FINAL REPORT 2007

Part 1 - Summary Details

Please use your TAB key to complete Parts 1 & 2.

CRDC Project Number: **CRC52C**
OR Cotton CRC Project Number: **1.3.02**

Project Title: Nutritional constraints to efficient cotton production

Project Commencement Date: 1/7/2003 **Project Completion Date:** 30/06/2007

CRDC Program: Off farm **OR CRC Program:** The Farm

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Part 3 – Final Report Guide (due 31 October 2006)

(The points below are to be used as a guideline when completing your final report.)

Background

The productivity of many commercial cotton crops can be limited by inadequate nutrition. In Project CRC19C, the optimum levels of all nutrients have been more closely defined for different stages of crop growth. Commercial crops have been assessed for nutrient status in most cotton growing districts each year. In particular, nitrogen (N), phosphorus (P) and potassium (K) have been examined closely, as they exert a profound influence on the growth, development and health of cotton. The importance of high levels of soil sodicity has been examined in preliminary experiments, particularly with respect to the effect of sodium uptake on the uptake of P and K by cotton. In addition, the use of rotation crops, especially legumes, has indicated beneficial effects on soil nutrient levels and soil health generally.

Objectives

<u>Diagnosis of nutritional problems</u> – identify cotton crops suffering nutrient stress (deficiency or excess) and situations where responses to nutrient application may occur. Examine the feasibility of using Near-Infra-Red (NIR) technology to quickly diagnose nutrient levels. Assess the importance of soil sodicity on nutrient uptake.

Of paramount importance is potassium (K) nutrition; we shall investigate the status of soil and plants growing under various degrees of K deficiency to improve recommendations for K deficiency diagnosis and fertilizer application strategies. We shall examine the forms, placement, and timing of K fertilizer application. Regional trials conducted each year of the project will allow assessment of crop nutrition under various management options and soil types.

<u>Improvement of soil health</u> **-** Legume cropping has shown considerable benefit in improving soil tilth, particularly by winter crops such as vetch and faba beans. Soil strength is reduced, allowing for easier cultivation and deeper root growth. Acid exudation by legume crop roots may help to solubilize natural gypsum and lime and assist in the release of insoluble nutrients (eg P, Zn). The cropping systems research involving the assessment of legume cropping within the cotton system will continue.

The fixation of nitrogen by free-living microorganisms delivered in commercial products (eg Bio-N) will be investigated. These organisms offer considerable potential to fix N during the growth of cotton and reduce the requirement for N fertilizer.

<u>Nutrition of high-yielding crops</u> – The nutritional demands of high-yielding crops will be examined with respect to nutrient uptake and the crops' fruiting pattern. This may be important for newer transgenic crops (Bollgard® II) and

these will be compared with conventional cotton crops under a range of fertility situations.

Methods

Many experiments were performed on commercial cotton farms to evaluate cotton nutrition. These experiments were sampled regularly to assess changes in crop nutrient status and yield effects. Leaf and other plant parts were collected and analysed for nutrient content. The cropping systems experiments in Field 6 at ACRI have been continued, and have been monitored to provide further data on cotton crop nutrition and soil health. Further laboratory and glasshouse experiments were conducted to ascertain the effects of sodium and legume cropping on cotton nutrition under controlled conditions.

Results

<u>Diagnosis of nutritional problems</u>

Many cotton crops were sampled during this project. Normally soil, leaf, and crop dry matter samples were collected at each site and yield estimated either by hand or machine picking.

Soil analysis

Soils were chemically analysed by one commercial lab to ensure uniformity between years and sites. Sites for on-farm nutrition experiments were normally chosen where growers had contacted the researcher and expressed concern in relation to the nutrition of their crop and were interested in examining fertiliser responses. While most soils were grey or brown Vertosols of medium to high clay content, their nutrient status varied considerably. Nitrogen, phosphorus and potassium contents ranged from deficient to abundant, while salinity rarely posed a problem for cotton growth. However, many soils that reportedly produced poor cotton yields often possessed elevated sodium concentrations in the topsoil and often very high levels in the subsoil. The ideal and critical levels of nutrients in soil have been incorporated into many extension messages (see section on extension) allowing growers to assess their soil chemical fertility and plan a fertiliser program based on their soil analysis data and the output from this program.

Leaf analysis

Leaves were collected throughout each growing season, dried and analysed by commercial and research laboratories. A pattern of optimal nutrient concentration emerged with several season's data. These data provide the basis for the NutriLOGIC program that enables growers to assess the level of each nutrient throughout the growing season.

Nutrient uptake was also determined prior to defoliation to measure the quantities of all nutrients contained in the plant tissues. Nutrients removed in the

seed cotton were also determined in some experiments. High levels of sodium uptake are associated with low P and K levels in cotton and are strongly implicated in the premature senescence syndrome of cotton.

Each season, the dried and milled leaf samples were scanned, using Near-Infra-Red (NIR) technology over a huge range of wavelengths. These data where then correlated with the traditional chemical analyses of the leaf material. It was anticipated that this technology may provide a means to quickly diagnose nutritional problems. However, the correlations between the two methods were poor for some nutrients, but good for others (eg N). Particle size and moisture content were identified as contributing to the variation, but did not improve the prediction of nutrient concentrations, such as sodium. There seems little value in pursuing this research further.

NutriLOGIC Decision Support System

The NutriLOGIC DSS was completely revised in 2006. Previously, this program only assessed N management by indicating the amounts of N fertiliser required for optimum cotton yield, based on soil and petiole-nitrate analyses. The upgrade now allows for producers to input the data from their soil analyses provided by commercial laboratories and suggests appropriate rates of N, P, K and S fertilisers and indicates whether the soil is sodic or saline and whether the soil is likely to disperse when irrigated. The petiole nitrate module has also been improved. However, the most substantial improvement has been the inclusion of the leaf analysis module which allows producers to input data from commercial laboratories for analyses of leaf blades collected throughout the growing season. All nutrients (including micronutrients) are assessed in this module and can therefore be more useful than soil testing. The program is located at the cotton CRC website:

http://tools.cotton.crc.org.au/CottonLOGIC/NutriLOGIC/

<u>Soil health</u>

The legume cropping systems experiment that was initiated in 1994 has provided much information regarding cotton nutrition and the impact of the various rotation crops used in this experiment. Those cropping systems that include legumes have generally improved soil quality/condition as measured by better physical soil structure, chemical fertility, more active soil microbial populations and increased organic matter where crop stubble was conserved.

Reduced tillage and permanent bed systems have enabled soil carbon levels to increase as soil organic matter does not decompose as quickly as when soil is regularly cultivated.

Biology

Some cropping systems promote a much healthier environment for microorganisms to thrive, cycle nutrients and support plant growth. Examination of the soil microbial biomass at several occasions through this project has consistently revealed a greater abundance of soil microorganisms in the soils of the cropping systems that include legume crops.

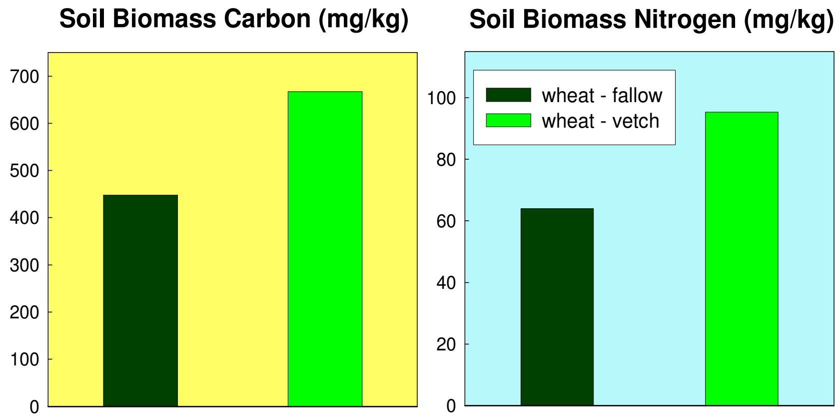

Figure 1. Soil microbial carbon and nitrogen determined in soil from two cropping systems at sowing time in 2005. The increased microbial biomass in the vetch-based systems was associated with a 5% increase in lint yield.

Physical fertility- soil structure

Soil bulk density was not affected by the rotation crops; changes in this soil property were only observed with depth and were consistent in all treatments. At the experimental site, bulk density increased from 1.25 g/cm^3 in the topsoil (0-30 cm) to 1.45 (30-60 cm) and to 1.50 (60-90 cm). This soil contains about 52% clay in the topsoil and is less likely to become compacted than heavier clay soils.

However, soil structure has been assessed more closely using a cone penetrometer, an instrument that measures soil strength. The soils within those cropping systems that include legumes such as vetch offer lower resistance to the cone penetrometer throughout the root zone of cotton, and this is indicative of a root's ability to more readily explore a volume of soil. Reduced soil strength allows the following cotton crop to more easily access nutrients and water for the soil profile.

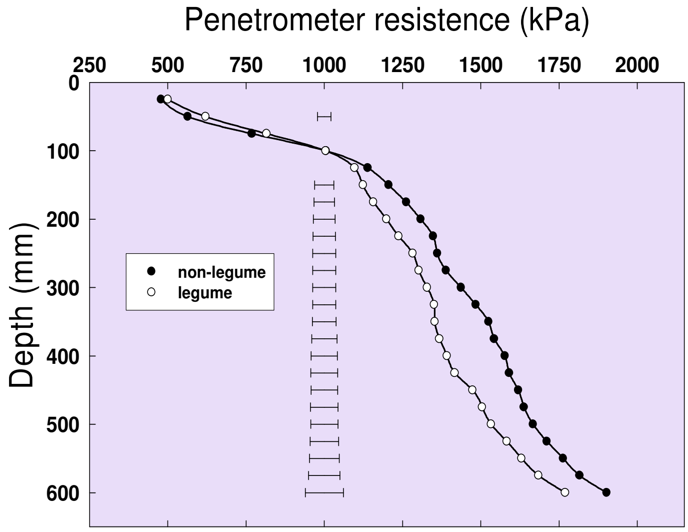

Figure 2. Differences in soil strength determined in cropping systems that grew either vetch or were fallowed (non-legume).

<u>*Chemical fertility – nutrient supply*</u>

Profound changes have been observed between the cropping systems. Those that include legumes have shown reduced soil pH, a consequence of acid exudation from the roots of the legume crops, especially vetch and faba beans. These organic acids may dissolve minerals, including those minerals that contain nutrients such as P and K and enhance the availability of those nutrients to following crops. This aspect of crop nutrition and soil chemistry may be further research as a means of remediating strongly alkaline soils.

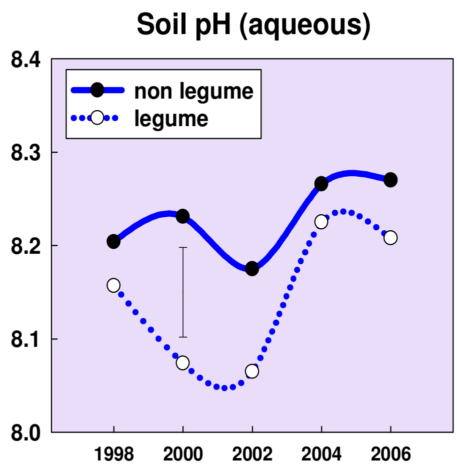

Figure 3. Soil pH was reduced where legume crops were included in the rotation systems.

Commercial soil analyses may not indicate substantial changes in nutrient availability afforded by changes in the cropping system, as nutrients are conserved in the soil organic matter. Greater nutrient uptake was measured from the legume-based systems, as shown in Table 1. Also, crop dry matter (DM) production was higher in the legume systems. The better nutrient acquisition of the cotton in the legume-based systems improved the yield of those crops. Leaf blade analyses have confirmed better nutrition of cotton crops grown in legume-based systems.

Table 1. Crop biomass production and nutrient uptake by cotton in 2006/07 season, meaned over the legume and non-legume cropping systems.

	Non-legume	Legume	% difference
Crop biomass (t/ha)	8.2	9.6	+ 18
Nitrogen (kg/ha)	135	179	+ 32
Phosphorus (kg/ha)	25.6	28.5	+ 11
Potassium (kg/ha)	152	177	+ 16
Sulfur (kg/ha)	31	36	+ 17
Zinc (g/ha)	99	129	+ 30

N fixation by legume crops

Large quantities of N have been fixed by the legume rotation crops since the start of this cropping systems experiment. N fixation in individual legume crops is given in Appendix 1. Vetch crops fixed ~150 kg N/ha on average, while faba beans returned 96 kg N/ha to the soil after the seed was harvested. All vetch crops were green-manured. Since the experiment commenced (11 years), faba beans have added 574 kg N/ha, vetch grown between continuous cotton crops has added more than 1600 kg N/ha. While much of this fixed N has been used by the cotton crops grown during this period, a substantial proportion of this N remains in the soil as organic N, as shown below in Figure 4. Fixed N that is added to the soil through legume cropping is relatively resistant to N loss processes (leaching and denitrification) as it remains mostly as organic N. Small amounts of legume–N can effectively meet the N needs of cotton, compared with the much higher rates of N fertilisers required in traditional non-legume systems.

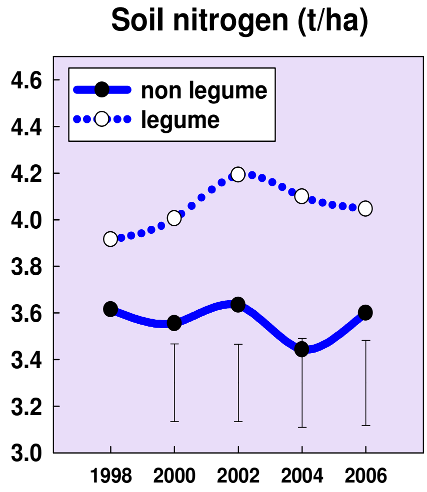

Figure 4. Soil total N content was substantially increased in those cropping systems that included legume rotation crops.

<u>*Soil organic matter*</u>

Soil organic C content was slightly higher with the regular inclusion of legume crops, as the comparative non-legume systems were fallow during those periods and less carbon was added to them. The data indicates that C levels have increased in all systems, a consequence of a permanent bed system with minimum tillage, thereby allowing C and organic matter to accumulate in these soils. Cotton soils have the potential to sequester large amounts of atmospheric carbon dioxide, and could be an avenue towards reducing the industry's emissions of greenhouse gases.

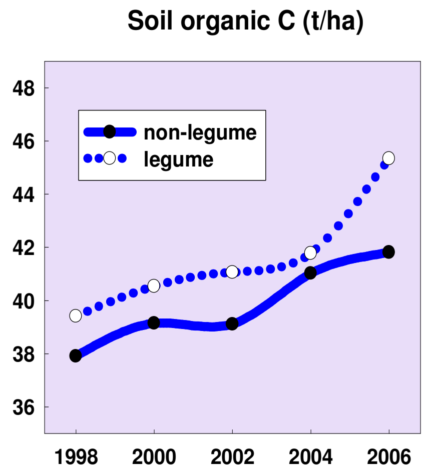

Figure 5. Soil organic C levels in soil (0-30 cm) during the experiment.

Cotton lint yield

Lint yield was assessed in each year of the experiment. The legume based systems surpassed the non-legume systems and required considerably less N fertiliser to optimise lint yield. This pattern has been observed since the experiment was initiated; the differences in yield between the five systems increased each season until 2005. Lint yields were low in 2003, a result of soil compaction following severe flooding in 2000 which was not alleviated until winter of 2003. The faba bean/ fallow /cotton systems remained the highest yielding system in the years studied. No N fertiliser was required in this system, even to attain 12 b/ha in 2005. Where vetch was included in either the cotton/wheat or the back-to-back cotton systems, the legume inclusive systems out-yielded the non-legume systems and required substantially less N fertiliser to optimise lint yield.

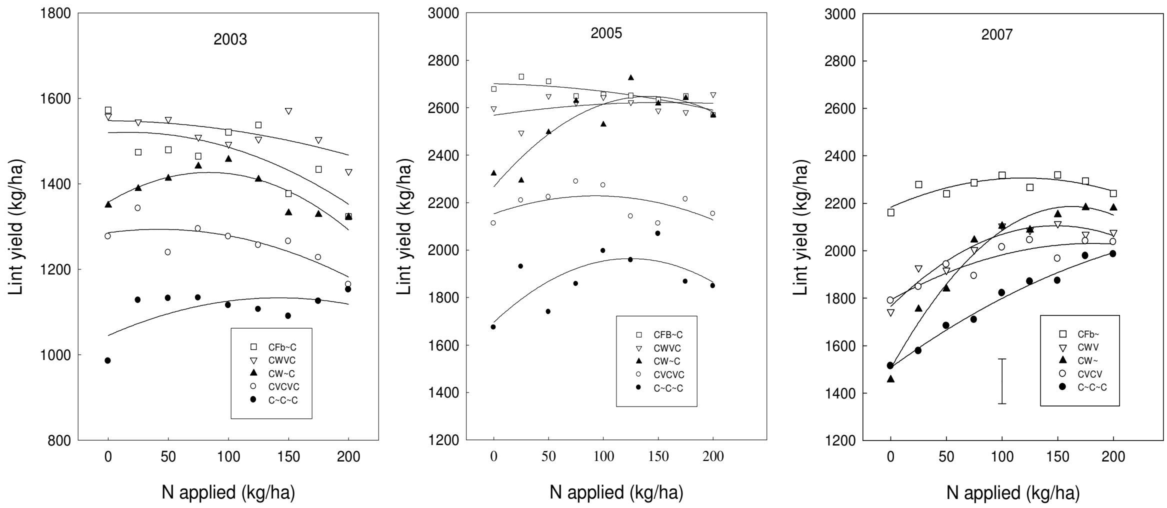

Figure 6. Lint yield, as affected by cropping system and N fertiliser application (note different yield scale in 2003).

Greater effort is being placed on the efficiency of N fertiliser use, with field experiment and crop monitoring in most cotton-growing regions.

Evaluation of gross margins afforded by the cropping systems

Meaned over the four cycles depicted in Table 2 below, the CVCVC system yielded 132 kg lint/ha more than the C~C~C system and required 62 kg fertiliser N/ha less; this increased the gross margin by $383/ha. Similarly, CWVC system yielded 46 kg lint/ha more than the CW~C system and required 67 kg fertiliser N/ha less; this increased gross margin by $202/ha. Where faba bean replaced wheat in the rotation system, lint yield was increased by 76 kg/ha, and cotton required 79 kg N/ha less N fertiliser, increasing gross margins by $286/ha. These

increases more than pay for the costs of sowing and green-manuring the vetch crops; the faba bean costs and returns are similar to wheat. In 2005, Emma Williams (student from University of Queensland, Gatton campus) conducted an economic analysis of this data to that point in time – a report was published in the Australian Cottongrower magazine.

Table 2. Economic optimum N fertiliser input and yield afforded by the cropping systems at the optimum N rate (see figure 6 for yield and N response data).

	2001		2003		2005		2007	
System	Y_{opt}	N_{opt}	Y_{opt}	N_{opt}	Y_{opt}	N_{opt}	Y_{opt}	N_{opt}
C~C~C	1317	137	1058	15	1952	103	2063	264
CVCVC	1410	61	1294	29	2209	55	2008	126
CW~C	1310	80	1410	42	2647	120	2181	148
CWVC	1473	0	1596	0	2568	0	2095	123
CFb~C	1376	0	1489	0	2700	0	2288	74

Assessment of products delivering free-living N fixing microorganisms

N fixation by free-living microorganisms delivered in commercial products (Bio-N and Twin-N) has shown no impact in field and glasshouse experiments. Anecdotal evidence suggests that these products may have a place in *some* agricultural crops, but these microorganisms have difficulty surviving on the foliage of cotton crops given the extreme environmental conditions they face mid-summer. Dr Oliver Knox counted the populations of surviving N- fixing organisms on the leaves of treated cotton plants, but numbers were similar to the untreated plants, suggesting that very few of these microorganisms had survived. Production of legume crops for grain or green-manuring is a more reliable means of fixing nitrogen biologically.

Nutrition of high-yielding crops

The nutritional demands of high-yielding crops are being assessed regularly. The critical values for leaf nutrient concentrations have not altered appreciably over the past 15 years, despite substantial increases in lint yield. Similar research has been done by Cotton Grower Services (Dale Clark) who monitored crop nutrient levels from crops that yielded more than 11 bales/ha; optimum leaf nutrient concentrations were either slightly lower or similar to those indicated by the NutriLOGIC DSS. This reaffirms the validity of the NutriLOGIC program in advising growers when they decide on nutritional matters.

Growers who assess soil fertility with regular soil analyses, conduct leaf analyses and apply adequate amounts of fertilisers when required, will ensure the crop is able to grow without nutritional problems. There is no evidence for the notion that lint yields can be increased with inputs of fertilisers in excess of optimum levels. There is a risk that this strategy will exacerbate greenhouse gas emissions and reduce the efficiency of fertiliser use.

Transgenic cotton requires no more nutrients than conventional cotton. Higher yielding crops may take up greater quantities of nutrients and similarly higher quantities of those nutrients will be removed in the seed, but this is independent of the cultivar grown.

Nutrient removal

Nutrient removal in seed cotton is directly related to lint yield. These relationships have been determined from the cropping systems experiment that covers a wide range of yield levels and fertility situations. Table 3 below has been included in the CRC website and it appeared in an Australian Cottongrower magazine article. It can be used as a guide to determine whether nutrients are being applied in sufficient quantities to avoid depleting the fertility of the soil.

Table 3. Nutrient removal by cotton at various yield levels.

b/ha	kg/ha						g/ha				
	N	P	K	S	Ca	Mg	B	Cu	Zn	Fe	Mn
4	35	10	15	4	2	5	13	12	53	85	6
5	50	12	18	5	3	7	20	14	63	98	8
6	65	14	22	6	3	8	28	16	72	112	9
7	80	17	26	7	4	10	35	18	82	125	11
8	95	19	29	8	4	11	42	20	91	138	12
9	110	21	33	9	5	13	49	22	100	151	14
10	125	24	37	10	6	14	56	24	110	164	15
11	140	26	41	11	6	16	63	26	119	178	17
12	155	28	44	12	7	17	70	28	129	191	18
13	170	31	48	13	7	19	78	30	138	204	20
14	185	33	52	14	8	20	85	32	148	217	21
15	200	35	55	16	8	22	92	34	157	230	22
16	215	37	59	17	9	23	99	36	166	244	24
17	230	40	63	18	9	25	106	38	176	257	25
18	245	42	67	19	10	26	113	40	185	270	27
19	260	44	70	20	10	28	120	42	195	283	28

Phosphorus and potassium deficiencies and responses to fertilisers

P and K nutrition remains one of the most important areas of nutrient research in the cotton industry. Commonly, excessive uptake of sodium exacerbates poor P and K nutrition in cotton. This phenomenon is often responsible for the "premature senescence" syndrome in cotton crops. Five experiments were initiated in the Macintyre and Namoi valleys between 2003/4 and 2006/7; the experiments showed no substantial response to either P or K fertilisers, although there were still indications of P and K stress in these crops towards the end of the season.

However, there was a substantial response to P fertiliser at one site in 2006/7, despite soil Colwell P levels being marginal; where soil Colwell P was low there was a highly significant response to applied P (Figure 7). These sites were marginal in terms of K nutrition – this results indicates the close interaction between theses two nutrients and the need for research to improve our understanding of these situations.

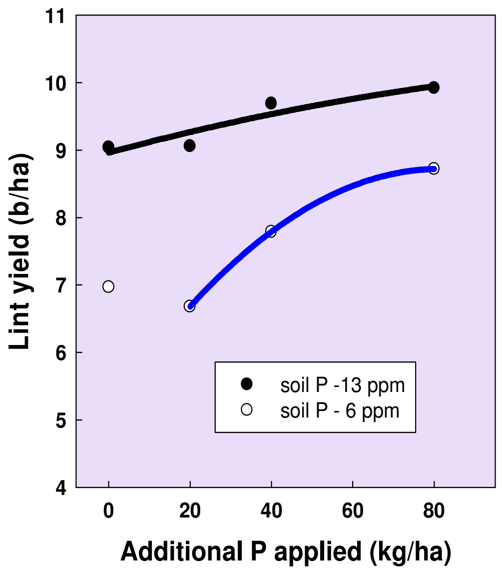

Figure 7. Response to P fertiliser at two sites; 10 kg P/ha had been applied prior to the experiment being initiated.

N use efficiency benchmarking across the industry

In the fourth year of this project, crop N use efficiency (NUE) was assessed on ~30 commercial cotton fields throughout the growing regions, assisted by the local extension officers. The methodology for assessing the crop NUE was determined the previous season, using data from the legume cropping systems experiment where the optimum rates of N fertiliser had already been determined and this could be related to crop N uptake and lint yield. Crop NUE, defined as kg lint produced per kg crop N uptake, should be between 11 and 12 if N use has been optimised. Our survey realised values between 7 and 21. Although a small number of fields were sampled, poor NUE was determined in half of them, with about 40 kg N/ha being applied in excess of the N fertiliser required by cotton in those fields (see Appendix 2). This research will continue for the next couple of seasons, with continued input from the regional extension team.

Outcomes

1. Diagnosis of nutritional problems

The project has identified for cotton crops the nutrient concentrations whereby nutrient stress is avoided. Near-Infra-Red (NIR) technology does not present a solution to quick diagnosis of nutritional problems. Soil sodicity poses a severe restriction on nutrient uptake by cotton, and is related to premature senescence. P rather than K is now believed to be more influential in remediating this problem, and this will be the focus of a new CRDC/CRC nutrition project.

Soil health improvement

Legume cropping has considerable benefits, including improved soil tilth, reduced soil strength, enhanced nutrient availability, slightly acidified soil, which provide a better environment for root growth and promote more productive cotton crops.

Biological N fixation

The legume crops (particularly the winter-growing faba beans and vetch) fixed substantial quantities of N, and in many instances, were able to supply sufficient N to maximise lint yield in the respective rotation system, or substantially reduce the requirement for fertiliser N. Unfortunately, the free-living microorganisms delivered to the roots or foliage of cotton crops in commercial products (eg Bio-N and Twin-N) did not supply measurable amounts of N to cotton.

Nutrition of high-yielding crops

The nutritional demands of high-yielding crops were examined. High-yielding cotton has similar nutrient requirements to average-yielding crops. Increasing fertiliser inputs beyond those indicated by soil and leaf analyses will not increase yields. However, higher-yielding crops will remove greater quantities of nutrients from fields which can hasten soil fertility decline if not addressed in the fertiliser program. This project has addressed both of these issues by

- Establishing the amounts of nutrients removed by cotton crops, as determined by yield

- Developing technology to measure crop N use efficiency, determine the ideal N use efficiency and apply this technology with the help of the cotton extension team to assess industry performance as a means to promote change.

Technical advances

a) technical advances. No commercially significant developments have been achieved, no patents applied for or licenses granted.
b) other information developed from research. Methodology has been developed to determine N use-efficiency in commercial cotton fields.
c) no changes are required to the Intellectual Property register.

Conclusion

The likely impact of these results and conclusions for the cotton industry are;

- Soil and tissue testing provides the basis for sound nutrition and optimising fertiliser use. Adhering to these testing practices will improve the use-efficiency of fertilisers and reduce the environmental impact.

- Legume cropping can dramatically reduce the requirement for N fertilisers and substantially enhance soil quality. Improved soil microbial biomass and reduced soil strength enables better root growth and facilitates cultivation and tillage, resulting in crops that are better nourished due to improved availability of nutrients. Economic analyses demonstrate higher gross margins from legume-based systems due largely to elevated cotton yields and reduced need for N fertiliser.

- Greenhouse gas abatement can be achieved through reduced N fertiliser use and minimum tillage or permanent bed systems.

Extension Opportunities

Detail a plan for the activities or other steps that may be taken:

(a) The results of this research project have provided the backbone for the revision and expansion of the NutriLOGIC program, which, to date, has not been fully utilised by the cotton industry.
(b) The NutriLOGIC DSS has not been promoted by the extension team – the team needs training within the next 12 months to become proficient in advising producers on how to sample soils and crops for analysis and make decisions on a fertiliser program based on the output of the NutriLOGIC program. An independent study on cotton nutrition indicates that the NutriLOGIC program delivers sensible and realistic recommendations for the highest yielding cotton crops.
(c) The research on soil health is ongoing; current information will be published in 2008. This research is being included in extension workshops.
(d) The extension team is being increasing involved with this research, particularly in the Nitrogen use-efficiency area. His is a critical area in terms of sustainability, economics, environment and ultimately BMP. The cotton industry must move to a more rational basis for fertiliser use, based on scientific understanding rather than guesswork.

List the publications arising from the research project.

Scientific articles

Rochester IJ and Peoples MB (2005). Growing vetches (*Vicia villosa* Roth) in irrigated cotton systems: inputs of fixed N, N fertiliser savings and cotton productivity. *Plant and Soil* **271**: 251-264.

Rochester IJ (2007). Nutrient uptake and export from an Australian cotton field. *Nutrient Cycling in Agroecosystems* **77**: 213-223.

Rochester IJ (2007). Nutrient acquisition by cotton growing in sodic and non-sodic soils. *Journal of Plant Nutrition (in review).*

Conference proceedings

Constable GA, Rochester IJ (2003) Leaf nutrient concentrations in cotton cultivars grown on slightly sodic soils. In Proc. World Cotton Research Conference-3. pp 681-685. Agricultural Research Council – Institute for Industrial Crops, Pretoria.

Rochester IJ and Constable GA. (2003) Variation in cotton cultivars to take up nutrients and tolerate soil sodicity. World Cotton Research Conference - 3 (Cape town, 2003).

Roth GW, Christiansen IH, Dugdale H, and Rochester IJ (2003) Collaboration: The key to developing research, development and extension priorities for cotton farming systems in Australia. 1st Australian Farming Systems Conference. 7-11 September 2003 Toowoomba.

Rochester IJ (2004). Soil fertility management and cotton nutrition. 12th Australian Cotton Conference. Broadbeach, Queensland.

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Errington M, Campbell L, Tan D, Rochester IJ (2006). The efficacy of foliar fertilisers on Bollgard II® cotton. 12th Australian Cotton Conference. Broadbeach, Queensland.

Dodd K, Guppy C, Lockwood P, Rochester I (2006) Overcoming the confounding effects of salinity on sodic soil research. ASSSI-ASPAC National Soils Conference. 3-7 December 2006. Adelaide.

Extension articles

Rochester IJ (2004). Vetch improves the productivity of irrigated cotton. *Australian cottongrower* (April-May) Vol 25(2) pp 58-61.

Rochester IJ (2004). Rotational vetch lifts cotton yields and profit. *Farming Ahead* No. 150 (July) pp 54-55.

Williams E, Rochester I, Constable G (2005). Using legumes to maximise profits in cotton systems. Australian Cottongrower magazine. (Oct 2005 p 43-46).

O'Halloran J, Rochester I, Dowling C (2005). New cotton nutrition sampling guidelines. Australian Cottongrower magazine. (Oct 2005, p 56-58).

Rochester I, Constable G, Dowling C (2005). Understanding Bollgard II nutrition. Australian Cottongrower magazine. (Dec 2005 p14-16).

Rochester I, Constable G (2006). Nutrients removed in high-yielding cotton crops. Australian Cottongrower magazine. (June 2006 p24-28).

Knox O, Rochester I, Vadakattu G, Lawrence L (2006). Composting in Australian cotton production. Australian Cottongrower magazine. (Aug 2006 p46-48).

Rochester I (2006). Efficient use of Nitrogen fertilisers. Australian Cottongrower magazine. (Dec 2006 p48-50).

Deutscher S, Rochester I, Clancy L (2006). Major upgrade for cotton nutrition tools. Australian Cottongrower magazine. (Dec 2006 p46).

Rochester I, O'Halloran J, Maas S, Sands D, Brotherton E (2007) Monitoring nitrogen use efficiency in your region. Australian Cottongrower magazine. (Aug 2007 p22).

B. Have you developed any online resources and what is the website address?

The NutriLOGIC DSS has undergone a major upgrade and expansion in 2006; it sits on the CRC website **http://tools.cotton.crc.org.au/CottonLOGIC/NutriLOGIC/**

Part 4 – Final Report Executive Summary

Provide a one page Summary of your research that is not commercial in confidence, and that can be published on the World Wide Web. Explain the main outcomes of the research and provide contact details for more information. It is important that the Executive Summary highlights concisely the key outputs from the project and, when they are adopted, what this will mean to the cotton industry.

This project has advanced the use of soil and tissue testing such that growers and advisors are now better able to optimise fertiliser use and have greater confidence in their management practices to provide sound nutrition for cotton crops. Adhering to these best management practices will improve the use-efficiency of fertilisers and reduce the potential for damage to the environment. The large quantities of macro-nutrients removed in seed cotton should be replaced to avoid depleting soil fertility.

Legume cropping can dramatically reduce the requirement for N fertilisers and substantially enhance soil quality. Legumes afford improved soil microbial biomass and reduced soil strength which enables better root growth and facilitates cultivation and tillage. Also, crops are better nourished due to improved availability of nutrients. Economic analyses have demonstrated higher gross margins from legume-based systems due to elevated cotton yields and the reduced requirement for N fertiliser.

By avoiding the overuse of N fertiliser, we can reduce greenhouse gas emissions via nitrous oxide. Further, atmospheric carbon dioxide can be sequestered and soil organic matter increased where tillage is minimised and permanent bed systems installed. Greater research effort is now being placed on the efficiency of N fertiliser use, and the regional extension officers are assisting this. This research offers the industry an opportunity to reduce N fertiliser use and greenhouse gas emissions, without reducing yield.

The results of this research are being extended to the cotton industry but have not been widely adopted by the industry. Further extension activity is planned and training for the extension team and industry on cotton nutrition and soil health issues.

Appendix 1. N fixation in legume crops since commencement of the cropping systems experiment. Since 1998, the following systems have been in place; C~C~C and CVCVC are continuous cotton, with and without vetch, CW~C and CWVC are wheat-fallow or wheat vetch systems and CF~C is faba bean-fallow system.

	C~C~C	CVCVC	CW~C	CWVC	CF~C
Winter 1995		113	~		101
Summer 1995/96	~			228 (soybean)	
Winter 1996	~		~		
Winter 1997	~	238		134 (Faba)	134
Summer 1997/98			~	244 (lablab)	
Winter 1998	~	172	~		
Winter 1999	~	208			85
Winter 2000	~	168	~	148	
Winter 2001	~	204			137
Winter 2002	~	176	~	142	
Winter 2003	~	57			35
Winter 2004	~	77	~	27	
Winter 2005	~	146		82	82
Winter 2006	~	58	~	267	
Total		1617		1272	574
Average		***147***		***159***	***96***

Appendix 2. Article published in the Australian Cottongrower magazine (Aug 2007).

Monitoring nitrogen use efficiency in your region

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Summary

- **We measured N use efficiency in 34 cotton crops in 5 valleys**
- **N use efficiency values were high in 2 fields, optimal in 8 fields and low in 17 fields**
- **Low N use efficiency values were a consequence of excessive N fertiliser application**
- **Averaged over all sites, about 40 kg N/ha too much N fertiliser was applied**
- **The data indicated that there is considerable scope to reduce N fertiliser inputs to cotton fields without reducing yields**
- **It is important to determine the appropriate N fertiliser rate using soil testing and a tool such as NutriLOGIC**

Increasing nitrogen (N) fertiliser costs and increased focus on greenhouse gas emissions have prompted greater attention to the efficient use of nitrogen fertilisers. These issues and the need to optimise fertiliser inputs to meet crop requirements have also increasingly been identified as priorities in feedback from cotton growers and consultants. So, how efficiently are nitrogen fertilisers currently being used in the Australian cotton industry?

The Cotton Nutrition Research Group and the Soils and Nutrition Priority Team (made up of members of the National Cotton Extension Team) initiated a nitrogen use efficiency monitoring program in several regions during the 2006/07 cotton season to gain some understanding of current nitrogen use efficiencies.

What did we do?
At various sites in the Namoi, Gwydir, Macintyre and Central Queensland regions, we measured the crop N uptake, crop N use efficiency and N fertiliser recovery, as described below. These measurements were compared using a relationship formulated from separate cropping systems experiments.

Crop N uptake refers to the amount of N (kg N/ha) taken up and contained in the crop. Measuring crop N uptake involves taking 1 square metre of crop (whole plants) after cut-out and approximately 3 weeks before defoliation (at about 10-15%

bolls open) and before leaf starts to drop. These plants are then dried, weighed, ground and analysed for N content.

Crop Nitrogen Use Efficiency (NUE)
This indicates how effectively a crop produces lint yield from the N that it has accumulated. The crop NUE measurement does not discriminate between soil N or fertiliser N sources and is therefore independent of how much N fertiliser was applied. It indicates how efficiently the cotton crop uses *all* N sources available to it. It is measured by dividing the lint yield by the crop N uptake (i.e. kg lint produced per kg N uptake). Hence, crop N uptake and crop yield must be determined. This is a detailed way of assessing how efficiently N is used by cotton and can indicate where inadequate, sufficient or excessive amounts of N fertiliser have been applied.

Nitrogen fertiliser recovery (NFR)
This indicates how well a crop uses the N fertiliser that has been applied. This is the proportion of the applied N fertiliser that is taken up by the crop, expressed as a percentage of that applied. It is calculated by taking the difference in crop N uptake between fertilised and unfertilised cotton, divided by the rate of fertiliser applied. This requires a zero-N fertiliser strip (plot) in the field being monitored.

Nitrogen use-efficiency – what is our target?
It is important to outline our targets for NUE before we discuss the results of our survey. Results from the past four years of a long-term cropping systems experiment at ACRI have been used to develop a relationship between fertiliser use and nitrogen use-efficiency (Figure 1). Earlier results were published in the Australian Cottongrower Magazine in December 2006. Crop NUE values between 11 and 13 indicate that N fertiliser rate was sufficient. Values less than 11 indicate excessive rates of N fertiliser may have been applied. Values greater than 13 indicate insufficient N fertiliser may have been applied, that the crop was drought stressed or another nutrient deficiency limited crop development.

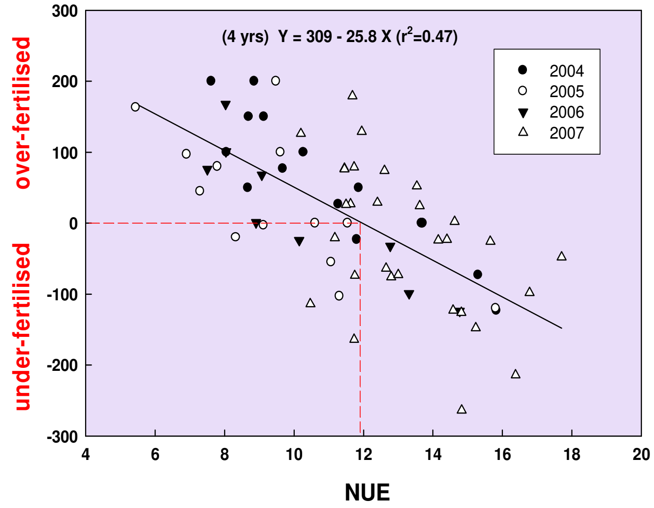

Figure 1. Crop N use-efficiency (NUE) measured in a separate crop rotation experiment where numerous N fertiliser rates were applied. Over-fertilised crops have low NUE whereas under-fertilised crops have high NUE.

What did we find?

We determined the crop NUE and NFR and estimated the N fertiliser requirement for the commercial cotton crops, as shown in Table 1. We used the relationship in Figure 1 to predict the N fertiliser requirement from the crop NUE value.

Table 1. Crop dry matter (DM), crop N uptake, lint yield, N use-efficiency (NUE) and N fertiliser recovery (NFR- where different N rates were applied) and estimated amounts of N fertiliser (kg N/ha) applied in excess (or insufficiency) for 34 cotton fields, of which 7 were Pima crops.

Valley	N rates applied	Crop DM t/ha	N uptake kg N/ha	lint b/ha	lint kg/ha	NUE kg/kg	NFR %	Fertiliser excess
Emerald		18.5	289	11.5	2611	9.0		76
		16.8	359	11.2	2542	7.1		126
		9.4	208	10.4	2361	11.3		16
		13.8	238	9.6	2179	9.2		72
		9.6	144	9.9	2247	15.6		-95
		11.2	268	8.3	1884	7.0		127
		11.6	151	8.3	1884	12.5		-13
		9.2	163	9.3	2111	13.0		-26
	mean	12.5	227	9.8	2227	10.6		36
Macintyre		10.9	190	10.1	2297	12.1		-2
Gwydir	0 N	10.3	219	8.6	1952	8.9	-	
	160 N	12.6	217	8.6	1953	9	-2	77
	320 N	8.7	210	9.6	2173	10.4	-3	42
		6.2	162	7.9	1790	11.1		24
		13.6	261	13.4	3051	11.7		7
		13.7	276	12.5	2847	10.3		43
	0 N	4.0	60	5.5	1256	20.9	-	
	180 N	6.8	144	5.5	1243	8.6	47	87
		10.4	250	7.5	1696	6.8		134
	mean	9.6	200	8.8	1996	10.9		59
	Pima	14.1	318	5.0	1132	3.6		?
		9.1	155	4.3	975	6.3		?
		9.1	211	5.8	1325	6.3		?
		11.3	235	6.0	1354	5.8		?
		14.3	346	7.8	1771	5.1		?
		19.5	349	8.6	1950	5.6		?
		10.3	236	8.6	1950	8.3		?
	mean	12.5	264	6.6	1494	5.9		
Namoi		10.5	218	10.1	2292	10.5		38
		9.5	180	8.7	1976	11		26
		7.0	166	7.4	1668	10		50
		11.7	241	9.8	2225	9.2		71
		12.3	256	9.8	2225	8.7		85
		13.0	246	11.1	2520	10.2		45
		6.1	105	9.1	2066	19.7		-199
		11.1	208	11.8	2679	12.9		-24
	mean	10.2	203	9.7	2206	11.5		12
Macquarie		13.8	258	12.7	2883	11.2		21
		15.4	311	12.0	2724	8.8		83
		10.7	237	9.0	2043	8.6		87
		14.2	259	12.2	2769	10.7		33
	mean	13.5	266	11.5	2605	9.8		56

Our survey fields covered a wide range of yield levels. Many crops yielded well as they were planted in fallowed fields and the growing season was long. However, some important trends in N fertiliser use have emerged.

N uptake

Research over many years has shown that 200-250 kg N/ha crop N uptake is sufficient to maximise lint yields. However, N uptake beyond this level will reduce NUE. Many of the crops in our survey exceeded 250 kg N/ha N uptake.

N use efficiency (NUE)

Obtaining the optimum NUE value of 11.8 kg lint/kg N uptake can be difficult, given the variability in growing conditions between seasons. About two-thirds of the crops had NUE values less than 11 (some as low as 6.8), but only 7% had NUE values more than 13. Eight of the 27 crops had optimum NUE values (11-13). The crop with very high NUE in the Namoi showed symptoms of poor P nutrition and slow crop growth; it took up inadequate amounts of N because of this.

N fertiliser excess or inadequacy

This survey indicates that 9 sites had sufficient N, 2 had inadequate N and 16 sites had excessive amounts of N. Averaged over all the sites (excluding the zero N plots) about 40 kg N/ha was applied in excess of the amount required by cotton. This will add about $50/ha to the growers input costs. Thus, there is scope to improve N use efficiency industry wide; we can reduce N fertiliser inputs by about 15%.

Most of the cotton fields chosen by the extension team were either adequately or over-fertilised with N. Excessive N application results in N losses and waste of money as N not used by the crop may be lost from the soil. By reducing N inputs to fields with poor N use-efficiency, we may improve yields while reducing costs and substantially improve gross margins.

Low NUE results from excessive N fertiliser application which increases the risk of enhancing greenhouse gas emissions (especially nitrous oxide) from cotton fields. This can be corrected by determining the appropriate N rate by soil testing and using a tool such as NutriLOGIC to predict the appropriate N fertiliser rate for cotton. Your local extension officer can help if you are not familiar with this technology. It is critical to determine if soil N levels have built up, especially where high N fertiliser rates have been used in the past.

N fertiliser rate trials

The N rate trials in the Gwydir valley show different responses to N fertiliser. In the first trial, crop N uptake was not increased with the addition of N fertiliser (there was already enough N in the soil) and lint yield was not increased by N addition.

Hence, N fertiliser recovery (NFR) was very low in this trial – the N applied was not used and much of this N may have been lost from the soil. The second N rate trial in the Gwydir was affected severely by limited water. However, crop N uptake was increased with N fertiliser and about 47% of 180 kg N/ha applied was recovered by the crop, although lint yield was unchanged.

Pima crops
The Pima crops took up more N than most of the upland cotton crops, but yielded considerably less. Hence the NUE values were substantially lower for Pima and there needs to be a separate NUE calibration for this species.

Where to from here?
We plan to continue nitrogen use efficiency monitoring during the 2007/08 cotton season and obtain data for each region so that the best N management practices are identified and extended to the rest of the industry. We will be conducting on-farm experiments to achieve this. If you are interested in this nitrogen use efficiency assessment program, please contact your local Regional Cotton Extension Officer. We are also working on a revised methodology to allow growers to assess NUE on each field at a small cost.

Reinvestment into regional cotton extension by the Cotton Research and Development Corporation has resulted in the recruitment of Regional Cotton Extension Officers for most cotton-growing regions.

Acknowledgements
Thanks to Jo Price for technical assistance, the many cooperating consultants and growers who allowed access to their crops and to CRDC and CRC for funding this research.