy Steps' guidelines for nutrient management (see extract below). The N rate discount amounts are correlated with the size of the soybean crop which, for ease of assessment by the grower, is defined by grain yield. The '6 Easy Steps' system of determining the nutrient budget for a cane crop incorporates an understanding of the soil types on farm, an interpretation of a soil test analysis, consideration of the prevailing soil conditions and a projected performance target for the cane crop. This simple tool allows growers to account for the nitrogen from soybean crops when determining a nutrient budget for the following cane crop.

Extract from Panitz *et al.*, 'Soil-specific nutrient management guidelines for sugarcane in New South Wales.' BSES Limited (2012).

BSES SIX EASY STEPS

NUTRIENT MANAGEMENT GUIDELINES FOR SUGARCANE IN NEW SOUTH WALES

Table 8 – Nitrogen (N) rate <u>discounts</u> following a well-nodulated, well-grown soybean crop

Estimated soybean 'grain' yield (t/ha)	When 'grain' crop is harvested (kg N/ha)	When 'grain' crop is not harvested (kg N/ha)
1	45	70
2	60	115
3	70	155
4	85	200
5	100	240

2. To realise the benefits of soybean rotations, cane growers must inoculate their soybean crops correctly. This may require some follow-up information or training to assist growers to better understand how to achieve optimum nodulation including how soybean inoculant works, how nodules function, the impact of starter nitrogen on nodule formation, improving drainage in the root zone of the soybean plant, guidelines for the correct inoculation of soybean planting seed, how to correctly identify a functioning nodule, the role of Molybdenum (Mo), and how to include trace amounts of Mo.

3. Cane growers should access training in best practice nutrient management by attending a '6 Easy Steps' workshop on nutrient management.

Publications

1. Table 8. 'Nitrogen (N) rate discounts following a well-nodulated, well-grown soybean crop' in Panitz, J., Schroeder, B., McGuire, P., Aitken, R., Beattie, R. and Wood, A. 2012. Soil-specific nutrient management guidelines for sugarcane in New South Wales. BSES Limited. In Press.
2. Moore N, Herridge D, Aitken R, McGuire P and Beattie R (2010). Improving soybean and nitrogen management in sugar cane systems in subtropical NSW. In '1st Australian Summer Grains Conference', Gold Coast, Australia (Eds B George-Jaeggli, DJ Jordan) (Grains Research and Development Corporation). The full paper is attached at Appendix 1.
3. Newsletters and other articles – see Communication Outputs above.

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Appendix 1. Moore N, Herridge D, Aitken R, McGuire P and Beattie R (2010). Improving soybean and nitrogen management in sugar cane systems in subtropical NSW. In '1st Australian Summer Grains Conference', Gold Coast, Australia (Eds B George-Jaeggli, DJ Jordan) (Grains Research and Development Corporation). Note that this paper was presented in June 2010 before complete data from all sites and benchmarking crops was obtained. Final recommendations from this project should be sourced from the project Final Report and Executive Summary. Australian Summer Grains Conference proceedings are available at the GRDC website: www.grdc.com.au.

Improving soybean and nitrogen management in sugar cane systems in subtropical NSW

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Appendix 2. Sugarcane crop data including leaf tissue analysis for all trial sites where a cane crop was established, cane biomass of 2-year crops at 10 months after planting and cane yield and POL data for trial sites 2, 3, 4 and 5.

As mentioned previously, local flooding and prolonged wet weather severely affected the 2-year cane crops at Sites 2, 3, 4 and 5. Measurements were taken as planned and the trials were harvested, but unfortunately trends that were visibly apparent between treatments earlier in the crop cycle were not apparent or statistically significant by the time the crop was harvested. This should be interpreted as a loss of nitrogen rate effects over time due to unusually wet conditions rather than there being no effect from any of the treatments.

Cane leaf tissue analysis
At approximately six months after planting, cane leaf tissue analysis was conducted according to the protocol described in the BSES Limited Q Crops Information Sheet IS10001 'Leaf sampling: a key to improved nutrient management'. The critical N concentration (%N in leaf tissue) for sugar cane declines with the age of the plant. For six month old cane, the critical N concentration is considered to be 1.8% N. Leaf tissue levels above this amount are interpreted as the plant being adequately supplied with nitrogen. The data in Table 11 show that all treatments at all sites, except for Site 6 treatment 1, showed leaf nitrogen values well above 1.8% at six months after planting.

The results of leaf analysis suggested that all the treatments were adequately supplied with nitrogen at that stage of growth. At that stage, very little visual difference was detected between the treatments at each site with the exception of the Treatment 1 plots at Angus Stainlay's site at Condong. The cane in these treatment plots received nitrogen only in the cane planting mix (17 kg N/ha) with no additional side-dressing. The plants appeared lower in stature and paler green in colour compared with the cane growing in the adjacent plots, which had received additional N fertiliser after the cane was planted. There was no marked visual difference between the remaining treatments at Angus Stainlay's site (Tr2, Tr3 and Tr4) that received total nitrogen from fertiliser applications of 72, 102 and 132 kg N/ha respectively. Refer to economic analysis of the cane and POL yields of these treatments on page 12 of this report.

Bernard Schroeder from BSES Limited at Bundaberg has been contacted to assist in interpreting these leaf tissue analysis data.

Table 11. Cane crop leaf tissue analysis at 6 months after planting for all sites where a cane crop was established (Kjeldahl, N%). Cane leaf tissue samples were taken according to protocols described in the BSES Information Sheet IS10001.

Site number, grower and mill area	**N rate treatment and field replicate**	**Fertiliser N rate treatment (Total kg N/ha)**	**Nitrogen in cane leaf tissue (%)**
1. A Stainlay, Condong	Treatment 1 Rep 1	17	2.2
	Treatment 1 Rep 2	17	2.1
	Treatment 2 Rep 1	72	2.3
	Treatment 2 Rep 2	72	2.4
	Treatment 3 Rep 1	102	2.4
	Treatment 3 Rep 2	102	2.4
	Treatment 4 Rep 1	132	2.3
	Treatment 4 Rep 1	132	2.2
2. J. Sneesby, Broadwater	Treatment 1 Rep 1	20	2.4
	Treatment 1 Rep 2	20	2.2
	Treatment 2 Rep 1	102	2.4

	Treatment 2 Rep 2	102	2.4
	Treatment 3 Rep 1	196	2.4
	Treatment 3 Rep 2	196	2.3
3. A Munro, Harwood	Treatment 1 Rep 1	18	2.1
	Treatment 1 Rep 2	18	2.1
	Treatment 1 Rep 3	18	2.2
	Treatment 2 Rep 1	57	2.3
	Treatment 2 Rep 2	57	2.2
	Treatment 2 Rep 3	57	2.4
	Treatment 3 Rep 1	86	2.2
	Treatment 3 Rep 2	86	2.2
	Treatment 3 Rep 3	86	2.3
	Treatment 4 Rep 1	113	2.2
	Treatment 4 Rep 2	113	2.3
	Treatment 4 Rep 3	113	2.3
4. A. Lawrence, Harwood	Treatment 1 Rep 1	28	2.4
	Treatment 1 Rep 2	28	2.3
	Treatment 2 Rep 1	102	2.5
	Treatment 2 Rep 2	102	2.4
	Treatment 3 Rep 1	193	2.5
	Treatment 3 Rep 2	193	2.5
5. D Small, Harwood	Treatment 1 Rep 1	0	2.1
	Treatment 1 Rep 2	0	2.1
	Treatment 1 Rep 3	0	2.1
	Treatment 2 Rep 1	85	2.1
	Treatment 2 Rep 2	85	2.2
	Treatment 2 Rep 3	85	2.1
	Treatment 3 Rep 1	113	2.2
	Treatment 3 Rep 2	113	2.3
	Treatment 3 Rep 3	113	2.1
	Treatment 4 Rep 1	156	2.3
	Treatment 4 Rep 2	156	2.1
	Treatment 4 Rep 3	156	2.2
	Treatment 5 Rep 1 ENTEC	115	2.3
	Treatment 5 Rep 2 ENTEC	115	2.2
	Treatment 5 Rep 3 ENTEC	115	2.3
6. A. & M. Brown, Condong	Treatment 1 (average of 2 Reps)	10	1.8
	Treatment 2 (average of 2 Reps)	60	1.95
	Treatment 3 (average of 2 Reps)	110	2.25
	Treatment 4 (average of 2 Reps)	155	2.35

Cane biomass of 2-year crops at 9-10 months after planting
At sites where two year old cane was to be grown (Sites 2, 3, 4 and 5) cane biomass measurements were planned for when the cane crop was approximately 10 months old. Biomass (tops + stalks) measurement at this time approximates the commercial cane yield were the cane to be harvested at 1 year old. These measurements were able to be completed at Sites 3, 4 and 5 (Table 12).

Table 12. Cane crop biomass of 2-year cane crops at 1 year after planting. Data represent the total number of cane shoots and millable stalks in a 10m length of row in each replicate plot. The method of Hogarth and Skinner (1967) was used to determine cane biomass (t/ha)

Site Number	**Grower, Number of N rates and replicates**	**Fertiliser N rate treatment (Total kg N/ha)**	**Average cane biomass yield (t/ha)**
3	Alan Munro 4 N rates x 3 reps	18	102.5
		57	116.1
		86	115.3
		113	129.3
			P=0.024 LSD = 14.6
4	Alan Lawrence 3 N rates x 2 reps	28	77.7
		102	87.9
		193	90.4
			Not Significant (P=0.823)
5	Daryl Small 5 N treatments x 3 reps	0	55
		85 (urea)	61.2
		113 (urea)	64.7
		156 (urea)	50.2
		115 (ENTEC)	87.3
			Not Significant (P=0.239)

Whilst there was no statistically significant effect between the treatments at Sites 4 and 5, there was a trend for increased yield with side dressed nitrogen. The data from Site 3 showed a significantly different yield response between the highest rate of applied nitrogen and the lower rates, which supports the results from the Stainlay trial at Site 1 in that some nitrogen following soybean is required and that, for a 1-year old crop, around 55 kgN/ha may be sufficient. The requirement for 2-year old cane may be different. Cane yield and POL data from these sites is presented in Table 13 below.

The trend for lower yield in the 156 kgN/ha (as urea) treatment at Site 5 is difficult to explain. There was a very patchy cane strike at this site and variable weed density through the block, with severe weed infestation developing in some areas. This is likely to have confounded the results. ENTEC, a product claiming slower release of N with longer availability to the plant after application, gave the highest yield in two of the three replicates at this site.

Cane yield and POL data for Sites 2, 3 and 4

The trial at Site 5 was harvested but no trial data was able to be collected. Cane harvest data for the remaining sites 2. 3 and 4 is presented in Table 13.

Table 13. Cane harvest results for Sites 2, 3 and 4.

	Treatment number	Total N rate applied (kg N/ha)	Field replicate number	Cane Yield (t/ha)	Sugar content (Average Pol in Cane)	Sugar yield (t Pol per hectare)
Site 2. J. Sneesby	1	20	1	70.1	12.73	8.92
Variety Q203			2	65.2	12.44	8.11
			Average	**67.6**	**12.59**	**8.51**
	2	102	1	122.3	12.4	15.16
			2	91.5	13.24	12.11
			Average	**106.9**	**12.82**	**13.63**
	3	196	1	89.0	13.36	11.89
			2	85.1	12.9	10.97
			Average	**87.0**	**13.08**	**11.43**
Site 3. A. Munro	1	18	1	193.30	12.87	24.88
Variety Q167			2	187.55	13.41	25.16
			3	193.98	13.42	26.04
			Average	**191.61**	**13.24**	**25.36**
	2	57	1	181.00	13.34	24.15
			2	195.54	13.43	26.27
			3	194.85	13.55	26.41
			Average	**190.46**	**13.44**	**25.61**
	3	86	1	183.34	13.14	24.09
			2	175.64	13.52	23.75
			3	200.84	13.58	27.27
			Average	**186.61**	**13.41**	**25.04**
	4	113	1	184.54	12.60	23.25
			2	190.20	13.34	25.37
			3	200.71	13.29	26.68
			Average	**191.82**	**13.08**	**25.10**
Site 4. A. Lawrence	1	28	1	148.03	13.75	20.35
Variety Q203			2	130.62	13.50	17.63
			Average	**139.33**	**13.63**	**18.99**
	2	102	1	142.72	13.49	19.25
			2	140.07	13.42	18.80
			Average	**141.40**	**13.46**	**19.03**
	3	193	1	132.61	13.32	17.66
			2	140.58	13.50	18.98
			Average	**136.60**	**13.41**	**18.32**