1997

94/010

CSIRO Plant Industry
Cotton Research Unit
Narrabri

FINAL REPORT

Project Title: **Nitrogen dynamics in modern cotton farming systems**

Project code: **CSP 54C**

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A final report prepared for the Cotton Research and Development Corporation

Project CSP 54C Nitrogen dynamics in modern cotton farming systems

SUMMARY

Cropping systems experiments at ACRI
N_2 fixation was assessed in legume rotation crops as well as their benefit to the following cotton crop. The legume crops contributed 100 to 300 kg N/ha. Novel techniques have enabled us to determine that about 40% of legume-N is associated with the root system. The importance of below-ground legume N has previously been underestimated. The N fertilizer required by the following cotton crop was reduced according to the input of legume N. Soil and petiole nitrate tests were able to predict sensible N fertilizer rates for all cropping systems.

Surveys of commercial legume crops
Faba beans, peanuts and soybeans fixed up to 400 kg N/ha; much of this N was removed in grain but these crops contributed up to 250 kg N/ha N to soil N. Adzuki bean, mung bean or pigeon pea fixed only small amounts of N. Winter legume crops including field peas, lentils and lupins and pasture species used for green manuring, fixed up to 170 kg N/ha.

Decomposition and availability of legume stubble-N
Loss of N from the legume stubble was about one/third that fertilizer N. As legume stubble N is in an organic form, it is conserved in the soil until it is mineralized. Possibly 50% of legume stubble N may become available to the next cotton crop. N loss from legume stubble is substantially less, compared with fertilizer N, hence legume stubble is considered of greater fertilizer value per unit of N.

Soil structural improvement
Legume crops improved soil structure. Faba bean, lablab and field pea reduced soil resistance to penetration for many months after the incorporation of stubble and these effects were still obvious during the next cotton cropping phase.

N fertilizer response following commercial legume crops
Following successful legume crops, N fertilizer rates rate can be substantially reduced (commonly halved) compared with rates a grower would normally apply in that situation, without impairing yield. Growers have not previously taken advantage of the contribution of legume crops to soil N.

CRC farming systems experiments
Soil analyses have indicated high levels of nitrate at depth at the Warra (dryland) site not apparent at the irrigated sites. Disrupted soil N cycling is suspected at Beechworth, where normal rates of fertilizer have been applied (according to soil N analyses) but crop N uptake and N fertilizer recovery has been low. Legume rotation crops have not contributed much N to the soil at these sites.

INGARD efficacy and N nutrition
Sicala V-2*i* yielded almost 10% higher, had only 25% of the insect damage compared with Sicala V-2 within a cropping systems experiment at ACRI. The Ingard crop matured almost 1 week earlier than the conventional crop and N fertilizer recovery was significantly enhanced. Because of the reduced insect damage, the Ingard crop set more fruit earlier, creating a greater demand for N. INGARD worked effectively, as this crop was not unduly stressed, being grown on well-structured, highly fertile soil.

Extension
All this information has been presented to the cotton industry via conferences, research coordination meetings, field days and extension articles. There has also been considerable publicity in the general press.

Project CSP 54C Nitrogen dynamics in modern cotton farming systems

Objectives:

- To evaluate a variety of leguminous crops in their capacity to fix N_2, provide a controlled release of N during their decomposition and determine the fertilizer N requirement for maximum yield of cotton following these legume crops.
- To evaluate the N status of treatments in the CRC farming systems experiments, to indicate where better N nutrition of the ensuing cotton crop is possible and the value of fallowing and inclusion of legumes in these systems.

Research project summary:

Field experiments at ACRI Narrabri were devised to evaluate summer and winter growing legumes with respect to the amounts of atmospheric N_2 fixed using the ^{15}N natural abundance technique. Commercial legume crops were also be assessed in this way. The benefit of these legume crops was assessed in the following year, by determining the N response of cotton to N fertilizer. Associated experiments were used to study the decomposition of ^{15}N-labelled legume crop residues and the uptake by the following cotton crop of legume N mineralised from the legume residues.

In addition, the CRC farming systems experiments are being used to evaluate the benefits of legume rotation crops. This project is continuing to evaluate the benefits of those treatments with respect to N, through assessing N_2 fixation and regular monitoring of the soil and crop N status.

Industry significance:

The CRC farming systems experiments are currently being used to evaluate the most effective (and sustainable) cotton systems. The inclusion of legumes into cotton farming systems will assist in maintaining desirable levels of soil organic matter, with possible improvements to soil structure, soil N reserves and increased availability of other plant nutrients. This will prove economically beneficial to growers through reduced N fertilizer input and long-term sustainability through remediation of soil chemical and physical characteristics. Management practices which reduce reliance on chemical fertilizers and which conserve and improve our soil resources are environmentally responsible and ecologically sound.

Scientific importance:

Measurement of the growth and N_2 fixation of summer and winter growing legumes has rarely been attempted in cotton growing systems. Commercial legume crops sown after cotton were also assessed throughout northern NSW for comparison with our experimental crops. The availability of N from these crops has not been assessed to this extent, previously. The introduction of new methods to determine N_2 fixation has facilitated these measurements. Further, the adoption of ^{15}N-labelling techniques has enabled more accurate studies of the decomposition of legume crop stubble. The determination of below-ground legume crop N has indicated that substantial quantities of fixed N remain underground after harvest. This component has not been included in N balances in cropping systems previously, hence the value of those crops has underestimated in the past.

Results:

A. Legume cropping experiments at ACRI

Experiment 1.

Cotton, soybeans and lablab were sown in November 1994. N_2 fixation was monitored in the soybeans and lablab and N removal was determined in the harvested produce, as indicated in Table 1. The cotton and soybeans were harvested, while the lablab was green-manured.

Table 1. Performance of winter rotation crops grown in 1994/5.

Crop	Crop biomass (t/ha)	Yield	N fixed (kg N/ha)	N removed (kg N/ha)	N balance* (kg N/ha)
cotton	12.0	7.7 b/ha	-	100	-100
soybean	12.1	3.7 t/ha	460	245	+215
lablab	5.3	-	180	0	+180

* N balance = (N fixed) - (N removed)

Soil samples analysed prior to cotton sowing in 1995 indicated higher N fertility in the lablab and soybean treatments. Cotton petiole nitrate analysis confirmed the optimum N fertilizer rates predicted from the soil analyses. Table 2 indicates the N fertilizer required for optimum lint yield.

Table 2. Evaluation of soil N status and cotton crop N status using soil nitrate and petiole analyses following summer rotation crops.

Previous crop	N balance (Table 1) (kg/ha)	Soil nitrate * (ppm)	Soil nitrate * *(NFR)* *(kg N/ha)*	Petiole nitrate ** (ppm)	Petiole nitrate ** *(NFR)* *(kg N/ha)*	N fertilizer for optimum yield (kg N/ha)
cotton	-100	2.6	*(150)*	5,800	*(160)*	160
soybean	+215	7.3	*(110)*	11,600	*(130)*	100
lablab	+180	14.0	*(60)*	14,500	*(80)*	60

* Measured to 30 cm in Sept (5 months after harvesting/green-manuring previous crop).

** Early flowering, 2 months after sowing.

NFR = predicted N Fertilizer Requirement

Cone penetrometer readings during growth of the following cotton crop indicated that the structure of the surface 30 cm of soil was significantly improved by growing soybeans and lablab, compared with growing cotton.

Averaged over all treatments, cotton N uptake was 75% higher in the soybean and lablab systems. N fertilizer recovery averaged 61% over all treatments and was not significantly affected by the previous crop.

Lint yield reflected the N fertility of each system although the maximum yield in all systems was identical. (Figure 1). The relatively low yields for this site reflect the delayed maturity, as hail damage necessitated resowing of the cotton crop.

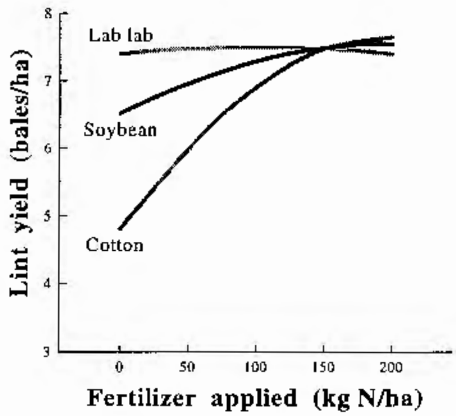

Figure 1.
Lint yield of cotton grown after legume and non-legume crops grown the previous summer.

Experiment 2.

Winter-growing crops were compared with the summer-growing crops (as used in Experiment 1). Field peas and lablab were green-manured, fababeans and soybeans were harvested. Non-legume crops (wheat and cotton) were included to provide lower N status systems. Because of the lateness of the previous cotton crop (hail damage warranted resowing) the winter crops were also late sown (July). The amount of DM produced by the legume crops was reflected in the amount of N fixed (Table 3).

Table 3. Performance of winter and summer rotation crops grown in 1995 and 1995/6.

Crop	Crop biomass (t/ha)	Yield	N fixed (kg N/ha)	N removed (kg N/ha)	N balance* (kg N/ha)
wheat	2.4	0.5 t/ha	-	10	-10
faba bean	3.5	1.1 t/ha	135	30	+105
field pea	3.2	-	130		+130
cotton	7.0	7.2 b/ha	-	130	-130
soybean	11.4	2.9 t/ha	460	180	+280
lablab	7.6	-	210	0	+210

Following these crops, cotton was sown in October 1996. The response in lint yield to applied N is displayed in Figure 2.

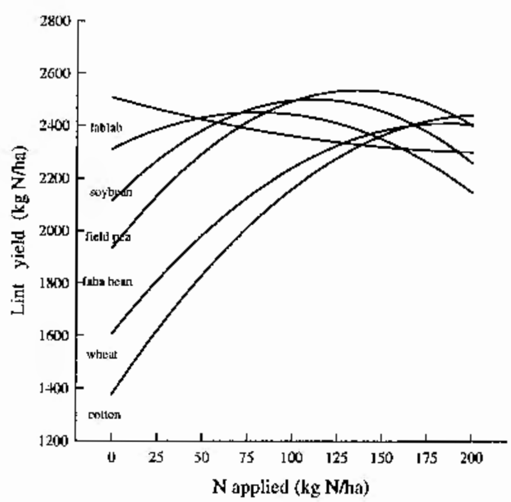

Figure 2.
Lint yield of cotton following legume and non-legume rotation crops. The wheat, faba bean and field pea crops were sown late.

Each rotation treatment produced a similar maximum yield, but the N fertilizer application rate at which this occurred was substantially different.

Combining data from Experiments 1 and 2, it is apparent that the growing of legume rotation crops significantly reduce the N fertilizer required by the following cotton crop, as shown in Figure 3.

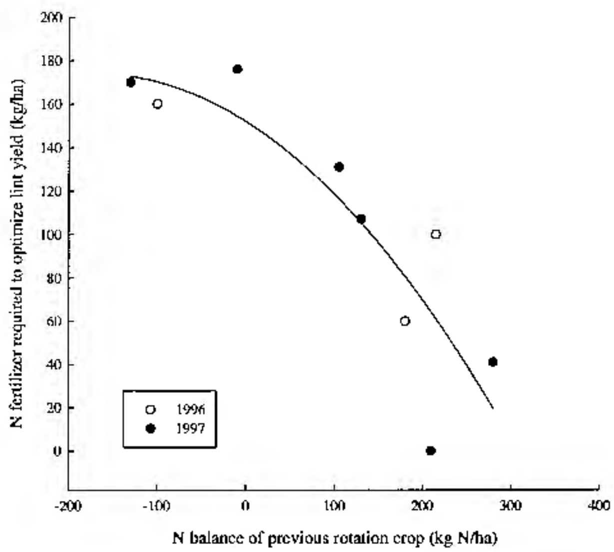

Figure 3.
Legume rotation crops can significantly reduce the N fertilizer requirement of following cotton crops.

Experiment 3.

A further experiment was initiated in 1996, to compare the winter crops wheat, faba bean and field pea. These crops grew substantially better than the late-sown winter crops used in Experiment 2. The N input/removal (N balance) for these crops is given in Table 4. The N fertilizer response of the cotton crop following these rotation crops will be evaluated during 1997/8.

Table 4. Performance of winter rotation crops grown in 1996.

Crop	Crop biomass (t/ha)	Yield	N fixed (kg N/ha)	N removed (kg N/ha)	N balance (kg N/ha)
wheat	2.8	0.6 t/ha	-	10	-10
faba bean	6.9	2.4 t/ha	240	90	+150
field pea	6.0	-	200		+200

Experiment 4.

This experiment was initiated in 1997, to compare rotation crops including wheat, faba bean field pea and pasture legumes (including vetches, clovers and medics), for inclusion in traditional rotation systems and for short-term green-manuring purposes between back-to-back cotton systems. A similar protocol for sampling and evaluation is being used as in previous experiments. The N fertilizer response of the cotton crop following these rotation crops will be evaluated during 1998/9.

B. Surveys of commercial legume crops following cotton in northern NSW

Legumes are becoming common rotation crops in cotton farming systems in northern New South Wales. We monitored over three years the growth, N_2 fixation and yield of faba beans and other winter and summer legume crops sown after cotton. Faba beans fixed up to 350 kg N/ha, removed up to 160 kg N/ha in harvested grain and contributed up to 270 kg fixed N/ha to soil N after harvest. Grain yields, N_2 fixation and DM production were reduced in the late-sown crops and those water-stressed during pod-filling. Most faba bean crops fixed twice as much N as was removed in grain.

Below-ground legume N (determined with ^{15}N shoot feeding techniques) accounted for 40% of the total crop N at peak biomass and represented about 100 kg N/ha for faba bean crops. Prediction of residual fixed N after harvest using crop DM and yield could be used by growers to assess the N input from faba beans. As much of the N fixed by faba beans and other crops is returned to the soil after harvest, the N fertilizer requirement of following cotton crops should be significantly reduced where faba bean or other legume crops are grown.

N_2 fixation in other legume crops (Table 5) ranged from 20 kg N/ha in adzuki bean and drought-affected lablab to more than 250 kg N/ha in irrigated soybean and peanut. Soybean, peanut and Dolichos lablab added more fixed N to the soil than adzuki bean, mung bean or pigeon pea. Winter legume crops including field peas, lentils and lupins and pasture species used for green manuring, fixed up to 170 kg N/ha.

Table 5. Values of crop DM, N fixation and residual fixed N from legume rotation crops used in cotton farming systems. Crops were green-manured where no grain yield is given.

Crop	Crop DM (t/ha)	Pfix (%)	N Fixed (kg/ha)	Grain yield (t/ha)	N Removed (kg N/ha)	Residual fixed N (kg N/ha)	
Summer							
soybean	8.5	79	319	2.5	154	165	37*
adzuki bean	1.9	25	16				
peanut	12.3	90	261	4.3	91	170	66*
(late sown)	9.3	40	84	3.0	51	33	0*
(saline)	9.3	14	37	2.8	42	-5	-20*
mung bean	3.7	52	52	1.0	37	15	-6*
cowpea	5.0	68	123				
pigeon pea	4.6	17	20				
lablab	5.3	73	152				
Winter							
faba bean	5.5	74	177	1.8	64	113	42*
lupin	5.7	72	176	1.7	79	97	27*
field pea	5.0	75	161				
lentil	6.6	61	169				

* indicates residual fixed N where below-ground N was not included.

C. Improvement to soil structure

In comparison with non-legume crops, the legume treatments improved soil structure, as measured by soil penetrometer. Siguificant effects were evident during the cotton cropping phase, many months after the incorporation of the legume crop stubble. In Experiment 1, both soybean and lablab improved soil structure, relative to cotton. In Experiment 2, the greatest improvement in soil structure was demonstrated by faba bean, followed by lablab, field pea, wheat, cotton and soybean. The effect of legume cropping on the improvement of soil structure in Experiment 2 was substantially more pronounced than in Experiment 1.

D. Decomposition of legume stubble

We followed the fate of legume N following harvest by feeding ^{15}N-enriched urea to faba bean, field pea, soybean and lablab. For comparison, ^{15}N-enriched urea (fertilizer) was applied to the wheat and cotton plots as the summer and winter crop stubbles were incorporated. Loss of fertilizer N was about three times that from the legume stubble. As legume stubble N is in an organic from, it is conserved in the soil in that form until it is mineralized ie a slow-release form of N. Hence losses are minimised and legume stubble N may be considered of greater fertilizer value per unit of N. Figure 4 indicates the amount of N recovered at the end of the following cotton season from that applied as legume stubble or as fertilizer N with wheat or cotton stubble when the stubble was incorporated.

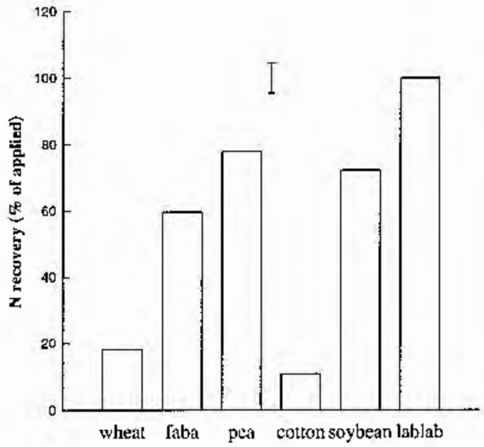

Figure 4.
Recovery of N from ^{15}N-labelled legume stubble or fertilizer applied after wheat or cotton harvest.

E. N fertilizer requirement of cotton following commercial legume crops

Following successful legume crops, a few growers implemented N fertilizer rate experiments in those fields where we had sampled legume crops. Normally, the optimum N rate was substantially lower than that which the grower would normally apply in that situation, as growers have not previously acknowledged the contribution of legume crops to the soil system. At Doreen (Wee Waa) in 1995/6, lint yield was optimal with 80 kg N/ha, although little response was evident beyond 40 kg N/ha. At Fairfield (Goondiwindi) in 1996/7, N fertilizer application reduced lint yield at a rate of 1 kg lint/ha for kg N/ha applied. These experiments have been published in the Australian Cottongrower.

F. Monitoring of N cycling in the CRC farming systems experiments

Soil and crop samples have been collected regularly from the 3 experiments. Many samples await processing and analysis at various laboratories. Soil analyses have indicated high levels of nitrate at depth at the Warra (dryland) site not apparent at the irrigated sites. Abnormal soil N cycling is suspected at Beechworth, where normal rates of fertilizer have been applied (according to soil N analyses) but crop N uptake has been slow and below normal levels. Recovery of N fertilizer appears low.

Legume rotation crops have not contributed large quantities of fixed N to the soil at these sites. At Warren, up to 100 kg N/ha were fixed by field peas in 1994. Several faba bean crops have not been successful because of delayed sowing and fixed only ~20 kg N/ha. Thus, these crops have not been as beneficial as those grown at other sites in rotation with cotton.

G. Efficacy of INGARD cotton with respect to N nutrition

In the 1996/7 season, Sicala V-2*i* was compared with Sicala V-2 within the cropping systems experiment at ACRI. The whole field was treated as for conventional cotton. However, the Ingard treatments yielded almost 10% higher, had only 25% of the insect damage of the conventional treatments and N fertilizer recovery and N uptake in the Ingard treatments were siguificantly enhanced. On average, crop maturity was hastened by almost 1 week in the Ingard treatments. Because of the reduced insect damage, the Ingard crop set more fruit earlier, creating a greater demand for N. These crops suffered little nutritional stress, being grown on well-structured soil of high fertility.

Links with other CRDC and CRC projects:

Collaboration with: Lewis Wilson, Paul Williams (insect over-wintering on rotation crops)
Steve Allen, Subbu Putcha (cotton seedling disease following legumes)
Nilantha Hulugalle (soil structure)
Grant Roberts (weed suppression and allelopathy following legumes)

Publications:

Rochester IJ, 'Legume crops in rotation with cotton'. Oral presentation at 8th Australian Cotton Conference. (Broadbeach, 1996).

Marshall J, Rochester I, *et al.* 'The benefits of rotation cropping to cotton'. 8th Australian Cotton Conference proceedings (pp 463-7).

Rochester IJ, Constable GA, Peoples MB, Gault RR. 'The contribution of summer legumes to cotton'.
A poster presented at: 8th Australian Cotton Conference. (Broadbeach, 1996)
9th Australian Soybean Conference (Leeton, 1996)
11th Australian N fixation Conference (Perth, 1996)

Rochester I, Constable G, Peoples M and Gault R. 'Legume crops and cotton farming'. *Australian Cottongrower* (Sept-Oct, 1996) pp 70-74. This article also appeared in *Australian Grain.*

Rochester I, Peoples M, Long K and Kauter G. 'Faba Beans reduce N fertilizer requirement of cotton.' *Australian Cottongrower* (Sept-Oct, 1997)

Rochester, I., Peoples, M., Constable, G. and Gault, R. (1998). Nitrogen fixation exceeds N removal in faba beans and other legumes grown in rotation with cotton (submitted to Aust. J. Exp. Agric.)

Rochester, I., Peoples, M., Constable, G. and Gault, R. (1998). The benefits of legume crops in cotton farming systems 1. N response by cotton to fertilizer N and legume-derived N (in preparation).

Rochester, I., Peoples, M., Constable, G. and Gault, R. (1998). The benefits of legume crops in cotton farming systems 2. Predicting the availability of legume N to cotton by soil and plant tissue testing (in preparation).

Other communication:

Oral presentations at Gwydir and Namoi Cotton field days (Feb/Mar 1996).

Telephone inquiries regarding cotton nutrition and legume cropping (average 1/day).

Newspaper articles have appeared in "The Land" and local newspapers and supplements.

Presentation at Cotton Media Day at ACRI (March 1996) - Local and Sydney Press.

TV interview for "The Farming Show"(Channel 9) shown on 7/12/96 regarding legume rotation crops in cotton systems.

Video article for "The Cotton Report" in 1995 regarding legume research in cotton industry.