I

January, August & Final Reports

Part 1 - Summary Details

REPORTS

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

CRDC Project Number: CSP95C

January Report:	☐	Due 29-Jan-01
August Report:	☐	Due 03-Aug-01
Final Report:	☒	Due within 3 months of project completion

Project Title: Development of agronomic management options for dry season cotton production in NW Australia

Project Commencement Date: July 1998 **Project Completion Date:** June 2001

Research Program: Farming Systems Agronomy

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Part 3 – Final Report Format

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

1. Outline the background to the project.

Productivity of the Australian cotton industry is constantly threatened by reduced availability of irrigation water in eastern Australia. Consequently there has been considerable interest from cotton growers, in the possibility of re-establishing cotton in the Ord River and other areas of NW Australia, where extensive supplies of water (> 20% of Australia's annual surface water runoff) and land are available. The development of a cotton industry in NW Australia would complement production in eastern Australia, providing reliability of supply to maintain valuable markets for high quality cotton lint. In the next 4 – 5 years about 50,000 ha of irrigation land is to be released in stage 2 of the Ord. A further 20-30,000 ha of irrigation land has recently been identified in the Katherine-Daly basin of the NT. There is also some 60-70,000 ha of potentially irrigable black soil on the Bains-Angallari rivers 150 km E of Kununurra and considerable areas on the Fitzroy River to the west.

Research during the 3 seasons previous to this project produced promising results: small plot yields were similar to eastern Australia; pest numbers were lower in the dry (winter) season and Ingard cotton was effective on relevant Lepidoptera pests. The installation of a 'research gin', at a cost of $800,000 by Colly Farms in partnership with the Ord River District Co-operative in 1997 has facilitated the expansion of integrated pest management studies (IPM) to commercial scale areas on-farm (250ha to 900 ha during 1997 to 2001). 'Best bet' agronomic practices, were tested in these on-farm IPM areas. This helped to fine-tune practices, but most importantly the on-farm research identified knowledge gaps and areas of further research. For example, a greater understanding of the water usage and ripening processes in this climate is required. Other important knowledge gaps included: the need to understand compensatory growth mechanisms in response to mirid damage; the need for varieties that produce a longer fibre when grown in the dry season; and nutritional requirements. This project aimed to address these and other questions as part of a broader objective to assess the feasibility of sustainable cotton production in NW Australia.

In 1999 this project became a collaborator in the Australian Cotton CRC's Program 1 'Growth into northern Australia', which incorporates cotton research sites near Broome and Richmond (Qld).

2. List the project objectives and the extent to which these have been achieved.

2.1. Broad Objective: In collaboration with other research projects assess the feasibility of sustainable cotton production in NW Australia.

There has been good progress with the evaluation of IPM systems that minimise insecticide usage and the integration of agronomic practices that support these systems. Table I shows that this research has reduced insecticide requirement dramatically without compromising yields. The results in Table 1 have greater significance in light of the 30-40 insecticide applications required on cotton during the 1970's by the previous industry. During the timeframe of the current studies there has been on going improvement in irrigation scheduling, fertiliser optimisation, and variety selection with respect to lint quality and minimal usage of herbicides.

Table 1: Average number of insecticide sprays and yield for 5 years 1996 to 2000, for IPM research at Kununurra (Data from Geoff Strickland and Amanda Annells AgWA).

Insect Pest Management Treatment	Heliothis Sprays	**Total Insecticide Sprays**	Average Yield (b/ha)
Ingard and soft insecticides	3.5	**4.8**	6.8
Ingard + Lucerne + soft insecticides	3.1	**3.7**	7.3
Conventional Cotton (1996 only)	8.0	**10.5**	6.4

2.2. Specific Objectives of the research funded in this project:

(a) To identify adapted varieties with respect to maturity, yield and quality;

Small plot screening has continued using material mainly from the CSIRO / CSD program and from Deltapine and other sources. These trials have identified cultivars with differeing maturities that are high yielding with high quality, particularly fibre length, and disease tolerance. One breeding line (not a current commercial cultivar) has been selected for larger scale evaluation.

Sowing date and variety maturity options have been investigated. These studies have also collected the data necessary to predict maturity differences, which are essential for future modelling studies that will assess the climatic risk of maturity X sowing date scenarios at a number of sites in NW Australia.

Large-scale variety trials (module size) coordinated by CSD in collaboration with farmers have been conducted over the past 3 seasons. These trials have provided valuable information on operational suitability of varieties and lint quality when commercially ginned.

(b) To develop appropriate agronomic practices for winter season cotton production

The bulk of the research conducted in this project was directed toward this objective.

The Cununurra clay is inherently low in available phosphorous. Progress was made to determine phosphorous fertiliser requirements, the interaction between N, P and K and the effect of phosphorus fertiliser source and placement. A series of factorial experiments were conducted to optimise duration and frequency of irrigation scheduling. Timing of final irrigation was also researched. Research continued into growth management using the regulator mepiquat chloride; biomass partitioning and the interaction with irrigation management. Single row and two row beds were compared under a range of irrigation frequencies and durations.

Monitoring of the commercial scale IPM paddocks for soil moisture, fruit production and retention and lint yield / quality was facilitated by Colly / Twynam Cotton in 1998 to 2000 and made available to this project. Additional resources were provided by CSIRO in 2000 with Greg Roberts conducting a study to calibrate NutriLOGIC for NW Australia. Chemical analysis to benchmark all paddocks was conducted by CSIRO and AgWA. A major outcome of this work was the identification of new research questions, such as, how does P stratification in the surface layers affect irrigation scheduling?

c) To integrate the above with other concurrent research particularly integrated pest management (conducted by Ag.WA).

The 'best bet' husbandry (e.g. irrigation scheduling) practices have been incorporated into the commercial scale IPM areas and monitored. For example Pix management incorporates the need for compensation from insect damage.

Experiments were conducted into agronomic and physiological aspects of compensation from insect damage. Yield, quality, maturity and response to Pix were key measurements. This work was designed to complement insect threshold experiments conducted by AgWA.

3. **How has your research addressed the Corporations three outputs: Sustainability, profitability and international competitiveness, and/or people and community?**

This project had aims which address all three CRDC outputs. The research was committed to developing sustainable production systems which are profitable and a successful northern industry would assist with international market competitiveness in having cotton available for market at a different time of year and being able to ensure delivery of cotton in times of drought or low production from eastern Australian regions.

4. **Detail the methodology and justify the methodology used.**

The project revolved around a series of replicated field experiments at Kununurra and some identical experiments at Katherine NT (variety screening, Pix, compensation). With the IPM research being conducted on-farm by AgWA and Colly/Twynam Cotton, a participatory approach to agronomic research was adopted in 1997. Research outcomes were tested on-farm and any problems identified. This process provided direct feedback into priorities for ongoing research.

Chemical bench marking of IPM paddocks was conducted by CSIRO and AgWA. In 2000 and 2001, 13 and 18 cotton paddocks were sampled respectively. Five cores were taken per paddock and bulked into the following depth increments 0-15cm, 15-

30cm, 30-60cm, 60-90cm, 90-120cm and 120-150cm. Calibration of NutriLOGIC methods are shown in appendix 1.

5. Detail results including the statistical analysis of results.

5.1. Identification of adapted varieties with respect to maturity, yield and quality;

Small plot and CSD variety trials found that there are several commercially available varieties that produce good yields when grown in the winter in NW Australia. Most are later maturing (Sicot 289i, NuCotn 37/38), although Siokra V-16i was high yielding and earlier maturing in this environment.

Fibre length is reduced compared with the same variety grown in southern Australia. Cool night temperatures have been found to be a factor in reducing fibre length in NW Australia. Sicot 289i has been the commercial variety with greater fibre length at low night temperature. One breeding line has been identified that has a longer fiber than Sicot 289i. This line is currently being backcrossed to include the Cry X gene prior to larger scale screening.

Work is progressing to measure variety maturity by sowing date differences. Due to rapidly rising end-of-season temperatures time to maturity differences appear less than southern Australia. Fig. 1 shows measured maturity differences for 2000, where only May sowing dates were possible. A similar experiment in 2001, not yet picked, will compare early April and mid May sowing dates. Maturity differences may be greater at an early April sowing date due to slightly cooler temperatures during boll maturation.

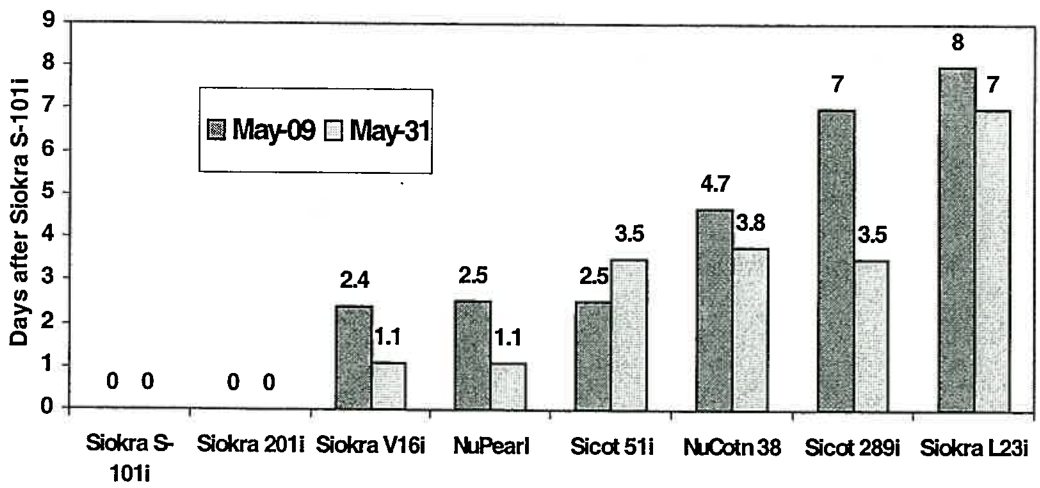


Fig 1: Variatal differences in time to 60% open bolls at May 9 and 31 sowing dates at Kununurra in 2000. NB at the May 9 sowing Siokra V16i, Nupearl, NuCotn 38 and Sicot 289i, had significantly higher yields than other varieties.

5.2. To develop appropriate agronomic practices for winter season cotton production

5.2.1 Phosphorus nutrition

Experiments were conducted over 2 seasons 1999 and 2000. With the resignation of Dr. Jay Singh in September 2000 and his replacement not commencing until June 2001, analysis of results is incomplete. However key findings can be reported.

Experiments were conducted on previously fertilised soils that had low available P, but greater than a virgin soil (Table 2). There was a significant yield increase to P fertiliser with approximately 50 kg P/ha being optimal.

Table 2: Available Phosphorus (Colwell) in experiments prior to fertilization compared to virgin Cununurra clay.

1999		2000		Virgin Cununurra Clay*	
Depth (cm)	P (mg/kg)	Depth (cm)	P (mg/kg)	Depth (cm)	P (mg/kg)
5	13.5	15	14.0	0 - 15	2.2
15	7.8	45	3.0	15-30	1.3
25	2.5	75	1.6	60-75	0.6
35	1	105	1.5	135-150	0.4

* Williams *et al.* (1985) p 90-91.

An experiment to determine the P fertiliser needs on virgin Cununurra Clay is planned for 2002. This experiment will provide important input information because any future cotton industry would commence production on the virgin soils in stage II of the ORIA or virgin soils in other nearby areas.

In a low yielding experiment, where P fertiliser was placed in a band 15 cm below seed, yield was affected by the type of fertliser (Fig 3). The better result with MAP was expected, as this form is recommended for alkaline soils (in preference to DAP). However, yield was not affected by fertiliser type when placed 30cm below seed. A follow up experiment was established in 2001, to hopefully test this response at high yield levels. The 2001 experiment will not be harvested until after this report is submitted.

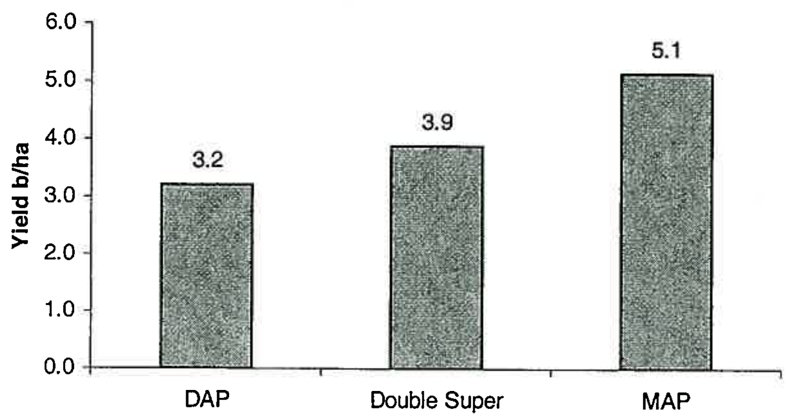


Fig 3: The effect of P fertilser type on lint yield when 50 kg P/ha was banded x cm below seed. Where DAP = diamoniuum phosphate and MAP = mono amonium phosphate.

In a nutrition experiment to evaluate the response to N, P and K, there were significant responses to N and P, but not to K. There were no significant interactions between any of these treatments.

5.2.2 Irrigation scheduling and crop water use.

A considerable research effort has been made into irrigation scheduling and crop water use over the last 3 years. With the resignation of Dr. Jay Singh in September 2000 and his replacement not commencing until June 2001, analysis of results is incomplete. However key findings can be reported.

The plant available water content (PAWC) for cotton has been measured for a cununurra clay in 2 paddocks. Cotton extracted 180 to 220 mm of water to a depth of 130cm.

Research into the timing of last irrigation has found that 80% of PAWC can be extracted by the plant following the final irrigation without affecting yield or quality. Knowledge derived from past experiments that correlated boll periods of the last effective flowers with temperature is combined with the number of days required to extract 80% of PAWC to calculate the date of final irrigation. This calculation has been successfully applied to commercial scale IPM experiments in 2000 and 2001.

As expected frequent irrigation (7 day intervals) of long duration (12hrs) induced water logging and reduced yields.

Seasonal crop evapotranspiration has been measured as between 5.5 and 7.5 ML/ha. The irrigation water required depended on seasonal conditions and soil moisture content at sowing. Field water use was measured in one field in 2000, where a total 7 ML/ha was applied to the field for an 8 b/ha yield; there was no in-season rainfall.

Single and two row beds were compared under different frequency and duration of irrigation. At the optimum combination 14day frequency and 9 hours duration there was no yield difference, however, at other scheduling combinations single rows beds were lower yielding than two row beds.

Current research is evaluating pre – flowering and post cut-out irrigation scheduling. Scheduling based on soil water monitoring tools (neutron probe or diviner) are being compared with pan evaporation methods.

5.2.3 On-farm soil chemical analysis

Except for available P and the ratio of Ca to Mg, chemical analysis was in line with expectations for a Cununurra clay soil with respect to the requirements of cotton. That is low organic carbon % (0.5 to 0.75%) and S. Zn is inherently low and has been built up in the surface layers with fertilization. Nitrogen as NO3 or NH4 was variable and very dependent on the time of sampling, due to leaching. Potassium appeared adequate based on critical values for cotton.

The Cununurra clay is inherently low in available P (Williams *et al.* 1985), and annual application of P fertiliser has been required. We found that fertilisation, while increasing available P above a virgin soil (5 mg/kg), has also stratified P in the surface 15 to 30 cm of soil (see Fig 4). Surface stratification of P has implications for irrigation scheduling in cotton because an increased frequency of irrigation may be required to ensure feeder root activity in the fertilised zone. Hence one objective for research into irrigation scheduling was to determine the need for irrigation strategies that increase nutrient uptake from the surface 30 cm.

Except for 3 paddocks Calcium to Magnesium ratios were less than the accepted critical ratio (2:1). Fig 5 shows the range in Ca to Mg ratios observed. It is not clear from research elsewhere what are the implications of a low Ca:Mg ratio for cotton. These Ca:Mg ratios in other circumstances would indicate gypsum might be required to alleviate soil crusting and other soil structure problems, however, crusting is not normally a problem in these soils, so the cations may not necessarily indicate a problem.

5.2.4. Calibration of NutriLOGIC.
This work monitored petiole nitrate-N over the growing season and evaluated the SPAD meter. Petiole nitrate followed the same trend as in southern Australia but with a slightly higher rate of decline. The decline in leaf N content was similar to southern Australia, however SPAD readings increased, which is the reverse of southern Australia. The SPAD meter did detect N fertiliser rate differences. These results are presented in Appendix 1.

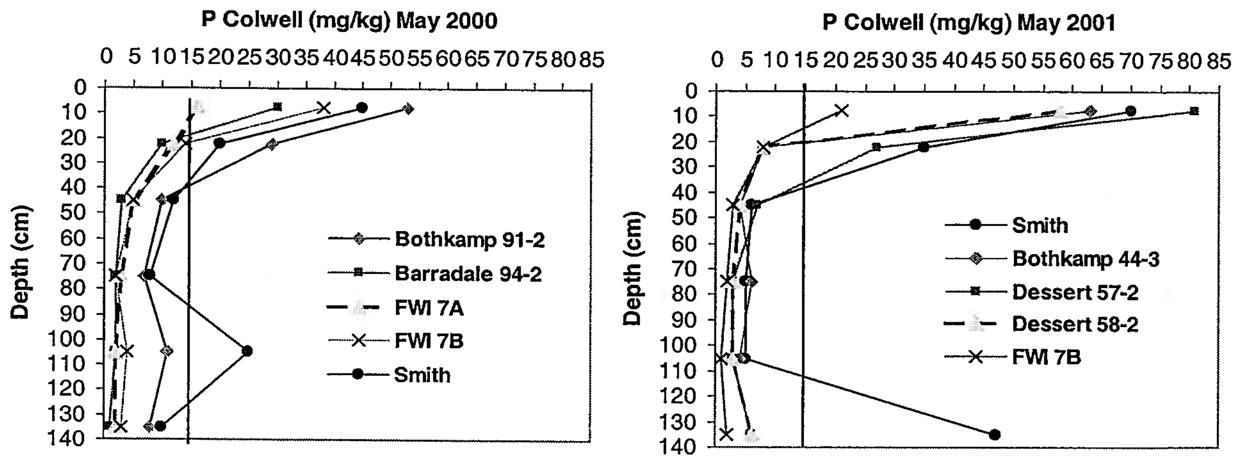


Fig 4: Soil profiles of available P. Shown are 5 fields that typify the range observed. The vertical line indicates the accepted critical value for cotton in southern Australia

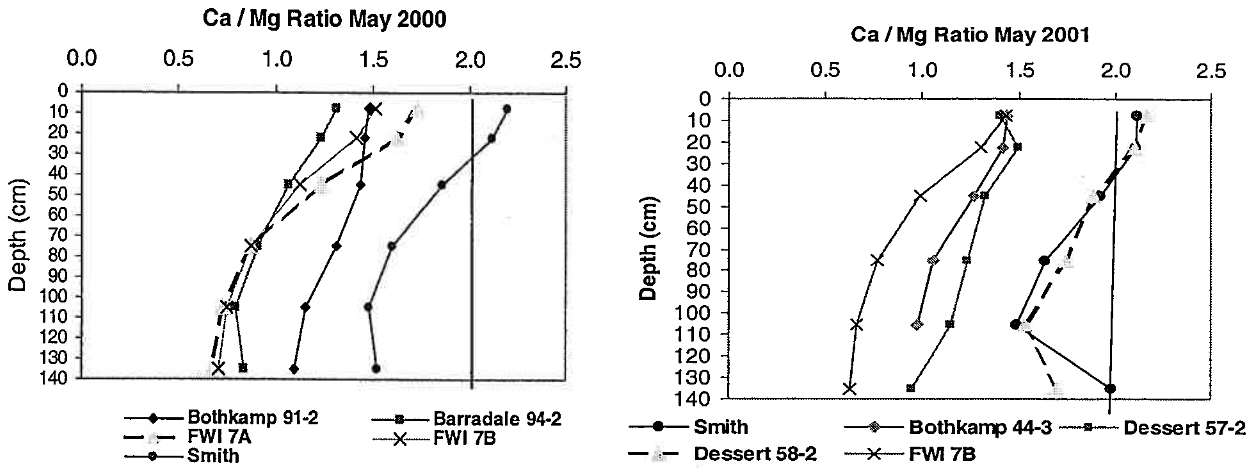


Fig 5: Soil profiles of Ca to Mg ratio for 5 fields that typify the range. The vertical line indicates the accepted critical value.

5.3. Integrate of agronomic with other concurrent research particularly integrated pest management

As described previously 'best bet' husbandry practices used in commercial scale IPM experiments are continually upgraded as more information is gained from the research conducted in this project. Similarly the IPM research has identified new research questions.

Compensation from simulated insect damage.

Experiments in 1999 and 2000 (in conjunction with Dr T. Lei, CSIRO, Narrabri) found that yield was not increased (with 1 exception) as a result of simulated insect damage (Fig. 6). There was no significant delay in maturity in damage treatments. However, yields were low in these experiments and responses need to be measured at high yield levels. Experiments are continuing in 2001 at Kununurra and Katherine with treatments included to evaluate the use of Pix in damaged crops and machine picking efficiencies on damaged crops.

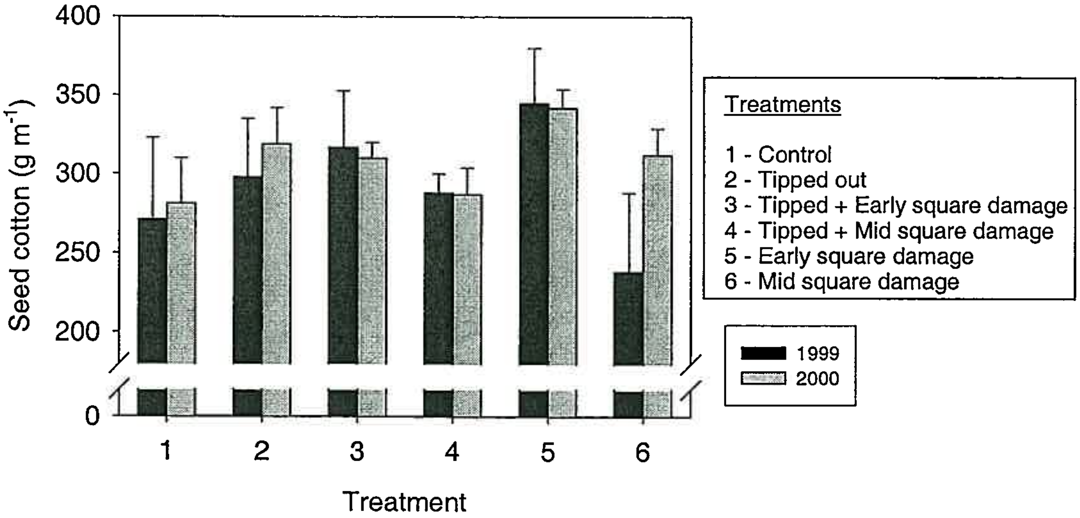


Fig 6: The effect of simulated insect damage on seed cotton yields (hand picked) at Kununurrra. NB all plants tipped out at 4 node stage. Early square damage = all large squares (> 1 cm) removed @ 800 DDS, mid square damage = all large squares removed @ 1200 DDS.

6. Discuss the results, and include an analysis of research outcomes compared with objectives.

This research has made significant progress in identifying the key criteria required in a variety adapted to this region. That is varieties that reliably produce high quality fibre and high yield. Of equal importance, but requiring greater effort over the last 3 years, has been the need for research to develop the most appropriate agronomic practices for these varieties. This project has evaluated P nutrition (unique to tropical soils), irrigation scheduling and manipulation of time to maturity using sowing date, variety and timing of final irrigation. The integration of the above objectives with IPM objectives has been achieved and is critical to the broader objective of assessing the feasibility of sustainable production in NW Australia. To this end outcomes of the above research have been incorporated into husbandry practices (e.g. varieties, sowing date, fertilisers, growth regulator and irrigation management). Research into agronomic and physiological aspects of compensation from insect damage and final irrigation scheduling are examples of new issues arising from this integration. Over the next 3 years of this project there will be a stronger focus to integrate agronomic, IPM and other objectives with research into appropriate rotations and wet season cover crops. Climatic risk assessment including crop combination, operational, yield and quality scenarios, using Ozcot and other crop simulation tools combined with economic analysis will form the final phase of the feasibility study.

7. **Provide an assessment of the likely impact of the results and conclusions of the research project for the cotton industry. Where possible include a statement of the costs and potential benefits to the Australian cotton industry and future research needs.**

This research forms part of a broader project involving collaboration with the Australian Cotton CRC, the Governments of WA and the NT, Twynam Cotton and local farmers, to assess the feasibility of a new cotton industry in NW Australia. Hence the key impact of this research will be a clear indication of the potential for expansion into NW Australia and if prospects are good the expansion will follow.

8. **Describe the project technology (eg. commercially significant developments, patents applied for or granted licenses etc).**

na

9. **Provide a technical summary of any other information developed as part of the research project. Include discoveries in methodology, equipment design, etc.**

none

10. **Detail a plan for the activities or other steps that may be taken;**

    (a) **to further develop or to exploit the project technology.** This project was extended in funding by CRDC for the next three years, with a review to be held in December 2001. Dr Brian Duggan was appointed to the position in June 2001, to replace Dr Jay Singh and Mr Steve Yeates and Ms Nerylie Gaff ensured the project was maintained for the few months while Dr Duggan was appointed. Research has continued on aspects of physiology, agronomy and cropping systems. We believe that many elements of a sustainable cotton production system have been identified or are being dealt with. Major constraints are land rights as well as government attitudes to GMOs.

    (b) **for the future presentation and dissemination of the project outcomes.** A number of scientific publications are being prepared by Dr Duggan, Mr Yeates and Dr Singh. These publications will be of great value for future research and extension of agriculture in northern Australia, as well as providing a broader data set for cotton production systems in general. ***As such we strongly believe research in northern Australia contributes to improving cotton production systems Australia wide.***

11. List the publications arising from the research project.

DK Singh, N Gaff and GA Constable (2000). Balanced fertilisation for optimising yield and quality of cotton in the Ord. Proceedings of the 10th Australian Cotton Conference, Brisbane, 2000.

DK Singh, N Gaff and GA Constable (2000). Optimising irrigation practices reduce stress and waterlogging on dry season cotton in the Ord. Proceedings of the 10th Australian Cotton Conference, Brisbane, 2000.

[A number of scientific papers are in preparation]

12. Are changes to the Intellectual Property register required?

No

Part 4 – Final Report Plain English Summary

The potential availability of land and water combined with new knowledge and production technology has stimulated recent interest in growing cotton in NW Australia. The development of a cotton industry in NW Australia would complement production in eastern Australia, providing reliability of supply to maintain valuable markets for high quality cotton lint.

This project formed part of broader objective involving the CRDC, CSIRO, The Australian Cotton CRC, the Governments of WA and NT, Twynam Cotton, Western Agricultural Industries and local farmers, to assess the feasibility of sustainable cotton production in NW Australia. There has been good progress with the evaluation of IPM systems that minimise insecticide usage and the integration of agronomic practices that support these systems.

The specific objectives of this project were:

1. To identify adapted varieties with respect to maturity, yield and quality.
2. To develop appropriate practices for winter season cotton production.
3. To integrate the above with other concurrent research particularly IPM research.

Commercial scale IPM research areas (250 to 990 ha / yr) were used to test outcomes and to provide feed back by identifying new research questions. For example soil chemical analysis from these paddocks identified available P accumulation in the surface 15 to 30 cm. P research has incorporated an irrigation scheduling component to find out if more frequent early season irrigation is required to maintain feeder root zone where the P is concentrated.

Varieties with differing maturities that are high yielding with high quality, particularly fibre length, and disease tolerance have been identified. One breeding line (not a current commercial cultivar) has been selected for larger scale evaluation. Variety maturity and sowing date studies were commenced to evaluate risk management strategies with respect to avoidance of harvest rain.

The majority of research conducted by this project has been toward optimising P fertiliser requirements, irrigation scheduling and crop water use. On soil inherently low in available P, a significant yield response to about 50kg P/ha was observed. Research is continuing to evaluate different P fertiliser sources following significantly higher yields applying 50kg P/ha as MAP compared with DAP or single supper phosphate. Research to calibrate Petiole N, leaf N and leaf colour (SPAD) was commenced. The plant available water content of Cununurra clay was measured for cotton, decision support for the timing of last irrigation was developed and tested, crop evapotranspiration was between 5.5 and 7 ML/ha and field water use from 1 field was 7Ml/ha. Research in 2001 is fine tuning pre flowering and post cut-out schedules and evaluating decision support tools (e.g. neutron probe vs pan evaporation).

Experiments in 1999 and 2000 found that yield was increased (with 1 exception) as a result of simulated insect damage. There was no significant delay in maturity in damage treatments.

Appendix 1:
Calibrating NutriLOGIC for Northern Australian Cotton,

FINAL REPORT

Chief Executives Award 2000

[a project funded by CSIRO]

CSIRO Plant Industry

Research **Greg Roberts**

CSIRO Plant Industry
Cotton Research Unit
Narrabri

Supervisor: Dr Ian Rochester
CSIRO Plant Industry
Cotton Research Unit
Narrabri

Calibrating NutriLOGIC for Northern Australian Cotton Crops

Objectives

- To determine the potential of NutriLOGIC for the cotton growing regions of Northern Australia.
- To compare SPAD meter measurements throughout the growing season with those from Eastern Australia and investigate the relationship between SPAD measurements and leaf nitrogen (N) content, petiole nitrate, crop N uptake and yield.
- Investigate the relationship between soil nitrate-N levels and cotton petiole nitrate levels for the Ord River Irrigation Area.

Background to the research project

NutriLOGIC is a computer-based decision support program developed by CSIRO. NutriLOGIC allows for the estimation of the economic optimum N fertiliser required for cotton using statistical relationships based on soil nitrate and petiole nitrate levels. This allows growers to use the optimal amount of nitrogen fertilizer and avoid over-fertilization, which is both costly ($1/kg N) and agronomical undesirable or too little fertilizer, which may limit crop yield. NutriLOGIC uses the soil nitrate and petiole nitrate tests which have been calibrated for the growing conditions and soils of the cotton growing regions of Eastern Australia.

However, cotton production is being re-established in the Ord River Irrigation Area (1,000 ha in 1999). Previous research (1995-7) by Mr. Steve Yeates (CSIRO) has shown that the optimal nitrogen rate for cotton in the Ord is around 200 kg N/ha. However there has been no calibration of the petiole nitrate and soil nitrate analyses for this region. This project will calibrate the soil nitrate and petiole nitrate tests for the Ord River Irrigation Area. These tests aim to estimate the amount of N fertilizer required by cotton, thereby allowing more efficient use of N fertilizer. A new 'in field' method of estimating the N fertiliser requirement of cotton using the SPAD leaf chlorophyll meter is being assessed in Eastern Australia.

Introduction

The development of NutriLOGIC for Northern Australia has the potential to enhance cotton production. NutriLOGIC has proven to be a useful tool for the successful growing of cotton in NSW and Queensland. This will provide economic benefits to growers through the optimal use of N fertiliser, and assist to minimize problems associated with over use of N fertilizer such as rank growth, late maturity, problems with insect pest control, reduction of fibre quality and problems with defoliation. Over-fertilizing also necessitates the use of growth regulators (eg Pix). Delayed maturity and the onset of the wet season may cause the postponement of harvest or possibly ceasing it altogether. Climatic conditions within the growing period (dry season) of the northern region are substantially different to those in the eastern cotton-growing regions. In Northern Australia, cotton crops experience warmer conditions at sowing and harvest, cooler conditions during flowering and boll-filling. Therefore, expectations and recommendations about the amount and timing of N fertilizer may differ between the northern and eastern cotton-growing regions.

Recent research has shown that the SPAD chlorophyll meter (which measures the greenness of leaves) is correlated with leaf N and N fertilizer requirements of cotton in Eastern Australia. This is a novel technology not yet included in NutriLOGIC. The data collected from Northern Australia will be compared with the calibration developed in Eastern Australia. This test will allow for immediate decisions for N fertilizer application, whereas current methods require several days or weeks for commercial leaf or petiole N analyses.

Methods and Materials

N fertilizer rate experiments where established on The Frank Wise Institute, Kununurra WA to determine the relationship between SPAD measurements, petiole nitrate, and N uptake and to assess differences between cultivars. Three commercial farms (Bardena, Bothkamp and Baradale) were monitored for soil and petiole nitrate, leaf N content and SPAD meter measurements. All sites were irrigated and represented cotton crops grown throughout the Ord valley. Bardena is situated on the western side of the valley, Baradale on the east and Bothkamp in the central zone. In all, seven fields were selected on the commercial farms for comparison with the three controlled experimental sites at the Institute. The three experiments at the Institute were established with rates of N fertilizer as indicated in Table 1.

Table 1. Experimental Sites

Exp.	Site	Planting date	N rate (kg/ha)	P rate (kg/ha)	Variety
1	Frank Wise	16/05/00	0,100,200	0,50,100,200	Sicot 289i
2	Frank Wise	13/05/00	0,63,200	50	189,289i,289ii
3	Frank Wise	13/05/00	0,63,200	50	V16i
4	Bothkamp	14/04/00	200	40	V16i
5	Bothkamp	04/05/00	200	40	V16i
6	Bardena	13/04/00	Varies	-	Sicot 289i
7	Bardena	02/05/00	180	-	Sicot 289i
8	Baradale	09/05/00	82+Side dress	-	V16i / L23i
9	Baradale	09/05/00	90+Side dress	-	V16i / L23i
10	Baradale	13/05/00	82+Side dress	-	V16i

Measurements

In-field leaf measurements were taken on all sites using the SPAD meter. The fifth leaf from the terminal was selected and 30 leaves measured in each replicate. The meter averages the 30 measurements. The leaf blades selected for the SPAD measurements were collected and dried at 60°C for 24 hours before being ground and analysed for N content using NIR equipment (Inframatic 8100) calibrated for Kjeldahl N.

Petioles were collected from the same leaves as used for SPAD measurements and dried for 24 hours at 60°C. The sample was then ground, weighed, extracted in 0.02 M K_2SO_4 for 1 hour, filtered and analysed using a nitrate electrode. The petiole nitrate, SPAD and leaf N content measurements were carried out every 14-16 days for a period of 8 weeks for Experiments 1, 2 and 3; the other sites were sampled every 7-10 days over the same period.

To assess crop nutrient uptake, dry matter samples were taken from all sites and from each plot in the 3 experimental sites. One metre of crop row was cut and a fresh weight taken. A sub sample of three plants were randomly selected, weighed and dried at 60°C for 48 hours. These samples will be ground for nutrient analysis. Lint yield results will be obtained after picking and ginning.

Existing calibrations of SPAD, leaf N and petiole nitrate N determined for cotton grown in Eastern Australia

The SPAD meter has been calibrated for cotton grown in Eastern Australia during the last three cotton seasons. During the early stages of growth, the SPAD meter has shown values around 57 at 550 Day Degrees (DD) and falls as the season progresses to around 45 at 1300 DD, as indicated in Fig 1.

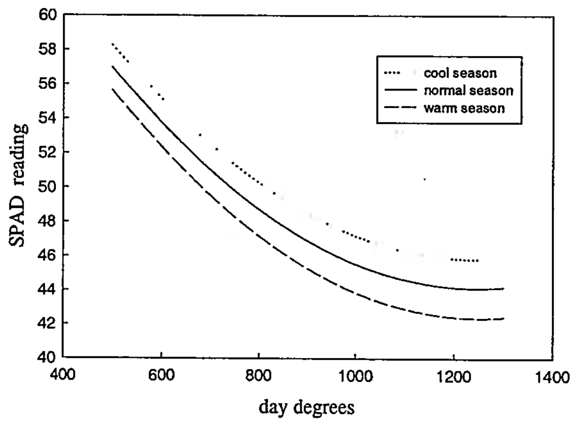


Fig. 1. Relationship between SPAD reading and day degrees for cotton grown in Eastern Australia. On average, SPAD readings are higher in cotton grown under cooler conditions and lower under hot conditions.

As with the SPAD meter readings in Eastern Australia, the petiole nitrate levels decline as the season progresses, with an average crop starting off at approximately 22,000 mg N/kg at 550DD and falling below 10,000 mg N/kg at 950DD. The rate of decline averages 33 ppm per DD, as shown in Fig 2 below.

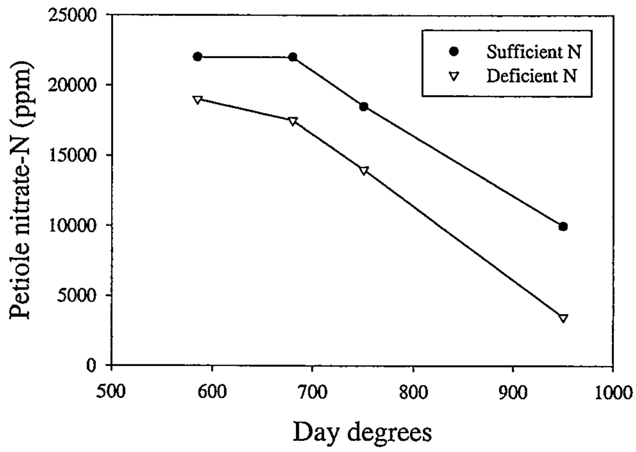


Fig. 2. Relationship between petiole nitrate-N and day degrees for cotton grown in Eastern Australia, indicating that nitrate-N declines as the plant matures.

Similarly, leaf N content declines in the Eastern Australian cotton-growing regions as the season progresses, as seen in the Fig. 3 below.

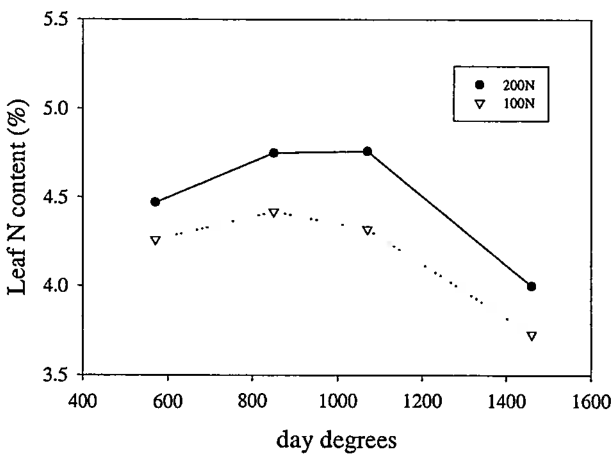


Fig. 3. Indicates the relationship between leaf N content and day degrees in the eastern states showing that as the plant matures the leaf N content declines.

Results

Observation of SPAD meter, leaf N, soil and petiole nitrate-N for Northern Australian cotton crops

The data collected in Northern Australia show different trends, particularly with respect to the SPAD meter measurements. Results from all sites indicate a general trend for the SPAD meter measurements to rise in normally fertilized cotton as the season progressed, starting at 54 at 450DD and rising to almost 60 at the end of flowering (Fig. 4, Experiment 1). Compare this with Fig. 1.

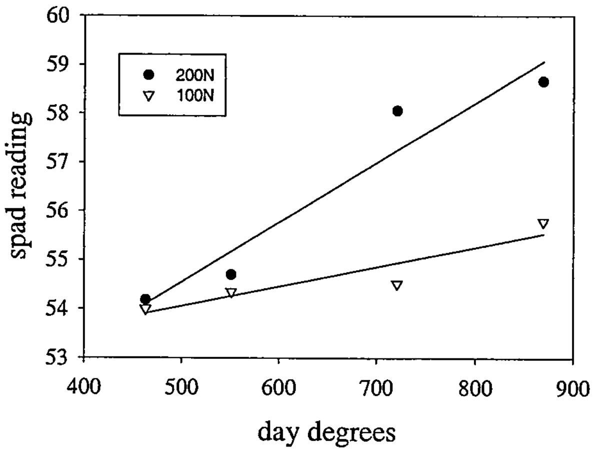


Fig. 4. Relationship between SPAD meter reading and day degrees in Northern Australia indicating that as the season progresses, SPAD reading increases. This is opposite to the trend in Eastern Australian cotton.

In Northern Australian cotton, leaf N content tended to decline slowly as the season progressed. This is similar to trends observed in Eastern Australia. Leaf N content was slightly lower in Northern Australian cotton, possibly due to stress imposed by poor irrigation management. The SPAD meter readings more closely followed leaf N content than petiole nitrate-N in all regions.

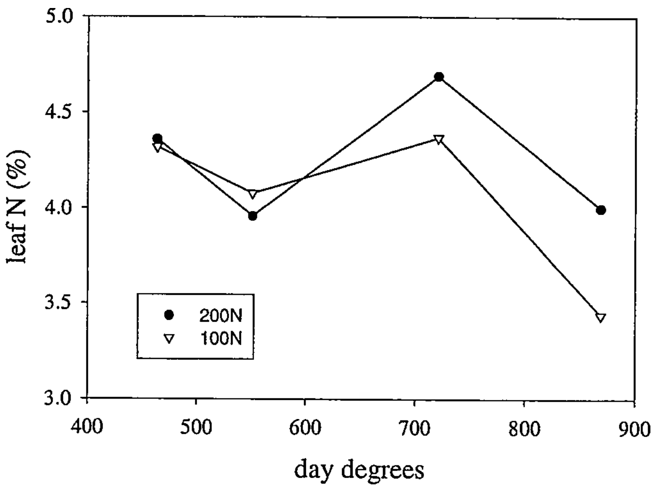
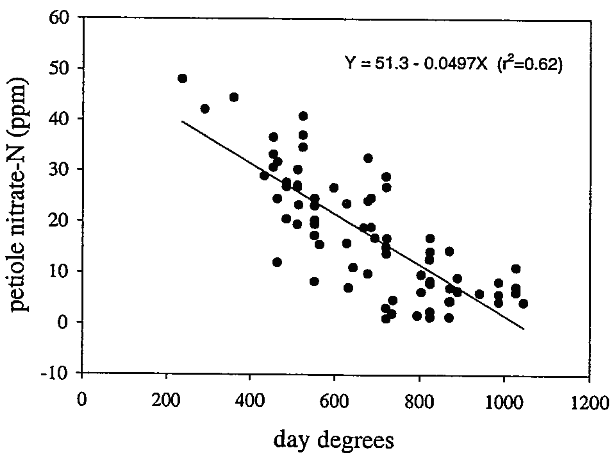


Fig. 5. Relationship between leaf N content and day degrees in Northern Australian cotton indicating a slow decline in leaf N content as the season progresses.

Nitrate-N concentrations in cotton petioles sampled from experiments covering a wide range of N fertilizer rates are shown in Fig. 6. The petiole nitrate-N data followed the same trend as occurs in Eastern cotton growing regions, although petiole nitrate-N declined more rapidly in the Northern regions at a rate of about 50 ppm /DD.

In the zero N fertilizer rate plots, petiole nitrate-N was about 20,000 ppm at 450 DD and fell to below 5,000 ppm at 800 DD. In contrast, the petiole nitrate N levels in the low N rates (100N) started at over 30,000 ppm at 450 DD and fell to 10,000 ppm at 800 DD. In comparison, the 200 kg N/ha rate plots contained35,000 ppm at 450 DD and fell to 15,000 ppm at 800 DD. Based on the calibration for Eastern Australia, the zero N rate was highly deficient. Petiole nitrate-N values should be greater than 19,000 ppm at 550 DD and 4,000 ppm at 950 DD to avoid N deficiency in Eastern



Australia.

Fig. 6. The relationship between petiole nitrate-N and day degrees. The rate of decline is greater in the Northern Australian cotton.

SPAD meter reading was related to the N fertilizer rate. SPAD meter values declined slowly in the zero N rate treatments as the season progressed, from over 48 to below 45. SPAD meter readings increased from 52 to 54 with low N fertilizer rates while the SPAD meter reading start at 54 and rose to over 56 for the higher N rates. Trends can be seen in Fig. 7. (Experiments 1, 2 and 3 only.)

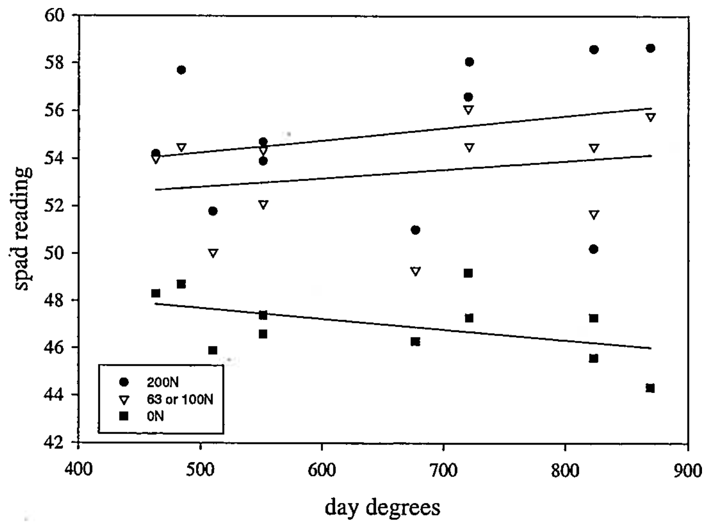


Fig. 7. The relationship between SPAD meter readings and day degrees in Northern Australian cotton. The SPAD meter was able to distinguish between N rates as in Eastern Australian cotton.

Comparison of the three experimental sites at the Institute suggested differences between the cotton varies. The varieties grown were V16i, L23I, Sicot 189i and 289i. In Fig. 8, the SPAD meter indicated higher values for okra-leaf varieties (V16i and L23i) than the normal leaf varieties (Sicot 189i and 289i).

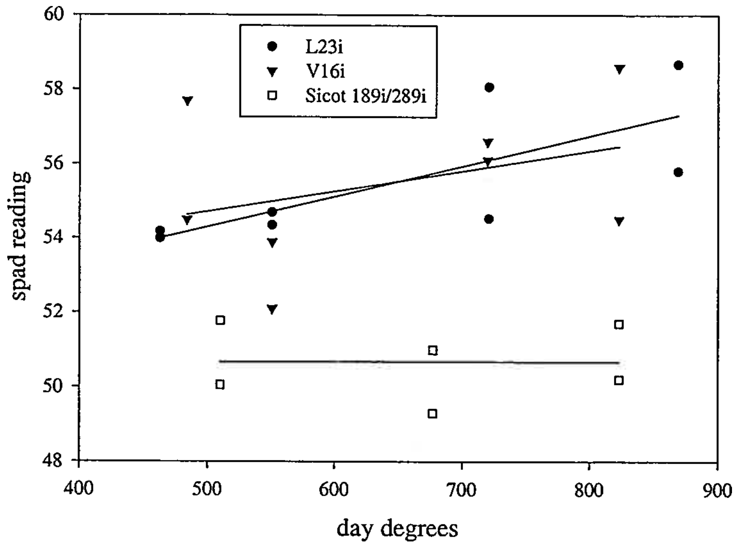


Fig. 8. The relationship between SPAD meter reading and day degrees indicating the differences between varieties in Northern Australian cotton. The okra leaf varieties recorded consistently higher readings than the normal leaf varieties.

Leaves collected at flowering were analysed for concentrations of other nutrients for comparison with those of cotton grown in Eastern Australia at flowering (Table 2).

Table 2. Leaf nutrient content at 800DD.

Exp	N %	P %	K %	S %	Ca %	Mg %	Zn ppm	Cu ppm	B ppm	Fe ppm	Na ppm	Mn ppm
1	4.0	0.28	1.3	0.69	3.6	0.93	22	6.8	67	206	2264	87
2	2.6	0.19	1.2	0.58	2.7	0.71	19	5.0	45	367	1277	42
3	4.8	0.35	1.9	0.98	4.1	0.91	30	7.5	63	184	1887	49
4	4.7	0.34	1.9	0.69	3.0	0.53	28	6.0	106	140	395	74
5	4.4	0.42	1.9	0.72	3.6	0.69	30	6.0	97	129	530	73
6	3.2	0.25	1.8	0.50	1.8	0.56	24	4.0	87	226	320	61
mean	**3.9**	**0.30**	**1.6**	**0.65**	**3.1**	**0.66**	**25.5**	**6**	**83**	**205**	**856**	**64**
*	4.0	0.33	1.8	0.66	4.03	0.92	15	6.8	70	204	60	84

* Means of a high yielding site ACRI Narrabri NSW.

Most nutrient concentrations are similar in both regions. Boron, which was suspected of being deficient in the northern region, is adequate, with a mean of 83 ppm compared to 70 ppm in Eastern Australian cotton. The Zinc concentration is higher due to high levels of fertilizer input in the northern region, although potassium (K) appears to be low, despite regular fertilizer inputs of 80 kg K/ha. Calcium (Ca) is low in Experiments 2 and 6 along with Copper (Cu) in Experiment 6. The Ca/Mg ratio was similar in both regions. Of great interest is the high Sodium (Na) concentration that indicates that the northern region has sodic soils. This was validated by a soil test which indicated an exchangeable sodium percentage (ESP) >20% in the subsoil.

Soil nitrate analysis

Compared with Eastern Australia, crop N uptake was low for the corresponding soil nitrate-N levels (Fig. 9). The data is from only one site at the Institute (Experiments 2 and 3). Although soil nitrate-N was 20 ppm at sowing, the crop took up only 78 kg N/ha. In the eastern states, cotton would take up approximately 140 kg N/ha where this level of soil nitrate-N is found (Fig. 9).

The apparent N fertilizer recovery at this site was about 65%. This field was previously used for cattle grazing and has numerous problems, including compaction. This is confirmed by the nutrient analysis of leaves (Table 2 – Experiments 2 and 3).

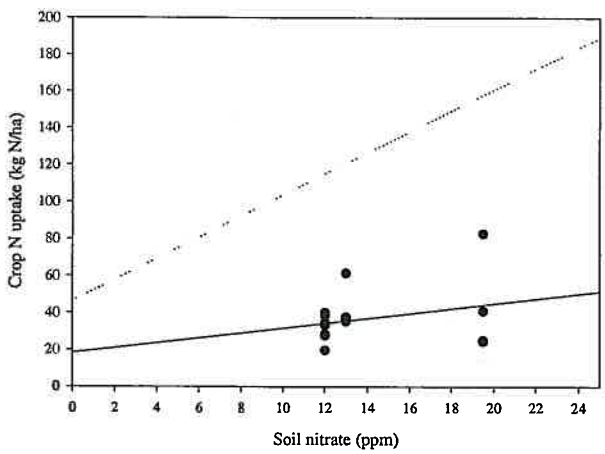


Fig. 9. Relationship between soil nitrate and crop N uptake in Eastern and Northern Australia. The relationship derived in the eastern states is indicated by the dotted line.

Discussion

The petiole nitrate-N data generally follow the same trend as in the eastern states, although the rate of decline is slightly higher (50 ppm / DD compared with 33 ppm / DD obtained in Eastern Australia). These findings can all be attributed to a number of factors. Firstly, the higher growth rate in Northern Australia creates a higher demand for N resulting in less storage of nitrate–N in the petiole.

Leaf N content decline similarly in both regions. In contrast, SPAD measurements rise as the season progresses in Northern Australia and decline in Eastern Australia.

The SPAD meter can detect differences in the N fertilizer rates applied, as in the eastern cotton growing regions. In contrast to Eastern Australia, SPAD meter readings rise as the season progresses.

Another factor that plays an important part in nutrition of cotton in Northern Australia is the practice of side dressing the crop with fertilizers such as urea, MAP, DAP and sulfate of ammonia. This practice ensures that the crop has a continual source of nutrients available, but may lead to over fertilization, causing serious crop management problems. Further, the isolation of this area creates a problem of accessibility to testing facilities. Thus, there is a tendency to use visual observations including leaf colour as a guide for fertilizer management. This is imprecise and subjective, whereas the SPAD meter quantifies leaf colour.

Growth regulators are used to reduce excessive growth as a matter of course, with no yield benefits, but crop height is reduced to improve insect pest management and the ease of picking. Growth regulators are known to affect SPAD meter readings.

Irrigation affecting N management
The importance of irrigation is now being studied in the northern region; the general practice of watering fields for 12 hours causes waterlogging. This practice has been developed for other horticultural cropping enterprises in the region and is proving less effective on cotton.

Conclusions

Nutrition of cotton crops in Northern Australia requires further investigation. There is substantial variation in the northern data from the calibrations developed in Eastern Australia to warrant further research and calibration of the various tests. When the soil and petiole nitrate-N tests are calibrated, NutriLOGIC will be able to estimate indicate crop N fertilizer requirement and improve N fertilizer management. The differences in SPAD meter reading in Northern Australian cotton varied from what is typical in Eastern Australia, whereas leaf N content and petiole nitrate-N was similar.

Acknowledgments

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