If you are participating in the presentations this year, please provide a written report and a copy of your final report presentation by 31 October. If not, please provide a written report by 30 September.

Part 1 - Summary Details

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

CRDC Project Number: **DAQ0901**

Project Title: Defining critical soil nutrient concentrations in soils supporting irrigated cotton in Northern NSW and Queensland.

Project Commencement Date: 1/12/2008 **Project Completion Date:** 30/9/2009

CRDC Program: Farming Systems

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Part 3 – Final Report Guide (due 31 October 2008)

Background

Over the past decade the cotton industry has made significant progress in many areas including water use efficiency, pest and disease management. Cotton yields have increased as a consequence of this research, but so have the quantities of nutrient removed from these farming systems. Recent work being conducted across the northern grains region has provided evidence of a need to redefine critical soil nutrient levels to optimise yield and predict response to added nutrients. This is in response to declining native soil fertility levels, changes in farming practices including tillage and residue management, controlled traffic, shallow placement of fertiliser despite reliance on stored moisture, new varieties and crop rotations.

The National Land and Water Audit (2001) and recent studies in the grains industry (Wang *et al*. 2007; Bell *et al*. 2005, 2008) have shown that soil nutrients, in particular phosphorus (P) and potassium (K), are being depleted in the soil profile, especially at depth. Interestingly, current commercial soil tests used to measure these reserves do not detect some of these changes because previously unrecognised pools of nutrients have been replenishing those measured by the extractants. Even when we supply enough nutrients at planting to maximise yields, inorganic pools of P and K which are not measured by commercial tests are decreasing. Across soil types these backup pools of nutrient range in size and their rate of supply, and in the case of K, the availability to plants can be moderated by high levels of other elements like Na.

It is important to quantify the size of these pools, their interaction with applied nutrients in fertiliser and their capacity to meet plant nutrient demands in our current farming systems.

Objectives

This project was a precursor to a larger, 3 year co-investment by GRDC and CRDC to improve decision support tools and resulting management practices to improve P and K nutrition in grains and cotton farming systems. This larger project will involve a series of field, laboratory and glasshouse studies examining the ability of different soil diagnostic tests to quantify plant-available pools of P and K in soils supporting the grains and cotton industries across the northern region. The primary objective of this pre-project activity was to characterise the soil P and K pools at sites across the cotton industry where these nutrients were known or suspected to be currently limiting crop performance. It was hoped that these analyses would indicate sites or regions where field studies could be initiated prior to the 2009/2010 cotton season. The late collection of these samples by regional extension staff meant that results were available too late to initiate field fertilizer trials, although a tissue sampling program has been initiated, including samples from crops on the sites sampled, to correlate soil results with crop nutrient status.

Methods

Regional cotton extension officers were contacted to identify blocks in some of the main cropping soils in their regions where they felt crop performance was being constrained by suboptimal P and/or K availability. Soil samples (0-10cm and 10-30cm depths) were to be obtained from these blocks and sent to Kingaroy for processing and analysis at DERM chemistry laboratories in Indooroopilly.

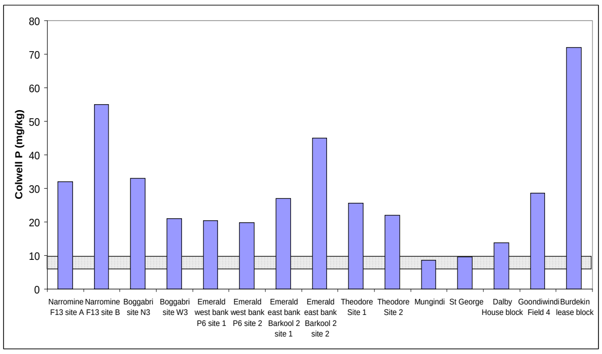
Analyses included both commercial soil P and K tests currently used as diagnostic indicators of the need for fertiliser applications (ie. Colwell P and exchangeable K) and also non-commercial soil tests for P (inorganic P extracted by dilute sulphuric or concentrated hydrochloric acid) and K (tetraphenyl-borate extractable K) designed to quantify the size of back-up P and K pools. These pools seem to be replenishing the easily available pools measured in the commercial tests. These new analytical techniques were developed in a previous nutrient management project in the grains industry (DAQ00084), and an improved understanding of the size and regional distribution of these reserves may alleviate some of the uncertainty with regard to fertilizer P and K requirements.

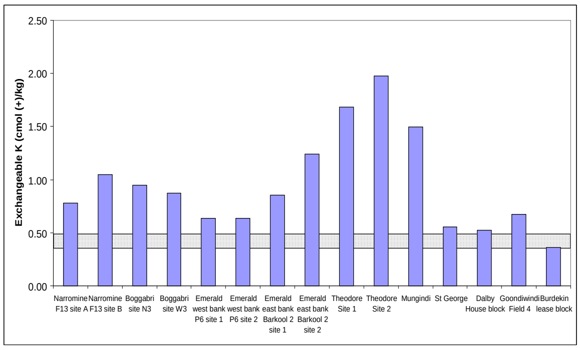
Results

Traditional soil analyses

The sites were initially assessed on the basis of current cotton industry critical soil test values for the 0-30 cm layer viz. Colwell P of 6 mg/kg and exchangeable K of 150 mg/kg, or ~0.4 cmol/kg, with results shown in Figure 1. I have used a band to indicate the critical value and an 'uncertainty' area above it where response might be expected.

Figure 1. Colwell P (mg/kg) and exchangeable K (cmol/kg) for the 'problem soils' submitted from various cotton growing regions. A sample from the Burdekin (Lafrenz block) has been included from another study.





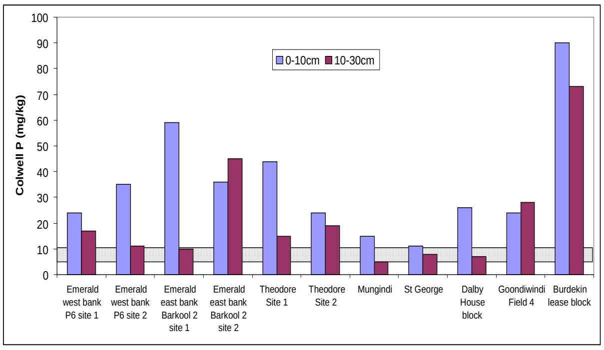
Using the existing soil test guidelines there would only appear to be 2 soils likely to be P responsive (the sites at Mungindi and St George), and while the St George and Dalby sites were near the band indicating possible K response, only the Burdekin site was within/below those critical values. This was surprising, as soils had been submitted on the basis of having low/marginal nutrient status and suspected problems with P and/or K nutrition. These data suggest the problems either may not be related to these two nutrients, or the situation is more complex than currently understood.

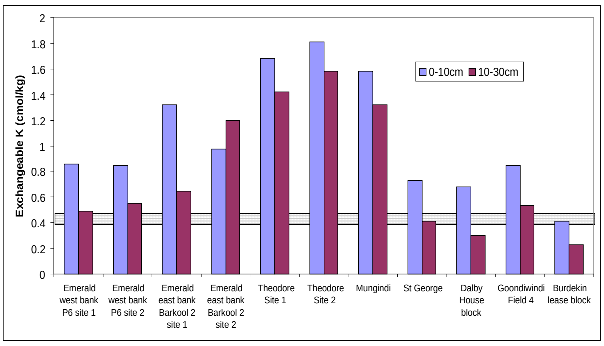
Most sites also had soil samples split into 0-10cm and 10-30cm depths, to provide an indication of the extent of P and K stratification, and also any increase in cations (like Na) that have been shown to interfere with K availability – either directly (through cation competition for uptake sites) or indirectly (through physical inhibition of the root system exploration and efficient exploitation of soil K reserves). Stratification refers to the relative enrichment of the top (0-10cm) layer, relative to layers below it in the soil profile. Results are shown in Figure 2, with the bands relating to 'critical' P and K concentrations again included, using similar reference values as in Figure 1.

This stratification approach provides more insight into possible limitations, given that the contribution of P and K derived by the crop from the top 10cm of the profile will vary depending on moisture availability during the season. The stratification was more evident in

Colwell P than it was in exchangeable K. Only two of the 11 sites had Colwell P in the 10-30cm layer similar to that in the 0-10cm layer (ie. Barkool 2 Site 2 and Goondiwindi Field 4), while five sites had Colwell P in the 0-10cm that was 3-5 times that in the 10-30cm layer. Collectively, nearly half the sites were characterised by low (<10 mg/kg) Colwell P in the 10-30cm layer (two sites at Emerald sites and the sites at Mungindi, St George and Dalby), suggesting that if roots were trying to accumulate P from these layers for extended periods then P access could be compromised.

Figure 2. Colwell P (mg/kg) and exchangeable K (cmol/kg) in the profile of a subset of the regional 'problem soils' submitted from various cotton growing regions. The Burdekin sample has again been included.



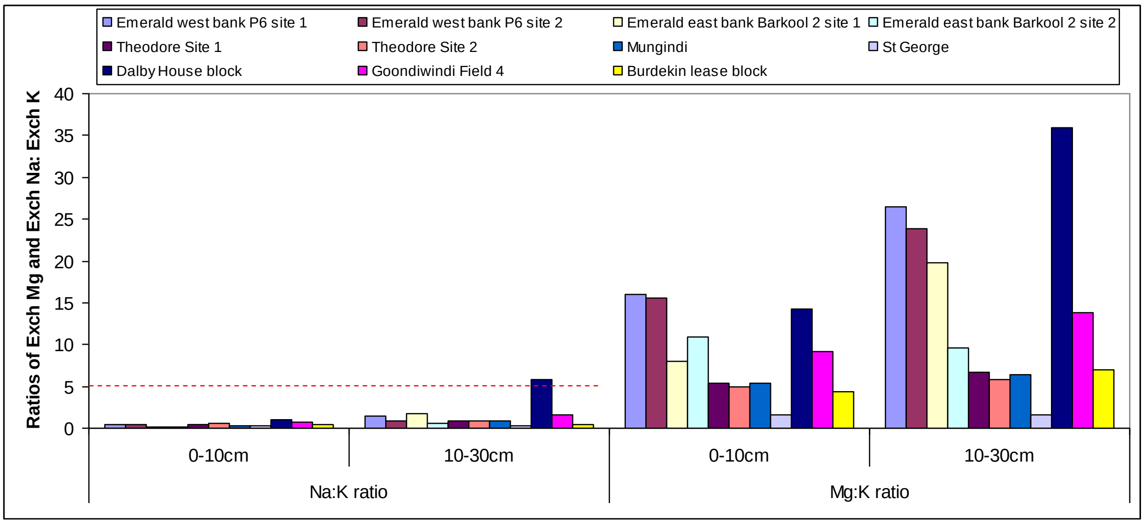


Exchangeable K was also stratified in a number of sites, but the relative surface enrichment was generally lower (ie. exchangeable K in the 0-10cm was generally < twice that in the layer below) and the frequency with which exchangeable K in the 10-30cm layer was ≤ critical soil K concentration band was lower (ie. only St George, Dalby and the Burdekin site).

Recent grains industry research has shown that not only the quantities of exchangeable K are important in determining plant K uptake, but also the relative abundance of K to other cations in the soil solution (especially Na and Mg). We use the ratios of exchangeable Na and Mg to that of K as an indicator of these effects. We have found that when the ratio of exchangeable Na: exchangeable K is >5, uptake of K from the exchangeable K pool is restricted. However, the only site in which the Na:K ratio exceeded 5 was in the 10-30cm layer at Dalby, where it was only 5.8 (Figure 3). This suggests that interference from Na in K availability at these sites was minimal.

We have less information about the impact of soil Mg on K uptake by plants, but there is evidence of very high tissue Mg in grain crops growing in soils with marginal exchangeable K. There are some wide variations in the ratio of K:Mg in the different soils (Figure 3), with ratios sometimes a lot higher in the 10-30cm than the 0-10cm layer. The tissue sampling that is being conducted as part of DAQ00148 should shed more light on this aspect of K nutrition.

Figure 3. Ratios of exchangeable Na: Exchangeable K and Exchangeable Mg: Exchangeable K, as indicators of possible cation interference limiting plant K uptake.



New measures of soil P and K reserves

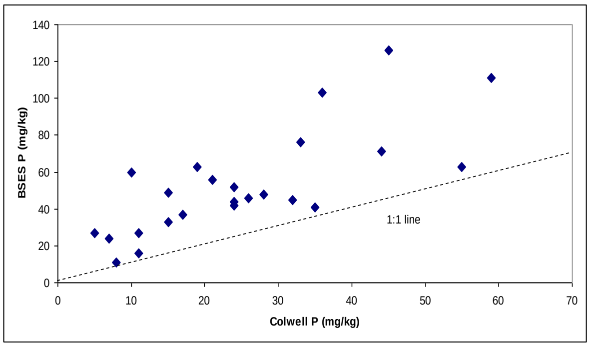
Acid-extractable soil P

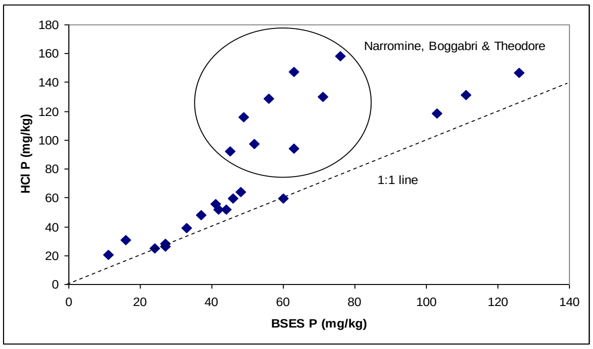
Acid-extractable soil P was determined using dilute sulphuric acid (0.005M H_2SO_4 – commercially available as BSES P) and concentrated hydrochloric acid (1M HCl – as used in the P fractionation procedure of Guppy *et al*., 2000). These acid extractants solubilise inorganic calcium phosphates which are not extractable in the Colwell test, but which have been found to contribute to plant available P for grain crops grown on alkaline clays (Wang *et al*, 2007). While often seen as sparingly soluble, these forms of inorganic P can represent significant reserves of slowly-available P that can be especially important for meeting crop demands from layers below the fertilizer and residue-enriched 0-10cm layer. The BSES test has been used in northern Vertosols in the grains industry, and a combination of Colwell and BSES-P was originally proposed to predict starter P requirements in wheat and sorghum. However, the weak acid extract can be neutralised by high pH soils (ie. >8.2) before being able to solubilise significant P reserves, so the HCl-P technique (which is not available commercially at this time) was used to ensure that soils with significant P reserves in this form were detected.

While there was a general trend for soils with higher Colwell P to also have more BSES-P (Figure 4a), there was considerable variability in BSES-P for a given level of Colwell P. For example, soils with the relatively narrow Colwell P range of 5-10 mg/kg (at or near the critical Colwell P for cotton) returned a much wider range of BSES-P ranging from 11 – 60 mg/kg. Variation in the amount of P reserves in these acid-extractable pools that are not correlated to Colwell P may well explain some of the reported variability in response to applied P fertilizer, and this will be confirmed in subsequent studies in DAQ00148.

The HCl-P analyses showed that in most cases the HCl-P did extract additional P over that obtained from the BSES-P extract (Fig. 4b), with exceptions being the subsoils from the Mungindi, Emerald East Bank Site 1 and Emerald West Bank Site 2 locations. The soils from the sites at Narromine, Boggabri and Theodore were exceptional in that the HCl extract removed 50-100% more P than that of the BSES-P extract, but this increased efficiency of P extraction was not related to effects of high soil pH – the initial reason for evaluating this second method. It is probably related to different soil mineralogy, but the availability of those additional P reserves for plant uptake has yet to be determined.

Figure 4. Relationship between (a) Colwell-P and BSES-P, and (b) BSE-P and HCl-P in soils from across the major cotton-growing areas of the industry.





Collectively these data show that at the very least, Colwell P may be a conservative predictor of plant available P reserves in many cotton soils across the region. The contribution of these reserves to meeting P demand in high yielding cotton crops will be a focus of field and glasshouse studies in DAQ00148.

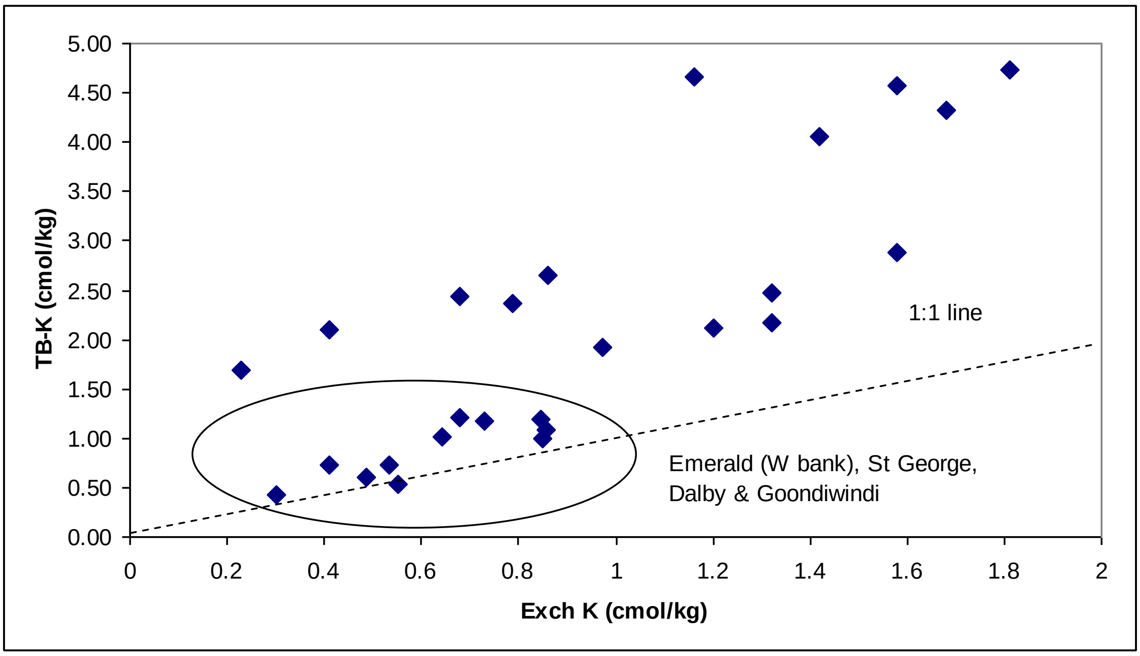
<u>Tetraphenyl borate-extractable soil K (TB-K)</u>

The TB-K method has been proven useful for detecting reserves of plant-available K that are not measured by the current exchangeable K soil test, with the difference between the TB-K test and the exchangeable K tests taken to measure both fixed and structural K pools. Recent work in soils with a variety of mineralogies shows that in some cases TB-K is so efficient that it extracts K from pools that are not available to plants. Results to date have shown that most of these 'false positive' results with TB-K (ie. more K measured than plants can actually extract) occur in alluvial soils east of the Great Dividing Range, although the studies have in no way been exhaustive. At this stage, the additional K extracted by the TB-K test is being used as a guide to pools of available K that can solubilise to replenish exchangeable K reserves between crop seasons.

Results of the TB-K analyses show that there are at least two distinct groups of soils with respect to K status – (i) those in which available K is predominantly in the exchangeable K pool and there is little or no slow release K as a backup (P6 Site 1 and 2 on the West bank at Emerald, and the sites at St George, Dalby and Goondiwindi); and (ii) the other sites in which there is a significant pool of fixed and/or structural K that is presumably available for plant uptake in the longer term. This demarcation between sites adds another level of complexity to interpreting site K status (Fig. 1b and 2b), as sites like the Burdekin block (low exchangeable K) have very large reserves of non-exchangeable K of unknown availability for plant uptake, while other low K sites (especially in the 10-30cm layers) have effectively no additional K reserves at this stage. The contrast between soils on the East and West bank of the Emerald Irrigation Area is also very interesting, as those on the East bank have 60-90% more available K (TBK - exch K) in backup pools than soils on the West bank (5-30% more available K). This suggests different mineralogies, although this has yet to be confirmed. The rate of

release of K from these different slow-release K pools, relative to the demand from high yielding cotton crops or the fallow period between crop harvest and the next planting (when fertilizer decisions have to be made), is yet to be determined.

Figure 5. Relationship between exchangeable K (cmol/kg) and tetraphenyl borate-extractable K (TB-K, cmol/kg) for soils from across the major cotton-growing areas of the industry.



<u>*References*</u>:

Guppy CN, Menzies NW, Moody PW, Compton BL, Blamey FPC (2000) A simplified sequential phosphorus fractionation method. *Communications in Soil Science and Plant Analysis* **31**, 1981–1991.

Wang X, Lester DW, Guppy CN, Lockwood PV and Tang C (2007). Changes in phosphorus fractions at various soil depths following long-term P fertiliser application on a Black Vertosol from south-eastern Queensland. *Australian Journal of Soil Research* **45**, 524-532.

Outcomes

While this preliminary project was not able to achieve its original intent, being early identification of trial sites with clearly suboptimal P or K status in order to establish trials in the 09/10 summer season, it has provided an initial evaluation of new soil test techniques in a representative subset of soils from across the major cotton growing regions. Results have illustrated that the variability already evident in traditional soil testing approaches (0-30cm depths and Colwell P/exchangeable K soil test methods) is accentuated when vertical stratification and reserve nutrient pools are considered. Key outcomes from this work are –

- Some profiles were quite strongly stratified within the traditional 0-30cm sampling layer, especially for Colwell P, and this may have significant impacts on the ability of crops to accumulate P during periods of rapid growth and/or dry topsoils. Some further regional sampling to assess the extent of stratification in more detail is clearly warranted.

- The new soil test diagnostics, while not yet validated in terms of quantifying nutrient pools available to cotton at rates required to support high yielding crops, do suggest that currently unmeasured pools of both P and K are potentially a significant contributor to crop P and K requirements in many soils and districts. Conversely, there are other areas where the traditional view of high fertility reserves in clay soils does not hold, and it will be important to differentiate between soils within and between regions on this basis if improved fertilizer use efficiency is to be achieved.
- Finally, the sites sampled in this project and the links made with local extension officers have allowed a targeted tissue sampling of crops on these (and other) soils across the cotton growing regions in the 2009/10 season. The links between soil tests undertaken in this project and the actual crop P and K status measured in the field will help build confidence in the ability of the soil tests to predict sites on which to conduct P and K fertilizer trials.

Conclusion

This preliminary project was able to provide a preliminary assessment of the P and K status of soils in most of the key cotton growing regions across the industry. New diagnostic soil tests were able to provide an assessment of the pools of each nutrient that are supplementing P and K measured in the current commercial soil tests, and have given a guide to potential combinations of soils and districts in which future detailed studies will be conducted. These will be confirmed by in-crop tissue testing over the 2009/10 season, and future trials will be conducted as part of the joint GRDC/CRDC project DAQ00148 from 2009-2012.

Extension Opportunities

Links have been established with the cotton extension team in this project, and they will form the basis of ongoing collaboration in DAQ00148 over the next three years. At this stage the main messages arising from this work are awareness that another look at P and K soil testing (both analyses and the soil testing strategies) is being undertaken, and that some detailed research into P and K fertilizer requirements and application strategies is planned.

More detailed feedback to officers who have supplied soil samples will be undertaken as the current crop season, and the active tissue sampling program, progresses.

Publications are not expected from this initial soil sampling exercise, although these data may well appear as part of a broader paper describing soil P and K fertility across the grains and cotton growing regions.

No online resources have been developed.

Part 4 – Final Report Executive Summary

Soil nutrients, in particular phosphorus (P) and potassium (K), are being depleted in the clay soils supporting the grains and cotton industries of northern NSW and Queensland, especially in the deeper layers of the soil profile. Current commercial soil tests used to measure these reserves do not detect some of these changes because previously unrecognised pools of nutrients have been replenishing those measured by the extractants. Even when enough fertiliser is applied to maximise yields, inorganic pools of P and K which are not measured by commercial tests are decreasing. Across soil types these backup pools of nutrients range in size and their rate of supply, and in the case of K, the availability to plants can be moderated by high levels of other elements like Na. It is therefore important to quantify the size of these pools, their interaction with applied nutrients in fertiliser and their capacity to supply plant nutrient requirements in our current farming systems.

In conditions where nutrient limitations are identified or where nutrient replacement strategies have been adopted for long term sustainability, effective fertilisation strategies need to be developed to ensure efficient use of those nutrients by plants. The experiments needed to make these assessments are expensive and time consuming, and so certainty of selecting responsive sites becomes important. The uncertainty with current P and K diagnostic tests, due mainly to the existence of variable sized pools of nutrient reserves, has complicated this selection process.

This small preliminary project was conducted to assess the potential of new P and K diagnostic tests to clearly identify sites with low levels of available P and K on which future fertiliser trials could be conducted. It was also part of an initial assessment of the variability in P and K reserves in different soils and cropping systems across the region. Findings from this project will feed directly into a joint GRDC and CRDC project in which laboratory, field and glasshouse studies will develop new guidelines to ensure profitable use of P and K fertilisers as well as long term sustainability of grains and cotton farming systems.

Key outcomes from this project included (i) evidence of strongly stratified reserves of P and K within the 0-30cm sampling depth in cotton growing soils across the industry, which may have significant implications for nutrient access by cotton crops; (ii) evidence that there is substantial variability in the P and K reserves in soils across the regions, and that the size of these reserves is often not related to existing soil test methods; and (iii) this variability is being used, in combination with in-crop tissue testing, to improve understanding of the relationship between soil tests and plant nutrient status, and to ultimately guide selection of sites for longer term experimentation to develop P and K fertiliser guidelines for the grains and cotton industries.