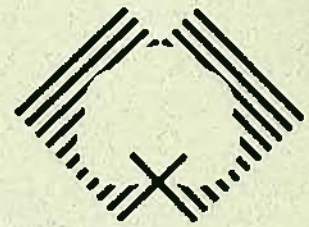


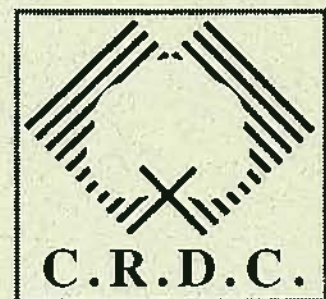


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**Cotton Industry Soil Research
Discipline Workshop
Narrabri 23rd June 2000**

**Report
By Alex McBratney
(July 2nd 2000)**



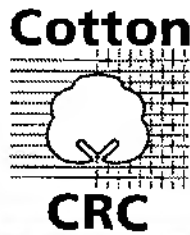


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The workshop was held in the Conference Room at the Australian Cotton Research Institute, Wee Waa Rd. Narrabri, NSW commencing from 8:30 am to 4:30 pm Friday the 23rd of June.

Purpose:

The workshop brought together soil researchers to discuss: existing research; issues arising; new developments; gaps and future directions. This workshop/meeting group is one of many specific discipline groups coordinated through the Cotton CRC.

This meeting/workshop will highlight the ongoing needs of both CRDC and the Cotton CRC and help in gaining an idea of the future needs and direction of cotton soil research.

History:

It has been recognised that whilst the farming systems forums previously held by CRDC have been effective in gaining cooperation and some feedback to researchers from their peers, it has grown to a size that makes it less effective as a workshop and leans more toward a research forum. The Cotton CRC has recognised the needs of all cotton researchers for a forum to present their work publicly and for comment from their peers. The Cotton CRC will be holding a research conference for this purpose in alternate years to the ACGRA Conference.

There will be a Farming Systems forum in December 2000, the topics to be discussed will be determined by the coordinators of each of the discipline groups at the coordinators meeting to be held around August. The forum this year is likely to be held in Dalby and numbers would be limited, however will be open to ACGRA & CCA members.

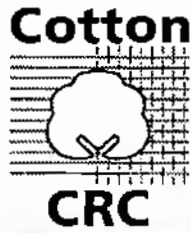
Aims:

- A better understanding of the depth of the topics and the research which has been conducted in these areas;
- Agree on research needs of industry and identify gaps and deficiencies;
- Determine the best ways of addressing these needs including collaborative opportunities;
- Discuss potential funding opportunities (particularly those beyond the limited resources of the Cotton CRC and CRDC);
- Discuss the lines of communication between the groups and their needs in this regard.

Process for this workshop:

In view of the fact that this workshop was held the day after the Cotton CRC review and that there was a number of people presenting their work at the CRC review, the suggestion was made that we focus the workshop discussion on new developments in the soil science area. These are developments which may require further research input or are opportunities for research funding.

Discussion areas are listed below:



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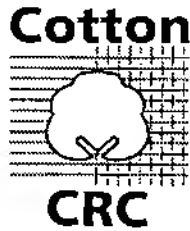
Topics for Discussion:

1. Drainage, storage and leaching in irrigated cotton soil
2. Soil tillage and structure including conservation tillage & GM cotton
3. Soil quality issues of:
 - Biodiversity;
 - The Greenhouse problem

We identified one person to give an overview of each topic and all the work that has been done in the area (not just a summary of their own work). We then provided an opportunity for anyone who would like to speak on the topic. When everyone who wished to speak had spoken, we held an open discussion considering other existing research; issues arising; opportunities for new developments; gaps and future directions.

Submissions:

To provide participants with an update of each other work, presenters asked everyone to submit a half page update of their own work.



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Program

Friday 23rd June Start 8:30 am

Welcome to the Workshop - Alex McBratney 5 min

1st Topic Drainage, storage and leaching in irrigated cotton soil

Chair: John Triantafilis - Sydney University

Time: Speakers should stay to time to allow

45 min discussion for this session

1. Overview of the topic - 30 min Willem Vervoort (Sydney University)
2. Rachael Zischke (QDNR)- 10 min
3. Janelle Montgomery (The University of New England)- 10 min
4. Esta Kokkoris (The University of Sydney)- 10 min
5. Mark Silburn (QDPI) -10 min
6. General discussion including: **Highlights, gaps, opportunities, links, future - 35 min**
10:30 - 11:00 - Morning Tea

2nd Topic - 11:00 Start Soil tillage and structure including conservation tillage & GM cotton

Chair: Ian Rochester - CSIRO Narrabri

Time: Speakers should stay to time to allow

45 min discussion for this session

7. Overview of the topic - 30 min David McKenzie
8. Dr. Nilantha Hullugalle (NSW Dept of Ag. Narrabri) - 10 min
9. Stephen Cattle (The University of Sydney) - 10 min
10. General discussion including: **Highlights, gaps, opportunities, links, future - 45 min**

12:35- 1: 35 - Lunch

3rd Topic - 1:35 Start Soil Quality issues of: - Biodiversity
- The Greenhouse problem

Chair: Odeh - Sydney University

Time: Speakers should stay to time to allow

45 min discussion for this session

11. Overview of the topic - 15 min Nilantha Hulugalle (Narrabri)
12. Overview of the topic - 15 min Georgie Melbourne (The University of Sydney)
13. Assoc. Prof. Les Copeland (The University of Sydney)- 10 min
14. John Buckerfield - 10 min
15. Dr. Balwant Singh - 10 min
16. Marion Dunbar - 10 min
17. General discussion including: **Highlights, gaps, opportunities, links, future - 35 min**

3:20 - 3:30 - CRDC Comment - Adam Kay - 10 min

3:30 - 4:00 - Afternoon Tea

Summary - Start 4:00 Alex McBratney 30 min

- Highlights for the day
- Gaps identified
- Opportunities
- Links
- Future directions

Closure 4:30 - Adam Kay - Director of soils CRDC - 5 min



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SUMMARY OF MEETING

Background

"We spend far too much money on soils research." "We have too many projects on soils". These statements are often heard, but are they justified? The Workshop showed that there are clearly ongoing and new soil-related problems for the cotton industry. It is clear we need high calibre focussed research. The workshop reminded the participants of important soil problems, succinctly described them and came to a general consensus on some soil research priorities in relation to cotton. The Scoping Study (To Identify Key Areas Where Strategic Investigation, Research Or Education Is Required To Retain Or Improve Soil Productivity In Irrigation Areas For Murray Darling Basin Commission Strategic Investigations and Education Program Irrigation Issues Working Group Project New 2 by CSIRO Land and Water PMB 2, Glen Osmond, SA 5064) is not regarded by most cotton-soil researchers as a useful document. It provides little new insight into soil research problems in cotton-growing areas, therefore this workshop seemed more of more importance than ever.

Cotton-soil research started off principally with a production focus, but lately the focus has been shifting to environmental and sustainability issues.

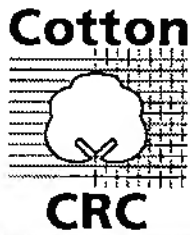
PRODUCTION to maintain or improve production, e.g., structure, plant nutrition
ENVIRONMENTAL to minimise environmental impacts, e.g., salinity, soil quality

About thirty people attended the workshop. Unfortunately there was no grower (ACGRA) representative. Of the 57% left at the end everyone thought that the Workshop had been useful because new information was presented and new issues were raised.

The Workshop is summarised below.

HIGHLIGHTS OF THE DAY

- Positive and open nature of discussion
- Recognition/concurrence/acceptance of deep drainage in cotton vertisols
- Structure - the quality of the Soilpak video
- Good explanation of greenhouse & biodiversity issues



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DRAINAGE, STORAGE, LEACHING

EXISTING KNOWLEDGE-

There was a summary of methods and discussion of measurement methods. It was clear that deep drainage ranged somewhere from 50 to 400 mm per growing season. It was unclear whether preferential flow and shrink-swell phenomena would have to be included in models for water balance. Lysimeters or drains provide the best data but are very expensive. The approach taken by Janelle Montgomery for her PhD work was seen as being adequate, less expensive and thus enabling several (many) sites to be measured. However some way of measuring composition of deep drainage water by electrodes or suction cups would need to be added. We have little knowledge of position, movement and composition of groundwater tables under our cotton-growing regions. This is required for assessing sustainability of the water and soil resource.

GAPS & OPPORTUNITIES -

There is a need for a database on estimates of deep drainage. Measurement of deep drainage are required to corroborate prediction from the Salf model. It has only been corroborated in two or three locations. This seems crucial!

The measurement of D and composition of leaching water is also crucial for the "water-balance project".

Groundwater measurement and monitoring is a key priority

In terms of farming systems and practices - lower-intensity irrigation and use of deep-rooted catch crops to dry profiles seem a possibility.

TILLAGE & STRUCTURE

EXISTING KNOWLEDGE

There has been a good uptake of tillage & structure research with a lot of knowledge from farming systems experiments and packaged in SoilPak NutriPak MachinePak Solicon. For prediction of structural behaviour

Electrolytic Stability Index, organic carbon, and carbonates are all needed. Cotton soil is variable.

GAPS & OPPORTUNITIES-

We need new research to identify the importance of sodic soil extent & dispersibility. The architecture of beds need to be investigated theoretically and experimentally.

LINKS -

There is now no clear group of tillage & structure researchers. We need to re-focus and re-establish links - and maintain knowledge of methods and results. The CRC should be the focus for this. We need a leader for 'structure/tillage' research.



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SOIL QUALITY ISSUES

EXISTING KNOWLEDGE -

The definition of 'soil quality' is somewhat vague but is probably useful. Soil organic C and pH are falling in cotton-growing areas. We don't know about pedogenic carbonates and their contribution to greenhouse. There are lots of data on carbon & pH for cotton soil but it needs to be collated and in a publicly-accessible GIS. PH may be limiting in some regions in the future and liming may be required.

Work has really just begun on biodiversity measurement. The work is funded and we need to see results before further investment is made.

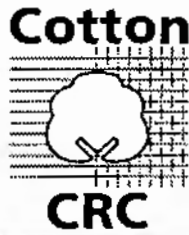
GAPS & OPPORTUNITIES -

We need to carry out carbon balance for cotton farms and look at other greenhouse gases such as methane and especially N_2O .

LINKS -

A CRC Group has been set up to look at carbon accounting - it needs to establish links with CSIRO Tropical Agriculture (Merv Probert) and the Greenhouse Accounting CRC. A leader for the greenhouse group should be named.

A Soil Quality group similar to the "Greenhouse" group needs to be set-up with the CRC and a leader named.



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APPENDIX: INDIVIDUAL UPDATES

From: **Stephen Cattle**

Title: **The development and adoption of a cross-platform computer program to quantitatively assess soil structural features**

Aims & Objectives:

- To modify the existing structure analysis program *Solicon 3.0* so that it is functional on all personal computers
- To widely distribute and demonstrate the converted *Solicon* program to researchers linked with the cotton industry who may have a need for accurate, quantitative measures of soil structural features

Method:

- Employ a computer programmer to become conversant with the code for the existing *Solicon 3.0* program (only Macintosh-compatible) and then to re-write or add portions of code to make this program Windows-compatible.

Highlights / Outcomes: The services of Mr Robert Farrell, who wrote *Solicon 3.0*, were secured to carry out the cross-platforming operation. Consequently, the conversion process has progressed well, with nearly all the original analyses now fully functional inside a new *Solicon* shell on the Windows platform. These analyses include 17 measures of pore and solid size, shape and distribution in horizontal section, 5 measures of pore and solid features in vertical section, and 2 fractal dimension measurements of soil images. Mr Farrell is also compiling a help manual within the profile, and is setting up a batch analysis system to allow the more efficient handling of large numbers of images. The completed program will be ready for distribution to interested researchers over the next few months.

from: **John Buckerfield**

Title: **[Research Director, EcoResearch]**

Aims & Objectives: To evaluate composted organic wastes as a soil amendment for sustainable cotton production. Low levels of soil organic matter were identified by growers as a major constraint in maintaining cotton production. Feedlot manure and gin-trash were identified as a local source of organic wastes which could be considered as an amendment to improve these soils for cotton growth.

Method: The composted wastes were tested in field-trials, at various rates, broadcast and incorporated prior to sowing of cotton. Growth parameters have been determined at flowering and harvest, and the influence of the organic amendments on yields assessed.

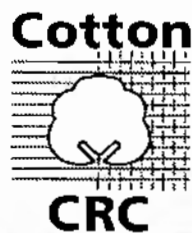
Highlights / Outcomes: The trials were extended following yield increases of up to 25% in the first year - alternative methods of application were considered, with other composted wastes compared. We have now completed monitoring of soil conditions and cotton growth and yields for a third season.

With the higher rates of compost we have doubled levels of organic carbon and nitrate nitrogen; soil potassium is higher and levels of soil phosphorus increased up to three times with increasing rates of compost. Electrical Conductivity, a measure of soil salinity also increased, but was still well below the level likely to affect cotton growth.

Over the last two years, measurements on cotton plants after flowering indicated larger plants, with additional bolls developing on plants with the compost amendments. We had some concerns with the increased plant spacing on the treated plots, suggesting that the extra organic matter may have affected germination and establishment.

The harvest several weeks ago confirmed substantially improved plant growth with the compost - larger plants, with increased boll number and boll weights. But with the reduced plant density, overall yields would have been reduced by around 25% if the treatment favoured by the grower had been applied more widely - this was a productive paddock, yielding around 5 bales at the last harvest.

It is disturbing to find that, in attempting to improve their soils, cotton-growers could be adversely affecting yields. But encouraging in that, after three years of treatments, we now have a range of soils which can be analysed and tested with glasshouse studies to identify key factors reducing cotton establishment. The possibility of a critical biological factor, associated with the compost, will be the basis for our approach to CRDC for further research on soil management.



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from: Rachael Zischke

Title: Estimation of Deep Drainage under irrigated cotton in Australia using a *Salt Balance – Soil Property* model

Cotton in Australia is grown on a wide range of soil types and under various climatic conditions. Previously, much of the research undertaken on cotton, or more specifically cotton irrigation in Australia, has dismissed deep drainage as negligible. It would be also true to say that most of this research has been undertaken on the temperate, NSW cotton growing areas. This project '*Advancements in Quantitative Irrigation Water Quality Guidelines*', and its predecessor '*Quantitative Irrigation Water Quality Guidelines*', have researched the accuracy and 'robustness' of a predictive drainage model over the past 5 years. The 39 sample sites for this project span from the semi-arid Trangie cotton growing area, to the sub-humid Darling Downs, and cover a wide range of irrigated cotton growing soils and irrigation application techniques.

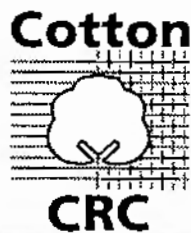
Leaching fraction predictions from Sodium SaLF (a salt balance-soil property model) were compared against the predictions of a mass balance model (USSL) and a transient mass-balance model (SODICS). The predictions from SSaLF were then further validated against actual drainage depths as measured by two lysimeters on the Darling Downs. The known effects on drainage of soil mineralogy and irrigation water quality are taken into account by SSaLF, and this is reflected in the drainage predictions of this model over the wide range of irrigation water qualities also encompassed by this project.

The strengths and limitations of the SSaLF model were highlighted during this project by both the wide range of cotton growing conditions and soils on which it was run, and the process of examining the similarities and disparities between the SSaLF leaching fraction predictions, and the predictions of the other two models.

SSaLF appeared to perform well, comparing favourably to other model predictions where the each model's assumptions allowed the comparison. High drainage predictions on the some sites on the Darling Downs were backed up by measured drainage results, and perhaps highlight the effects of irrigation with high EC water. Commensurate with other research, low drainage was predicted for the low EC irrigation water, grey clay cotton areas surrounding Wee Waa in NSW. A table summarising some of the results of the projects is displayed below.

Summary of water quality information and drainage predictions for sites sampled during the CRC projects, '*Advancements in Quantitative Irrigation Water Quality Guidelines*' and '*Quantitative Irrigation Water Quality guidelines*'.

Area	Property	yrs irr as of 1998	Ave rain mm/yr	Irrigation mm/yr ave	Irrigation EC dS/m	Predicted Flux mm/yr SSaLF	Predicted Flux mm/yr SODICS	Predicted Flux mm/yr USSL
<i>Darling Downs</i>	Plains	20	664	450	1.5	81	145	145
<i>Darling Downs</i>	Maclea	23	664	420	4.1	290	367	358
<i>Lockyer Valley</i>	Moira (dam+bore)	27	786	457	1.1	165	112	108
<i>Lockyer Valley</i>	Moira (bore)	31	786	420	7.2	1009	597	628
<i>Namoi Valley</i>	Doreen	23	591	346	0.4	15	9	18
<i>Namoi Valley</i>	Belgammon	9	591	624	0.7	44	122	146
<i>Macquarie Valley</i>	Nundah	8	533	780	0.4	972	801	748
<i>Macquarie Valley</i>	Elengerah	11	533	685	0.5	51	61	61



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From: *Marian Dunbar and Inakwu Odeh*
Title: *A Soil Database of the Upper Namoi Cotton-Growing Region*
Australian Cotton CRC
Department of Agricultural Chemistry & Soil Science,
The University of Sydney
Ross Steet Bld. A03, Sydney NSW 2006

Efforts to provide a soil database covering the cotton-growing region of eastern Australia is well under way. The database, which includes information on soil properties that are indicators of soil quality, provides the baseline information for monitoring of the environment. The soil quality indicators are also required for appropriate land management for sustainable cotton production.

The work briefly described here is part of a wider project that is providing a wide ranging information on soil quality indicators for the cotton industry. The work covers the Upper Namoi Valley of approximately 70 110 km², around Gunnedah in northwestern NSW. The work has been planned to proceed in three stages: 1) Field survey 2) Laboratory analyses and 3) Geostatistical and statistical analyses. Stage one has been completed. A total of 164 sampling locations were visited and soil samples taken at 6 depths, down to 2 meters, at each site. The stage two involving routine laboratory analyses, such as particle-size analysis, determination of organic carbon, total nitrogen, pH, CEC, phosphorus content, carbonate content, etc, is almost completed.

The stage three is ongoing, that is making maps of individual soil attributes and soil types as indicators of soil quality. Geostatistical techniques, combined with statistical methods, are being applied in this regard. Preliminary results in predicting topsoil % clay suggest promising results. Additionally, high spatial-resolution satellite imageries have been acquired and are to be used to augment the production of quality attribute maps that will provide more accurate information on the soil quality indicators.

Allocation of soil types (at individual sites visited) to classes in accordance with The Australian Classification System (Isbell, 1996) will be carried out. Through combined use of the satellite imageries and other ancillary information such as geology, land facies and digital elevation model (DEM), accurate prediction of soil types across the study region will be made. The ultimate results of such an exercise is to provide better quality soil map than any before it.

All the soil data collected and analysed will be collated into the soil database. There are plans to produce digital maps of soil quality indicator and soil type which will be incorporated into a GIS for easy dissemination and distribution to the stakeholders (interested farmers, land managers and other land resource researchers in the cotton industry).



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From: Les Copeland, Tony Vancov, David Nehl and David Backhouse
Title: Cotton soil health: influence on cotton root diseases

Aims & Objectives: To quantify soil microbial diversity in cotton soil and determine its influence on root diseases of cotton

Method: This new project will combine community level physiological profile analysis with a molecular marker approach to quantify microbial diversity in cotton soil and determine its relationship to cotton root diseases, especially black root rot and Fusarium.

Highlights / Outcomes: Sustainable agricultural production requires proper management of the soil resource, based on an understanding of the interactions between physical, chemical and biological factors. There is a particular need to better define soil microbial parameters because of the potential importance of the contribution of microbial communities to nutrient recycling, the breakdown of organic matter and mineralisation of agrochemicals. Soil microorganisms also play a vital role in soil formation and maintaining and soil structure, and a significant decline in soil microbial activity is likely to have an adverse effect on soil quality and fertility. The dynamics within a microbial community can also have a major influence on whether disease-causing pathogens proliferate or are suppressed by better-adapted competitors.

Diversity in soil microbial communities relates to both the number of groups (ie, richness) and the abundance of individual species within each group. Members of a community may be classified taxonomically or according to their capacity to perform a particular function (eg, diazotrophs, ability to utilise a substrate). Certain species in a microbial community may be well adapted and proliferate, whereas others may be suppressed because they are at a competitive disadvantage or because of the presence of antagonistic species. For example, a disease outbreak may occur when conditions favour a pathogenic species, but on the other hand, a pathogen may be suppressed because of competition from better-adapted or antagonistic species in the community. This project aims to quantify microbial communities in cotton soil by measuring functional diversity and species abundance and determine how the incidence of root diseases of cotton is influenced by soil microbial diversity.

From: Sevag Bedrossian
Title: Potassium Status and Mineralogy of Soil in relation to Premature Senescence in Cotton in Northern NSW

Aims & Objectives: At the moment Australian farmers are using the value of 150 mg kg⁻¹ of ammonium acetate extractable potassium (K) as a guide to whether their soil is K deficient or not. However, soil with greater than this level of K are still showing signs of premature senescence (PS). Therefore the objectives/aims of my research are:

To determine and compare the mineralogy and forms of K in some representative cotton soil of known PS problems with soil with no PS problems.

To determine the amount and rate of K release for mineralogically contrasting cotton soil.

To relate the soil K levels and the release rates with the K uptake by the cotton.

Method: Soil samples have been taken from areas at Narrabri, Moree, Pilliga and Warren (different soil types) which are affected by PS, as well as from areas of similar soil not affected by PS. Soil samples have been taken from five depths (to 120 cm). Soil characteristics which are being studied include CEC, exchangeable cations, EC, pH, soil particle size distribution, exchangeable K, non-exchangeable K, total K, mineralogy (XRD) of the four size fractions of soil, Greene-Kelly Test, K release kinetics of these soils (cation exchange resin), organic carbon, water soluble (soil solution) K and Cotton plant tissue sample analysis. Other tests may be undertaken at a later time. Following the above work, there will be an attempt to develop a method for determining the K levels in the soil, which is a better determinant of whether PS is going to be a problem in a cotton crop.

Highlights / Outcomes: Based on this research, the expected outcomes are, firstly, to gain a better understanding of:

The K dynamics of the soil types under the study

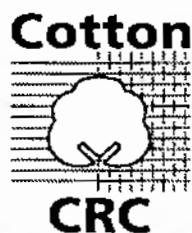
The equilibrium of K in the soil solution in relation to the mineralogy

The relationship of K levels in the soil and premature senescence

And, secondly, to determine:

The sustainability of K levels in the soil

K fertiliser application rates if required



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From: Chris Dorahy

Title: The effects of pH changes within the rhizosphere of cotton on phosphorus availability in alkaline soils

Aims & Objectives: To investigate the ability of cotton to decrease the pH of its rhizosphere
To investigate the role of cations play in any shift in rhizosphere pH
Explain how cotton is able to meet its P requirements on soils with low extractable P status

Method: Cotton plants are being grown in cotton soils of adequate and deficient P status, but with similarly low extractable P concentrations.

They are being grown in pots which have been split into upper and lower sections, by a 20um polyester mesh. This is fine enough to stop root penetration, whilst still allowing water and root solute movement between the sections of soil.

Rhizosphere pH is being measured by taking 10 x 1mm thick slices of soil, starting from the root soil interface and moving away into the bulk soil. These slices of soil are extracted in a

1: 5 soil: 0.01M CaCl₂ solution and shaken for 1 hour. The extracts are then measured for pH and P concentration.

Comparisons are being made between -/+ P application and supplying N as NO₃⁻ or NH₄⁺ on plant nutrient uptake, rhizosphere pH and P availability in the soil solution.

In situ, experiments are also being conducted to estimate the effects of acid addition on soil pH and P solubility.

Highlights / Outcomes: Changing the pH on the non-responsive soil markedly increased the concentration of P in the soil solution. This effect was not as great in the P deficient soil which indicates that there are smaller P pools the cotton plants can draw from in order to meet their P requirements.

The pot experiments are underway. Preliminary harvests have shown that the pH of the rhizosphere soil is 0.3 pH units lower than that of the bulk soil in some treatments. This equates to a 2-3 fold increase in P concentration in the soil solution.

Experimentation is due to be completed by the end of June.



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from: **Balwant Singh**
Title: **Buffering capacity of cotton soils of NSW**

Aims & Objectives: To determine the pH buffering capacity of major soil types of cotton region
To predict the soil acidification rate for the cotton soils

Method: The pH buffering capacity (pHBC) was determined by (i) titration method using incremental volume of 0.2 M HCl until pH 5 was obtained, and (ii) by incubation method, where 40 g soil was incubated with 10 ml of 0.2 M HCl for four months.

Highlights / Outcomes: The mean pHBC value by both titration and incubation method was 4.5 cmol/kg/pH unit. No correlations were observed between pHBC and soil pH, clay content and organic carbon content. Soil pH may decrease by about 1 pH unit within 15 years in 10% of the cotton soils from NSW

From: **Willem Vervoort**
Title: **Developing pedotransfer functions to predict hydraulic properties of cotton growing soil in eastern Australia (CRC project 1.2.4)**

Aims & Objectives: Establish water retention, conductivity and shrinkage relationships for cotton growing soils in 4 geographical regions, and use this as a prediction data set.
Develop pedotransfer functions to predict these hydraulic relationships from more basic soil properties.
Verify the developed functions against data from an *in situ* drainage experiment and literature data (the verification data set) using a simple numerical model.

Method: Sampling of 20 different sites in the cotton growing area of Eastern Australia to create a database of hydraulic properties, such as hydraulic conductivities and shrink-swell properties basic soil properties, such as texture, exchange capacity and major anions soil structural properties using an image analysis technique Develop pedotransfer functions which predict hydraulic properties from basic soil properties and soil structural properties

Highlights / Outcomes: Significant progress has been made in this project since last year. Sampling of all sites will be completed in soon, with two final field trips planned for June and July 2000. All field data for the 14 sites already sampled have been analysed and stored in a database.

Laboratory analysis is progressing, with many of the sites completely determined. Although in-depth analysis of all laboratory results will be performed in the last half year of this project, some interesting relationships are immediately apparent. Excluding subsoil samples, K_s is strongly correlated to the effective CEC and the exchangeable K content of the soil.

As expected, exchangeable Na and effective CEC have an effect on the shrink-swell capacity of the soil. Total Carbon did not appear to have a direct influence on soil physical properties, however there was an indication that its effect might be complex and not easily determined.

The interpretation of soil structure using the program Solicon is indicating some promising results. A completed fourth year project, performed as part of this study found a clear relationship between soil porosity, measured on large intact columns using image analysis, and the K_s at the CRC management sites in Warren and Merah North. A publication discussing these results is in preparation.

An *in-situ* drainage experiment was performed next to one of the fields at ACRI. The results indicated drainage of about 10-15 mm water per irrigation event beyond 1.5 m depth.



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