Australian Government
Cotton Research and Development Corporation

FINAL REPORT 2015

For Public Release

Part 1 - Summary Details

CRDC Project Number: UNE1501

Project Title: Phosphorus availability in raingrown cotton

Project Commencement Date: 1/06/2014 **Project Completion Date:** 31/02/16

CRDC Research Program: 1 Farmers

Part 2 – Contact Details

Administrator: Dr Kathryn Dougall
Organisation: University Of New England
Postal Address: Research Services, University Of New England, Armidale, 2351.
Ph:0267 732398 **Fax:**0267 733398 **E-mail:**kjacques@une.edu.au

Principal Researcher: Brendan Griffiths
Organisation: University Of New England
Postal Address: P.O. Box 1044 Goondiwindi, Qld 4390
Ph: 0427 715990 **Fax:** 0746 715991 **E-mail:** bgriffi2@une.edu.au

Researcher 2: Chris Cuppy
Postal Address: Agronomy and Soil Science
University of New England
Armidale 2351
Ph: 0267 733567 **Fax:** **E-mail:** cguppy@une.edu.au

Signature of Research Provider Representative:

Date Submitted: 24/03/2016

Part 3 – Final Report

Background

Originally intended to be conducted in Northern NSW at an Incitec-Pivot Tulloona research trial , in northern NSW, this experiment was relocated to Qld to another long term site, due to lack of adequate rainfall to sow raingrown cotton at the NSW site.

The site chosen was another Incitec Pivot long term nutrition experimental site , at 'Colonsay' via Brookstead. Incitec Pivot Ltd. in conjunction with collaborative independent researchers, has conducted a long term farming systems experiment at 'Colonsay' , since 1985. The experiment has been conducted in a completed randomised block, split plot, design with the treatments being 0 , 10, 20 kg/ha P and 0, 40,80, 120 kg/ha N : and all permutations of the above, this experiment has focussed on the P dynamics, and as such a sub-sample of treatments has been taken to include all 4 Phosphorus treatments, and 0N and 80N and permutations of these. Nutrients, as urea and triple super, have been applied either pre or at plant for each crop planted, and rotations have included, sorghum, wheat, chickpeas, and barley, throughout the duration of the project. The site has previously been shown to be responsive to both N and P, with background Colwell P values > 10 mg/kg, and with soil N levels varying depending on fallow mineralisation.

The three rates of P and have been established creating a range of Colwell P values from 8.27 to 64 mg/kg. This created the opportunity to investigate dryland cotton P responses and responses to residual fertiliser P. The range of soil test Colwell P values and in-kind contributions from Incitec to measure Colwell, and BSES pool dynamics in raingrown cotton, grown on vertisols, and to give a better prediction of when and how dryland cotton will respond to P applications.

The current soil test critical P value, developed in predominantly banded irrigated cotton scenarios indicates no cotton growth response where Colwell P is greater than 6 mg/kg, Dorahy et.al 2004. Recent evidence, however, suggests that cotton does not respond readily to banded applications of P fertiliser, potentially due to a greater reliance on mycorrhizal infection, and the dynamics of root development by the cotton plant, in the cotton system.

For the 2014/15 summer the rotation crop chosen for the site was raingrown cotton. This followed raingrown wheat sown June 2013. There had previously been very little previous experimentation investigating performance of raingrown cotton under these scenarios, and in this region .With soil test Colwell P values showing residual soil P levels ranging from 8.27 mg/kg P in the untreated treatments, up to 64 mg/kg in the 20 kg/ha P treatments, this site provided an ideal and unique scenario to investigate cotton crop performance under a range of residual P values, and also to investigate as to whether applied fertiliser P at sowing is providing a crop response or if labile P being released into solution is in fact the primary source of P. This experiment also potentially provided a means for validation of soil test critical values investigating soil test extraction methods currently being employed such as Colwell P, BSES P, as well as providing a basis for the validation of in crop-tissue testing as a method of ascertaining in crop nutrient status.

Acknowledgement needs to be given to the contribution to Incitec Pivot Limited and Bede O'Mara for allowing the experiment to be conducted on their site, for the soil testing conducted in the experiment, for the planting of the experiment, and for assistance during the tissue sampling period of the experiment. Also, the contribution of Prof Mike Bell, of QAFFI, and Dr David Lester, and Peter Want of QDPI for their contribution to this project for the use of drying and grinding facilities to process tissue samples, and for collaboration with their CRDC funded project UQ1302. Also, to the UNE students Kate Lumber and Luke Simpson who completed their BRurSc Hons projects as part of this experiment.

Objectives

To investigate phosphorus uptake dynamics under the range of treatments outlined below.

1. Under a range of background soil colwell P values – enriched through the continuous addition of P based fertiliser over time.
2. To investigate the effect of the addition of deep applied P fertiliser.
3. To investigate the impact of the dispersion of an enriched layer of P on plant P uptake.
4. To investigate the adequacy of plant P concentration (as leaf tissue testing) to reflect plant nutrient status.
5. The final principal aim is to look at correlations between plant nutrient uptake and the soil test extraction methods of Colwell P and BSES P. These measurements should also assist in the calibration of soil test P values for raingrown cotton as well.

Methods

'Colonsay' is a long term experimental site conducted by Incitec Pivot Ltd. since 1985. The experiment has been conducted in a completed randomised block, split plot, design, with three replications. Each year of the experiment the treatments of 0 , 10, 20 kg/ha P and 0, 40, 80,120 kg/ha N : and all permutations of the above.. Nutrients, as urea and triple super, have been applied either pre or at plant for each crop planted. The cropping sequence over this time has included sorghum, wheat, chickpeas, mung beans, and barley. 2014 was the first time raingrown cotton had been added to the cropping system.

For this experiment a subsample of the treatments including 0, 10, 20 kg/ha P and 0 and 80 kg/ha N, and their permutations, were investigated.

The original plots were 55m long. For the 2014 experiment the treatments were modified in a latin square type design, where the plots were divided into 3, 18m lengths and across the plots was applied 20kg/ha P, applied to 20cm depth, in bands 50cm apart, and finally and 18 m strip tilled across the plots to 20cm depth, with tynes spaced 50cm apart, to ensure no confounding tillage effect, and to mobilise any stratified layer of applied fertiliser.

Residual soil N values were in excess of 120 kg/ha, as such all of the P treatments had added 80 kg/ha N applied pre plant as urea to ensure a total pre-plant N availability of 200 kg/ha N. Surface variation in background soil test P levels in the 0-10cm segment was investigated extensively in this project due to the influence of applied fertiliser P over time and will be discussed extensively throughout this paper. BSES P levels at depth 10-30cm when all treatments were averaged were around 41 mg/kg.

Table 1. Chronology of events

Timing	**Date**	**Day Degrees**	**Physiological stage**	
1.	15th November		sowing	
2.	3rd February	1101	1st Flower	14 nodes
3.	16th February	1254	Mid flowering	17 nodes
4.	3rd March	1455	Peak flowering	21 nodes
5.	19th March	1665	Cut out	24 nodes
6.	17th April	1966	Physiological maturity	24 nodes
7.	10th June		Crop harvest	100 % open

Each plot was 2.5m x 18m. The crop was configured such that two rows of cotton, spaced one metre apart, and were sown down the centre of each plot.

Planting rate was 12 seeds/ metre of row using a four row experimental seeder using Kinze twin disc opener sowing units, and the crop was sown on Nov 15, 2014.

At timing 2, on two lineal metres of row, whole plants were harvested from ground level, and stored in hessian sacks. On the same day as field sampling, these samples were dried at 80^0C, and weighed once dried. These samples were then ground to 100 uq and prepared for tissue analysis via ICP, for N and P concentration. Plot sample biomass was multiplied by subsample nutrient concentration to give a plot nutrient content. The youngest mature leaf was also harvested from 30 mainstems plants from each plot .These were also dried and ground and prepared for ICP analysis. The plant tissue concentrations from the youngest mature leaf were to replicate the commercial method of tissue testing for plant nutritional status.

At timing 3, 4, 5, & 6, on one lineal metre of row, whole plants were harvested. All samples were otherwise prepared in an identical manner to those taken at sampling timing two.

Harvest was conducted on the 10th June 2015, using a modified JD 7710 spindle cotton picker. Total seed cotton for the plot was weighed, and subsamples taken and weighed. The subsamples were processed using an experimental saw gin, where the seed was removed and outturn of lint recorded and plot lint yields could be ascertained by multiplying lint out-turn to the harvested plot seed lint weights. The extracted seed was then ground and prepared for nutrient analysis, via ICP, so nutrient removal amounts may be ascertained.

Statistical analysis was conducted was conducted using analysis of variance, and multifactorial analysis using Gylling data management – Agricultural research manager v 9. Regression analysis was conducted using Genstat v 17.1.

Results

Table 2. Soil test Colwell P 0-10cm, and lint yield, by treatment.

Treatment	**Colwell P (mg/kg) 0-10cm**	**Lint Yield (ba/ha)**
80N 0P	8.67	5.62 a
80N 10P	30.56	7.46 b
80N 20P	64.33	7.92 b

(P=0.05) means followed by the same letter do not differ significantly

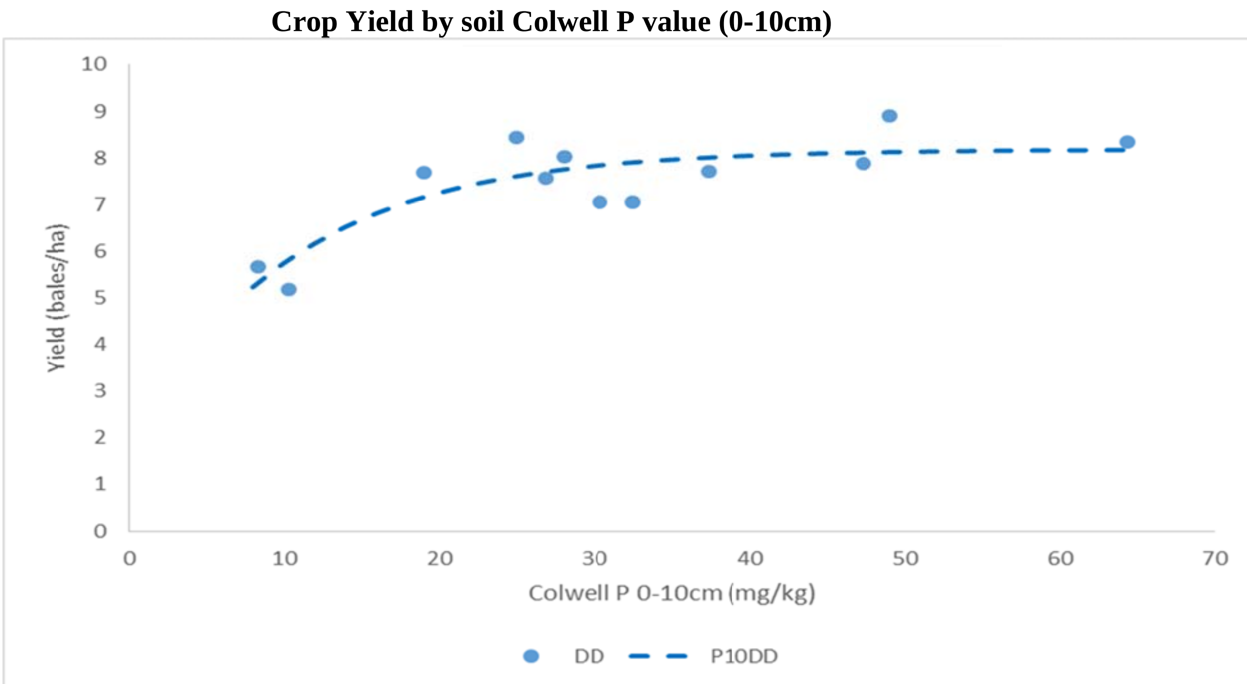
Surface Colwell P values have been enriched, through the continued addition to fertiliser P over time, to the point where the treatments now show a gradient of Colwell P values see Table.2. In this particular experiment the result in terms of yield were significant when the zero and 10kg/ha P treatments were compared. Whilst there was a trend towards an increase in yield between the 10 and 20kg/ha P treatments there was no statistical difference.

Table 3. Soil test results (mg/kg), by extraction method 0-10cm soil profile.

Treatment	Colwell	DGT P	BSES P
80N 0P	8.67	5.83	45.17
80N 10P	30.56	30.44	87.22
80N 20P	64.33	138.33	206.67

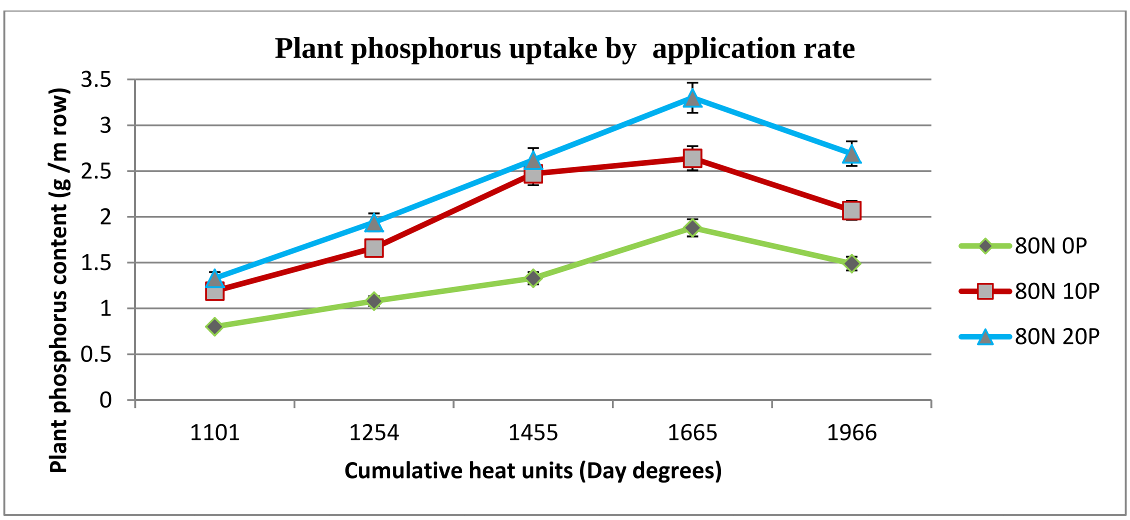
A similar trend with respects to enrichment of P values was also reflected in the other soil test methods investigated, ref. table 3. Whilst interesting to show there was a similar response in terms of soil test values, and their increase, the literature would suggest that the Colwell P soil test for the surface is still the method that is most likely to relate to plant-available P, McLaren et. al, 2013. It was unlikely in the scope of this experiment to find any more reliable a soil test in the 0-10cm than Colwell, and certainly in the deeper part of the profile 10-30cm any method more than BSES P, in examining soil P reserves, in the slower release pools, McLaren et. al., 2014.

Fig 1. Crop yield by Colwell P value



Soil test Colwell P values, as outlined in Fig 1., indicate a flattening response when compared to crop yield at levels of approximately 25 mg/kg or higher. This is significantly higher than outlined by Dorahy et.al. 2004, who established the likely colwell P soil test critical value was around 6 mg/kg or lower.

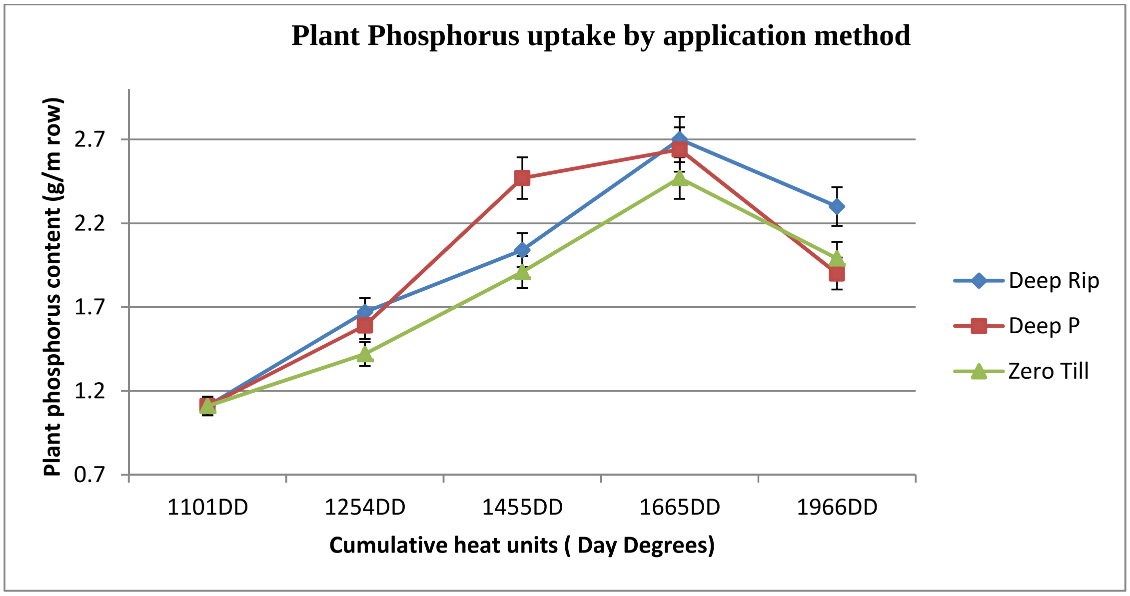
Fig 2. – Plant phosphorus uptake by P rate



In line with the response in yield there were significant differences between the P treatments, with respects to phosphorus uptake, as shown in Fig. 2.

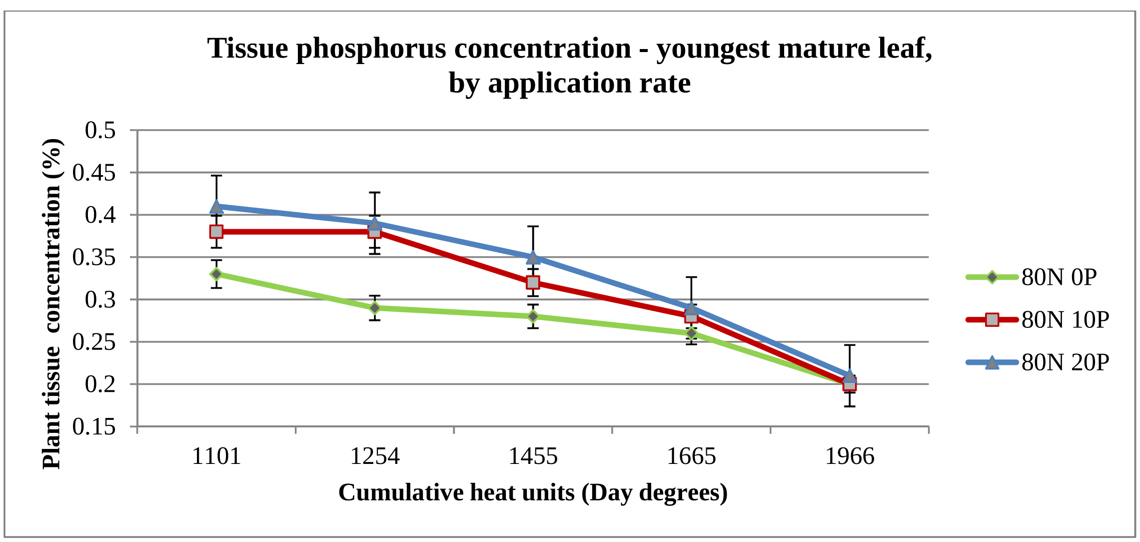
Maximum uptake was achieved at 1165DD which was the crop stage of cut-out where the 20 kg/ha treatment showed P uptake of 3.2 g/m row or 32 kg/ha. Interestingly the 0 P treatment was around 1.8 g/m row or around 18kg/ha P uptake.

Fig 3. – Plant phosphorus uptake by application method



When the methods of application of P were compared, there was very little difference between the treatments as shown in Fig 3. At 1455DD, which was around peak flowering, there was a spike of uptake of P in the deep P treatment. This spike of uptake was not long lasting and again by, 1665DD, or plant cut out, there was no significant difference in plant P uptake between any of the treatments.

Fig 4. Plant tissue concentration by fertiliser P rate.



In terms of tissue P concentrations, taken from the youngest mature leaf, Fig 4., shows there is a significant response between the zero treatments and the 10kg/ha treatments. There has been further analysis conducted with respects to plant tissue concentration to be discussed further in this paper.

Fig 5. Plant tissue concentration by fertiliser application method

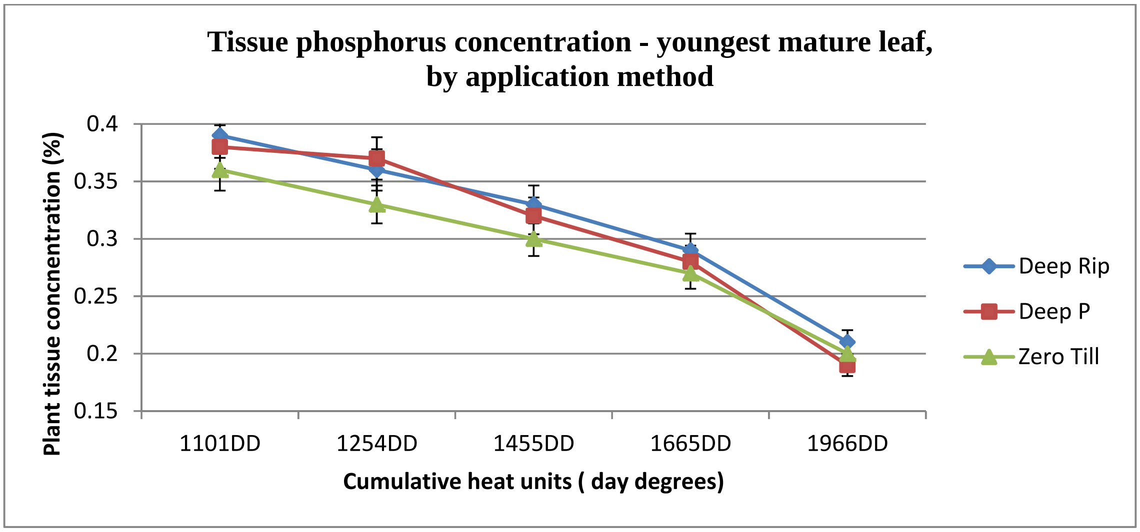
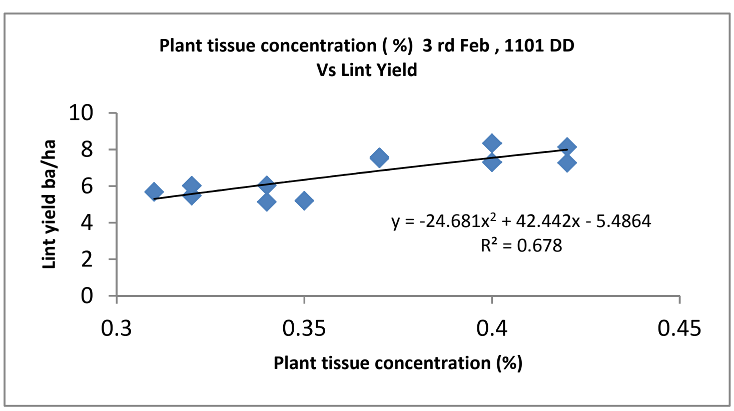
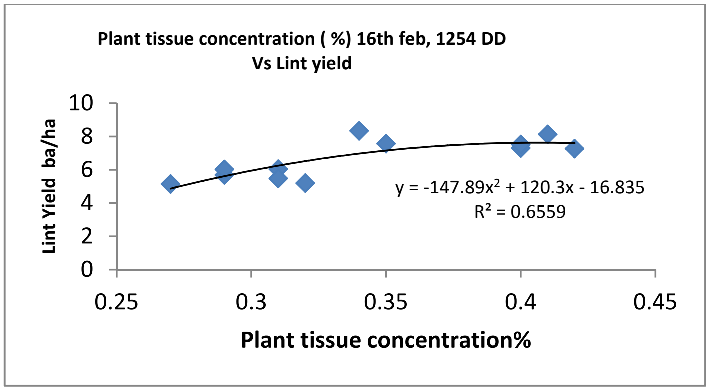
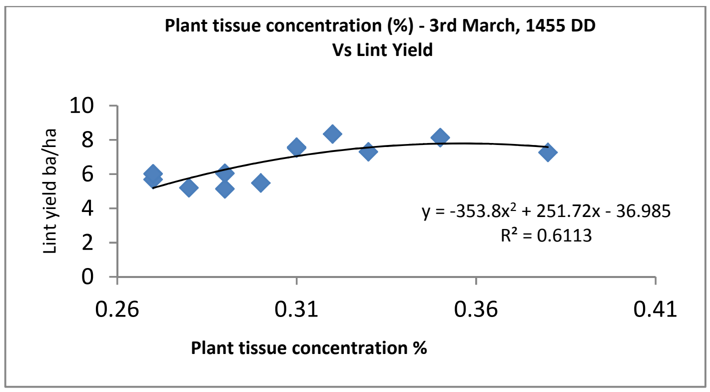


Fig 5. shows there was no significant difference with respects to plant tissue concentrations in the youngest mature leaf (YML) at any of the five sampling timings when application methods were examined.

Fig 6. Correlation between plant tissue concentration (YML) and crop yield, by sampling timing.







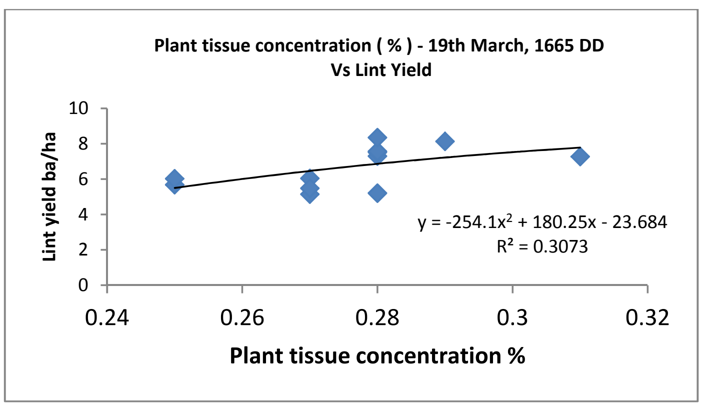


Fig 6. Displays correlations, for the first four sampling timings (up until plant cut out -1665DD), between plant tissue concentration at the youngest mature leaf, and yield. The first three sampling timings showed strong linear relationships, reinforcing the reliability of tissue testing of the youngest mature leaf as a valid method of assessing plant P status. The reliability decreases at the final two sampling timings, the last of which is not displayed in Fig 6. due to a poor linear relationship. This decrease in reliability as the plants mature is largely due to the partitioning of nutrient into reproductive growth, and the developing seed.

Fig7. Plant tissue P concentration - critical values at 90 % of lint yield

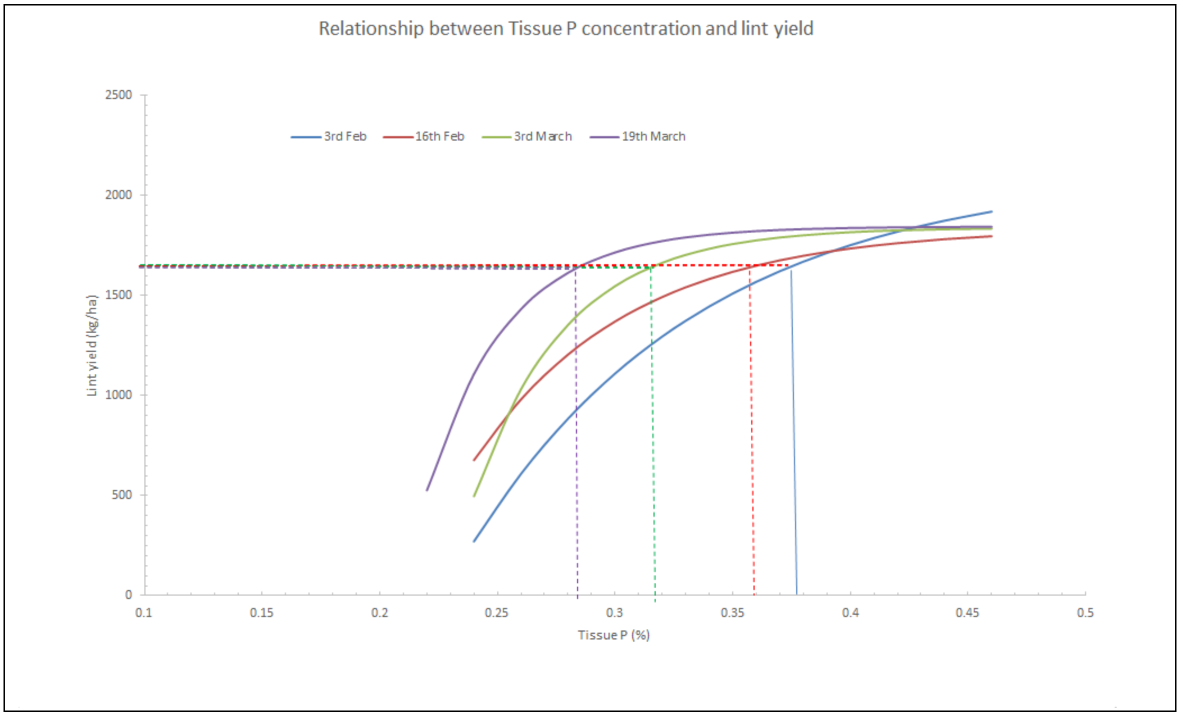


Fig 7. Illustrates the critical plant tissue phosphorus concentrations for the 90% of maximum yield (1700kg/ha) in this experiment. Strong correlations between lint yield at the first four sampling timings as shown in Fig 6.,have allowed plant tissue P concentration critical values for the first four sampling timings, taken at first flowers (1101 DD – 3rd Feb), mid flowering (1254 DD – 16 Feb), peak flowering (1455DD – 3rd Mar), and cut out (1665DD – 19th Mar), to be developed. Critical plant tissue P concentration values for the four sampling timings are approximately 0.38% at 1101 DD, 0.36% at 1254 DD, 0.32% at 1455DD, and 0.285% at 1665DD.

References

Dorahy, C.G, Rochester I.J, Blair, G.J., 2004, ' *Response of field-grown cotton(Gossypium hirsutum L.) to phosphorus fertilisation on alkaline soils in eastern Australia*'. Soil Research 42 (8) *pp* 913-920

Lester, D., Bell, M. Weier D.,2014, ' *Phosphorus, potassium and cotton : where are we up to*? , proceedings 17th Australian Cotton conference, Gold Coast, *pp* 37-39

McLaren T.I, Bell, M.J., Rochester I.J, Guppy C.N., Tighe M.K., Flavel R.J., 2013. ' *Growth and phosphorus uptake of faba bean and cotton are related to Colwell-P concentrations in the subsoil of vertosols'*, Crop and Pasture Science, 64, *pp* 825 -833

McLaren Timothy I; Guppy, Christopher N; Tighe, Matthew K; Bell, Mike; 2014, ' *Dilute Acid Extraction is a useful indicator of the Supply of Slowly available phosphorus in vertisols'*, Soil Science Society of America Journal, 78, *pp* 139-146

Wang, X., Lester, D.W. Guppy C.N., Lockwood P.V., Tang, C. 2007. ' *Changes in phosphorus fractions at various depths following long-term P fertiliser application on a black vertisol from south-eastern Queensland'*, Australian journal of soil research , 45, *pp* 524-532.

Outcomes

The project set out to fill in some of the knowledge gaps behind P dynamics in the cotton system. This project has very successfully been able to do so, being one of the few experiments in recent times showing positive responses to the application of P. This has been explained clearly throughout this paper, and was possibly due largely to the fact that the P sources utilised in this experiment were essentially not entirely from fertiliser P applied in the year of the experiment. Coupled to this very good surface root growth, as a result of high early season rainfall, allowed for excellent uptake of surface stratified P accumulated over time through the continued application of P based fertiliser.

Conclusions

1. Work by Bell et. al. 2015, and Dorahy 2004, and others have shown little response to the application of fertiliser P, in the season that it is applied, in cotton. This experiment provided the researchers with a unique set of circumstances where the soil had been enriched with P such that a gradient of background soil test values was achieved. In this particular experiment very good results with respects to both plant phosphorus uptake, and yield were achieved. It is not perfectly clear as to the mechanism driving these responses although it is postulated that the favourable early season growing conditions resulted in excellent surface root activity, or that soil enriched with P behaves differently than that with fertiliser P applied for that growing season, or a combination of both.
2. Very little response was observed when both deep applied P was added, or when tillage was included to disperse bands of enhanced P. This may concur with other

work by Wang et. al., 2007, inferring that deeper in the profile the plant is likely to be drawing on native, and other reserves of P held in a range of P pools, most notably that measured using the BSES P extraction method. Also, again that applied fertiliser P (as the deep applied P) is unlikely to provide a short term response in terms of either plant P uptake, or yield. Because of the favourable early season root activity in this particular experiment, it was difficult to distinguish between nutrient that had been taken up from dispersed P, and nutrient taken up from P held in a band.

3. Tissue testing still provides a valid basis for assessing in-crop P status. The reliability decreases after peak flowering, as plants partition nutrient into maturing fruiting bodies, and seed.
4. The critical value for cotton for a likely response to soil P is likely to be much higher than the accepted 6 mg/kg using the Colwell method (0-10cm), and may be more likely to be around 25 mg/kg.

Extension Opportunities

Extension material has been developed and delivered during the 2016 cotton info nutrition tour. A powerpoint presentation of this material has been attached.

This material has also been delivered at the Monsanto/McGregor Gourlay ‘Wallangra’ dryland cotton field day at ‘Wallangra Station’ on Feb 22nd 2016.

UNE cotton production lecture material has also been updated to include this most recent information on P uptake.

Hardcopy material will also be modified from this report to be disseminated to the Cottoninfo team.

9. Publications

It is anticipated that two papers will be produced from this work, the first will include the direct findings of the experiment conducted in UNE 1501, the second will be a collaboration from work conducted in this project, and findings from UQ1302 Prof Mike Bell, and Dr David Lester, and lab experimentation conducted at UNE by Dr Richard Flavel, and Ass. Prof Chris Guppy.

Part 4 – Final Report Executive Summary

UNE 1501 – ‘ Phosphorus availability in raingrown cotton’, was conducted at ‘Colonsay’, via Brookstead, on the Darling Downs in Queensland, at a long term nutrition site, owned and maintained by Incitec Pivot for 30 years. The experiment was conducted in raingrown cotton *cv* SICOT 74 BRF. At this experimental site, phosphorus had been applied to the same plots at the rates of 0, 10, and 20kg/ha P each year since the commencement of the experiment. For the 2015 experiment, the existing 50m plots were then split into three treatments to include the addition of deep applied P, applied at 20kg/ha to 20cm depth on 50cm spacing, and a tillage treatment to disperse any bands of enriched nutrient.

Work by Bell et.al. 2015, and Dorahy 2004, has shown little response in cotton, in terms of yield or plant nutrient uptake, to the application of fertiliser P in the season that it is applied. This experiment provided the researchers with a unique set of circumstances where the soil had been

enriched with P such that a gradient of background soil test values was achieved. In this particular experiment very good results with respects to both plant phosphorus uptake, and yield were achieved. Colwell P values in the 20kg/ha P treatments had been enriched to 64 mg/kg in the surface, whilst the 0 kg/ha P treatments were at around 8.6 mg/kg (Colwell), and had remained relatively unmoved for the duration of the Incitec Pivot experiment (30 years). The 20 kg/ha P treatments showed maximum plant P uptake of approximately 32 kg/ha, the yield being 7.92 ba/ha. The uptake in the 0 kg/ha P treatments was around 18 kg/ha in the plant tissue, with a yield of 5.62 ba/ha. It is not perfectly clear as to the mechanism driving these responses although it is postulated that the favourable early season growing conditions resulted in excellent surface root activity, or that soil enriched with P behaves differently than that with fertiliser P applied for that growing season, or a combination of both.

When looking at the response curve comparing yield and soil test Colwell P values, it appears as if the critical level, for cotton, using Colwell P (0-10cm) may be around 25 mg/kg, significantly higher than the accepted 6 mg/kg.

Very little response was observed when both deep applied P was added or when tillage was included to disperse bands of enhanced P. This may concur with other work by Wang et.al. 2007, and McLaren et.al. 2013, inferring that deeper in the profile the plant is likely to be drawing on native, and other residual reserves of P held in a range of P pools, and again that applied fertiliser P (as the deep applied P) is unlikely to provide a short term response in terms of either plant P uptake, or yield. Because of the favourable early season root activity in this particular experiment, it was difficult to distinguish differences in nutrient taken up from soil containing dispersed P, or soil containing P held in a band.

Plant tissue testing using the youngest mature leaf, still provides a valid basis for assessing in-crop P status in cotton. The reliability decreases after peak flowering, as plants partition plant P in to maturing fruiting bodies, and seed.

.