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Assessing the real nitrogen benefits to subtropical cane from soybean break crops: final report 2016/404

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Sugar Research Australia

FINAL REPORT 2016/404

Assessing the real nitrogen benefits to subtropical cane from soybean break crops: final report 2016/404

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ABSTRACT

There is concern among subtropical cane farmers that much of the N in the residues of summer soybean crops is lost over the winter fallow period prior to cane planting. Nitrogen fixed in 10 soybean paddocks over summer 2016-17 was assessed using ^{15}N natural abundance methodology. Owing to wet autumn conditions, four of these crops were not harvested and were sprayed out or ploughed in. ^{15}N-labelled soybeans (i.e. isotopically labelled plants) were grown in the glasshouse and residues were applied to three replicate boxes in three fields in the subtropics to track the fate of N over winter. In spring, prior to land being ploughed in preparation for cane planting, soil samples were taken to a depth of 90cm in each box to quantify the amount of soybean residue-N remaining in the soil profile. Losses of 32-45% of soybean residue-N occurred over winter, with the 45% losses occurring on a sandier soil. Notably, around 20% of the remaining ^{15}N from the soybean residues in the sandy soil was located at 300-600 mm depth in early spring, and given that there was further heavy rainfall between the soil sampling in September prior to soil cultivation and sowing of plant cane in October it is possible that much of this N may have moved deeper into the soil beyond the root zone. The use of winter cover crops should be investigated as a means of retaining the N in the systems and potentially adding further species diversity into subtropical cane systems.

EXECUTIVE SUMMARY

Issue and objectives

Soybeans grown as a break crop in subtropical cane rotations can fix substantial amounts of nitrogen (N) and some N remains in residues even after the bulk of N has been removed in harvested beans. However, there is concern among growers and advisors that much of this N may be subsequently lost over the winter fallow period prior to cane planting in spring. This project measured the amount of N fixed in cane paddocks and quantified N lost from soybean residues over the 2017 winter fallow in three fields differing in soil type.

R&D methodology

The amount of N fixed in 12 commercial cane paddocks in the Northern Rivers district of NSW was quantified at the mid pod filling stage using standard ^{15}N natural abundance methodology. In three of these paddocks, three 0.6 m x 0.6 m boxes (0.4 m high) per paddock were inserted 0.30 m into the soil and the soybean residue within these boxes was replaced with residue from soybeans of the same cultivar that had been grown in the glasshouse and labelled with ^{15}N isotope. Recovery of the ^{15}N isotope in different depths of the soil was quantified in spring prior to cane planting using an isotope ratio mass spectrometer at Southern Cross University, and N losses from the residues at a field scale were extrapolated from the isotope results.

Project outputs

The project provided quantitative data on N fixation in soybean paddocks and potential N losses over the winter fallow. A draft research paper for submission to an international journal was also developed, and it is anticipated that the results will be communicated to growers in up-coming newsletters.

Outcomes and implications

While soybean crops can fix up to 300 kg N ha^{-1} when grown as a break crop in subtropical cane systems, the actual amount of N from green manured soybean available to subsequent plant cane crops is substantially less, with losses of 32-45% of the N over the winter fallow period. The use of winter cover crops should be investigated as a means of retaining the N in the systems and potentially adding further species diversity into subtropical cane systems.

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1. BACKGROUND

Summer legume crops (mainly soybean) are widely used in subtropical cane systems as a break crop between successive cane crops. SRDC PROJECT GGIP050 (“Improving soybean and nitrogen management in subtropical NSW cane systems”) demonstrated that cultivation of a soybean crop could reduce the amount of N fertiliser required for the subsequent plant cane crop owing to the retention of some soybean residue N in the soil. Estimates of the amount of fixed nitrogen (N) from the legumes that is retained (after grain harvest) were made based on the yield and a ‘conversion factor’, and this amount of retained fixed N is deducted from the standard N fertiliser recommendation calculated using the ‘6 easy steps’.

While there appears to be N benefits to the following crops, there is a reasonable prospect that these N benefits are not as great as they could be due to N losses over the winter fallow period following soybean harvest. In the subtropics, the 4-6 month fallow period following soybean harvest can receive large and intense rainfall events, which are likely to leach any N that has been mineralised from the soybean residues. This could potentially result in substantial economic losses for farmers and contribute to water quality issues. Previous projects in the region have not investigated potential N losses from soybean residues over the winter fallow period, hence this project was undertaken to resolve the fate of soybean residue-N following the winter fallow period in the NSW subtropical cane industry.

2. PROJECT OBJECTIVES

The project had two simple objectives:

1) To assess typical amounts of N fixed by soybean crops in the NSW subtropics and the amount present in residues after harvest, to estimate the *potential* amount of soybean residue-N that could be available to subsequent cane crops

2) To resolve the fate of soybean residue-N following a winter fallow, in terms of percent recovery and distribution in the soil profile, to determine the *actual* amount of soybean residue-N available to subsequent cane crops

3. OUTPUTS, OUTCOMES AND IMPLICATIONS

3.1. Outputs

The project provided quantitative data on N fixation in soybean paddocks and potential N losses over the winter fallow. A draft research paper for submission to an international journal was also developed, and it is anticipated that the results will be communicated to growers in up-coming newsletters. Further research in subsequent seasons, and the potential for winter catch crops to mitigate N losses, need to be addressed before grower adoption of practice change.

3.2. Outcomes and Implications

While soybean crops can fix up to 300 kg N ha^{-1} when grown as a break crop in subtropical cane systems, the actual amount of N from green manured soybean available to subsequent plant cane crops is substantially less, with losses of 32-45% of the N over the winter fallow period. In addition to this N loss representing a dollar value cost to growers, the likely loss pathway was N leaching which suggests that subtropical cane systems are contributing to nutrient load in waterways. The use of winter cover crops should be investigated as a means of retaining the N in the systems and potentially adding further species diversity into subtropical cane systems.

4. INDUSTRY COMMUNICATION AND ENGAGEMENT

4.1. Industry engagement during course of project

The project engaged with five local cane farmers who hosted the trials, and Rick Beattie (Sunshine sugar) was consulted to discuss the implications of the results. This project did not have any extension activities embedded within the project, but it is envisaged that the results of the study will be extended to growers in upcoming newsletters and at field days.

4.2. Industry communication messages

1) Losses of 32-45% of soybean residue N can occur over the winter fallow period when soybean is green manured, so growers should not discount the total amount of soybean residue-N from estimated N fertiliser requirement of the following cane crop

2) Opportunities for green manure cover/catch crops, or possibly harvested cash crops, over winter should be considered for future research to minimise N losses and add diversity into the cane system.

5. METHODOLOGY

5.1. Soy bean N Fixation

Twelve paddocks from five commercial farms across the far north coast of NSW were selected to measure N fixation in December 2016. The location of the trial sites in shown in Fig. 1. Prior to sowing of soybeans by farmers, three soil cores from each paddock were taken and homogenised and soil properties from 0-100 mm horizon along with mineral N content to a depth of 900 mm are shown in Table 1. Details of trial management including key dates (sowing, harvest) are shown in Table 2.

Post emergence plant counts were taken by counting seedlings within four 1 m lengths of row at each site. At pod filling (growth stage 6) three 1m cuts of soy bean were sampled randomly from each paddock along with any available weeds within the paddock to use as a non N fixing reference at dates listed in Table 2. Plant material was dried for 7 days in a 400° oven, then weighed and finely ground. The %Ndfa in legumes was estimated using the natural ^{15}N abundance technique (Shearer and Kohl 1986):

$$\%Ndfa = \frac{100(\delta^{15}\text{N reference plant} - \delta^{15}\text{N legume})}{(\delta^{15}\text{N reference plant} - \text{B})}$$

Nitrogen isotope ratios in dried tissue samples were quantified with a DeltaV Isotope Ratio Mass Spectrometer (Thermo Scientific, Bremen, Germany) following combustion on a Thermo Flash EA 1112 elemental analyser (Thermo Scientific, Bremen, Germany). B values for the three soy bean varieties used (Asgrow, Manta and Richmond) were generated by growing each variety in an N free environment using nutrient solution as per Rose et al. (2008). Total fixed N in legume shoots at the time of termination was calculated by multiplying the shoot N content by the respective %Ndfa.

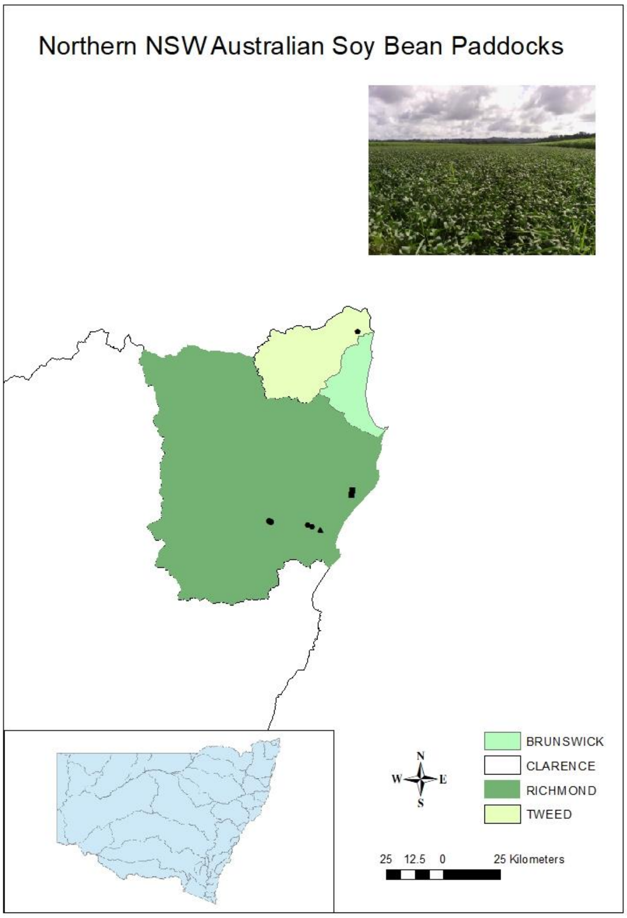

Figure 1 – Location of paddocks used for soybean N fixation assessment

Table 1 – Soil data from ten trial paddocks where soybean nitrogen fixation was assessed

Soil Property	Golan		Pye			Carusi			Rogers		Quirk	
	1	2	1	2	3	1	2	3	1	2	1	2
Total C (%)	4.06	2.91	5.94	4.59	4.41	3.58	2.79	2.79	3.71	2.30	5.45	5.87
Total N (%)	0.44	0.21	0.59	0.47	0.42	0.32	0.25	0.25	0.27	0.19	0.35	0.38
pH ($CaCl_2$)	5.17	5.66	5.81	6.05	6.17	5.31	5.22	5.22	5.17	5.21	5.19	4.88
EC (dS m^{-1})	0.15	0.06	0.17	0.12	0.25	0.08	0.09	0.09	0.10	0.06	0.15	0.34
Bray 1 P (mg kg^{-1})	8.6	18	184	105	60	7.3	18	18	9.6	59	21	12
CEC ($cmol^{+}$ kg^{-1})	4.9	3.5	6.8	7.9	16.2	27.1	24.3	24.3	10.3	7.9	4.5	12.5
Mineral N to 0.9 m (kg ha^{-1})	185	127	188	117	165	39	38	38	106	52	72	33
Base cations (%)												
Calcium	34.9	45.8	68.3	62.8	64.5	39.9	39.6	39.6	23.4	30.4	53.0	32.7
Magnesium	35.2	37.3	23.4	30.6	30.9	38.9	35.9	35.9	35.3	24.5	14.2	14.8
Potassium	1.7	3.1	3.4	1.9	2.0	2.2	2.2	2.2	2.9	2.7	4.6	1.8
Sodium	2.2	1.8	1.4	2.8	1.7	2.3	2.5	2.5	2.7	2.0	1.6	3.7
Aluminium	14.2	6.8	1.6	0.7	0.2	9.9	11.5	11.5	20.7	23.6	14.4	19.0

Table 2 – Trial management for 12 paddocks assessed for soybean nitrogen fixation

Farm	Paddock	Soybean variety	Sowing date	N fix measurement date	Harvest date
Golan	1	Manta	20/12/16	22/3/17	15/05/16
Golan	2	Manta	20/12/16	22/3/17	15/05/16
Pye	1	Asgrow	21/12/16	29/3/17	01/05/16
Pye	2	Asgrow	21/12/16	29/3/17	*
Pye	3	Asgrow	21/12/16	29/3/17	*
Carusi	1	Richmond	19/12/16	22/3/17	16/05/16
Carusi	2	Richmond	19/12/16	22/3/17	16/05/16
Carusi	3	Manta	19/12/16	22/3/17	16/05/16
Rogers	1	Manta	16/12/16	22/3/17	03/05/16
Rogers	2	Manta	16/12/16	22/3/17	03/05/16
Quirk	1	Asgrow	15/12/16	29/3/17	*
Quirk	2	Asgrow	05/01/17	29/3/17	*

*Flood damaged crops were not harvested

5.2. Residue-N losses over the winter fallow period

Three of the paddocks used to estimate N fixation in soybean crops (Pye 1, Pye 2 and Rogers 1) were subsequently used to quantify the fate of soybean-residue-N over the winter fallow period. In each paddock, three 0.6 m x 0.6 m boxes (0.4 m high) per paddock were inserted 0.30 m into the soil and the soybean residue within these boxes was replaced with residue from soybeans of the same cultivar that had been grown in the glasshouse and labelled with ^{15}N isotope. In spring, prior to cultivation of fields in preparation for cane planting, soil samples (0-100 mm, 100-300 mm, 300-600 mm and 600-900 mm) were obtained by compositing two cores per box using a 75 mm-diameter soil corer. Samples of soil from the same layers were also taken from a single soil core at a distance of 1 m from the boxes to obtain background $^{15}N/^{14}N$ ratios in soil. Soil samples were oven-dried for 72 h at 60°C.

Total N in each composited sample was measured by Dumas combustion using an LECO TruMAC CNS analyser with the combustion chamber set at 900 °C. Total N per soil layer (kg ha^{-1}) was calculated using the soil bulk density from each layer in each paddock. Nitrogen isotope ratios were quantified on 4 mg portions of dried soil using the equipment described above for plant samples.

The percentage of soil N in each soil layer (0-100mm, 100-300 mm, 300-600 mm and 600-900 mm depths) derived from soybean residue ($\%Ndsr_{soil}$) was calculated as follows:

$\%Ndsr_{soil} = 100 \times (g-h)/(c-i)$

where g is the atom % ^{15}N in the soil sample, h is the % ^{15}N in the control soil sample without N fertiliser, c is the atom % ^{15}N in the soybean residue (5.1atom%) and i is the natural atom % ^{15}N abundance in unfertilised soil.

The percentage of soybean residue-^{15}N recovered in soils (%N recovery) was calculated as:

$\%N\ recovery = (\%Ndsr_{soil} \times j)/f$

where $\%Ndsr_{soil}$ is the percentage of soil N derived from soybean residue, e is the total N in soil (kg N ha^{-1}) and f is the amount of N applied in soybean residues (kg N ha^{-1}).

6. RESULTS AND DISCUSSION

6.1. Nitrogen fixation by soybeans in subtropical cane rotations

Soybean dry matter yields at mid pod filling (when cuts were taken for N fixation assessment) ranged from 3.4 – 12 t ha^{-1} with shoot N contents of 91 – 343 kg ha^{-1} (Table 3). The poor growth and N accumulation in both paddocks at Golan's property were due to low plant numbers and wet conditions during early growth which affected plant vigour. The range in shoot N accumulation was similar to the range of 130–420 kg ha^{-1} reported for soybean crops grown in the region from 2009-2012 by Moore et al. (2012) (SRDC Project GGIP050 Improving soybean and nitrogen management in subtropical NSW cane systems).

The % of N fixed from the atmosphere (%Ndfa) ranged from around 30% in both paddocks on Golan's property to over 90% (Rogers paddock 1) (Table 3). These values are not dissimilar to the range of 55 – 96% reported in the same region by Moore et al. (2012) but the higher values are above typical %Ndfa values reported for the USA (around 60%) and Brazil/Argentina (80%) (Herridge et al. 2008). Disregarding the poor performing crops on Golan's property the amount of N fixed by soybeans ranged from around 100 to 290 kg ha^{-1}. Notably these values do not include any fixed N that may be present in the root systems of the soybean plants.

Table 3 – Soybean N fixation, yields and potential nitrogen residue contributions was assessed

Farm	Paddock	DM yield (t ha^{-1})	Total N accumulation (kg ha^{-1})	%Ndfa	Fixed N fix (kg ha^{-1})	Paddock grain yield (t ha^{-1})
Pye	1	9.4 ± 1.0	290 ± 46	78 ± 0.5	224 ± 36	3
Pye	2	7.6 ± 0.6	225 ± 34	89 ± 2.4	200 ± 32	Manure
Pye	3	8.0 ± 0.3	227 ± 6	78 ± 2.2	176 ± 2	Manure
Golan	1	3.4 ± 0.7	91 ± 11	27 ± 16.7	28 ± 8	1
Golan	2	4.3 ± 0.5	128 ± 25	31 ± 15.2	40 ± 18	1
Rogers	1	8.9 ± 0.7	287 ± 35	91 ± 1.3	262 ± 35	3
Rogers	2	8.7 ± 1.0	310 ± 46	89 ± 2.0	279 ± 46	3
Carusi	1	5.7 ± 0.5	137 ± 23	75 ± 3.1	105 ± 21	1
Carusi	2	6.3 ± 0.1	149 ± 18	83 ± 4.2	122 ± 11	1
Carusi	3	6.9 ± 0.6	189 ± 12	69 ± 6.4	131 ± 19	1
Quirk	1	12 ± 0.1	343 ± 8.7	85 ± 2.7	290 ± 13	Manure
Quirk	2	6.7 ± 0.5	177 ± 3.6	82 ± 2.8	144 ± 8	Manure

6.1.1. Losses of soybean residue-N over the winter fallow

The recovery of soybean residue-^{15}N in spring ranged from 55-68%; it is not known whether the unrecovered 32-45% was lost through leaching via gaseous loss pathways (Table 4). The highest losses of 45% were in the lighter soil type (Rogers paddock 1), which also received much higher winter rainfall than the two paddocks located at Pye's property (Fig. 2). Notably, around 20% of the remaining ^{15}N from the soybean residues at the Rogers site was located in the 300-600 mm layer in early spring, suggesting that leaching was a key loss pathway. Given that there was further heavy rainfall in late spring after cane planting (Fig. 2), it is possible that much of the N located in the 300-600 mm layer may have moved deeper into the soil beyond the reach of the newly emerging cane roots.

Table 4 – recovery of soybean residue-^{15}N throughout the soil profile

Soil depth	**% recovery of ^{15}N**		
	Pye 1	Pye 3	Rogers 1
0-100mm	52.9 ± 2.7	44.3 ± 2.6	21.4 ± 2.4
100-300mm	6.7 ± 0.3	11.3 ± 0.7	12.1 ± 4.6
300-600mm	4.9 ± 0.2	4.0 ± 0.4	19.4 ± 1.7
600-900mm	3.7 ± 0.4	1.6 ± 0.2	2.0 ± 1.1
Total recovery	**68.3 ± 3.4**	**61.3 ± 2.3**	**54.9 ± 4.8**

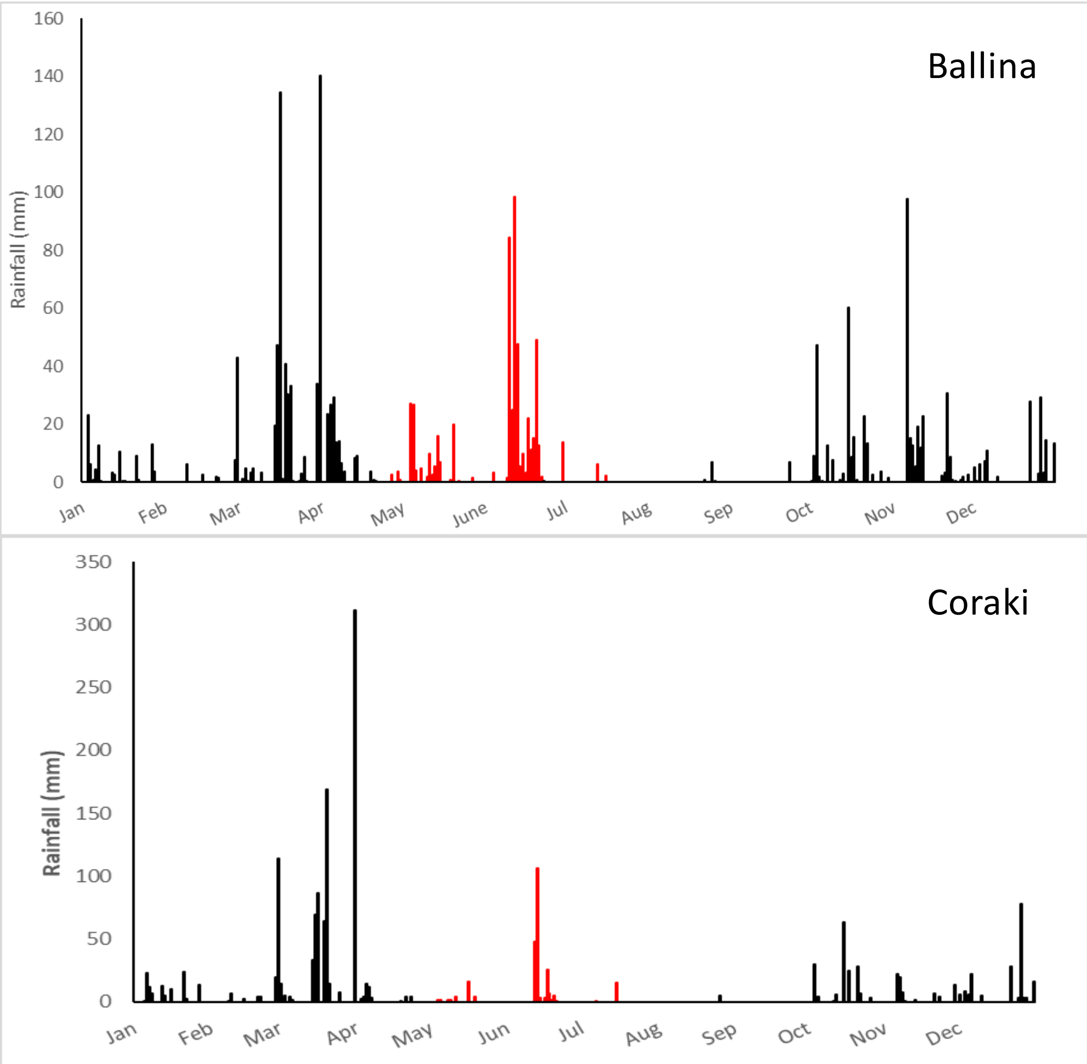

Figure 2 – Rainfall in 2017 at Ballina (Rogers site) and Coraki (Pye sites). Red bars indicate rainfall during the period where soybean residue N losses were quantified.

Losses of N over winter fallows has been reported in maize cropping systems (Staver and Brinsfield 1998) but we are not aware of any reports in sugarcane systems following soybean rotation crops. To a large degree this issue may be specific to the subtropics where a substantial fallow period exists between soybean harvest/manuring and cane planting, in contrast to tropical cane systems where cane is planted shortly after termination of the break legume crop.

Two key questions arising from this work are:

1) to what degree similar percent losses of N would be observed from soybean residues where beans are harvested, since the C:N ratio of the stubble is much greater (around 65:1) than the 12:1 ratio in green manured soybean material;
2) Whether winter cover crops (or harvested cash crops) could minimise N losses over winter without having a negative impact on the subsequent cane crop

7. CONCLUSIONS

While soybean crops can fix up to 300kg N ha^{-1} when grown as a break crop in subtropical cane systems, the actual amount of N from green manured soybean available to subsequent plant cane crops is substantially less, with losses of 32-45% of the N over the winter fallow period. The use of winter cover crops should be investigated as a means of retaining the N in the systems and potentially adding further species diversity into subtropical cane systems.

8. PUBLICATIONS

A draft paper is under development for submission to European Journal of Agronomy.

9. ACKNOWLEDGEMENTS

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