# Relationship between Phosphorus uptake and cotton lint yield

Ian Rochester, Brian Duggan* and Greg Constable

CSIRO Plant Industry, Australian Cotton CRC, Locked Bag 59, Narrabri, NSW 2390

* Current address: Oregon State University, 850 NW Dogwood Lane, Madras, OR 97741, USA

Uptake of phosphorus (P) by cotton crops demonstrated an excellent correlation with lint yield. Despite high levels of P fertiliser being applied, crops in Kununurra took up less than 15 kg P/ha and failed to produce lint yields greater than 8 bales/ha. Lint yields and P uptake at Narrabri however were considerably greater, indicating that another factor was preventing P uptake at Kununurra and thus limiting yield potential. These results confirm the P fertiliser recommendations suggested in the NUTRIpak manual.

## Introduction

P nutrition is of increasing concern for cotton production in Australia and a relationship between P uptake and yield is required to understand fertilizer requirements as cotton lint yields continue to climb. P is essential for growth although much of it is exported in the seed (Halevy, 1976) and should therefore be replaced in a sustainable production system to avoid soil P concentrations falling to levels below those considered deficient.

## Materials and methods

*Kununurra*

Experiments were conducted at the Frank Wise Institute of Tropical Agriculture, Kununurra, WA, in the 2002 and 2003 dry seasons. The soil in Kununurra is predominantly a uniform dark brown medium to heavy clay with swelling and shrinking characteristics (Gunn, 1969). Prior to sowing in 2002 and 2003, various rates of phosphorus were applied as double superphosphate 20cm deep and 2cm outside the proposed plant line. Soil tests taken prior to sowing indicated that the soil contained 3mg $kg^{-1}$ of available P (Colwell bicarbonate extraction (Colwell, 1963)). This soil was depleted in available P and should be highly responsive to P fertiliser application (Dorahy et al 2004). Sulphur, zinc and nitrogen were balanced across the experiment using $ZnSO_4$ and urea. The crops were sown into dry soil on the 28$^{th}$ of April 2002 and on the 28$^{th}$ of March 2003. The cultivar chosen in 2002 was Sicot 289i while in 2003 the cultivar was Sicot 289B.

Crop nutrient uptake was assessed at cut-out (mid to late boll-fill). Above-ground crop was removed from 1m of crop row to determine crop dry matter (DM). A subsample (2-3 plants) was selected to determine nutrient concentration following drying at 70$^{o}$C for 72h in a forced-draught dehydrator. Subsamples were ground and P concentrations were determined by ICP-AES analysis after acid digestion. Nutrient uptake was determined as the product of nutrient concentration and the mass of crop DM. Lint yield was determined by mechanically picking one of the central rows of each six row plot. Samples were weighed and a subsample (~300 g) of seed cotton was ginned to determine % lint.

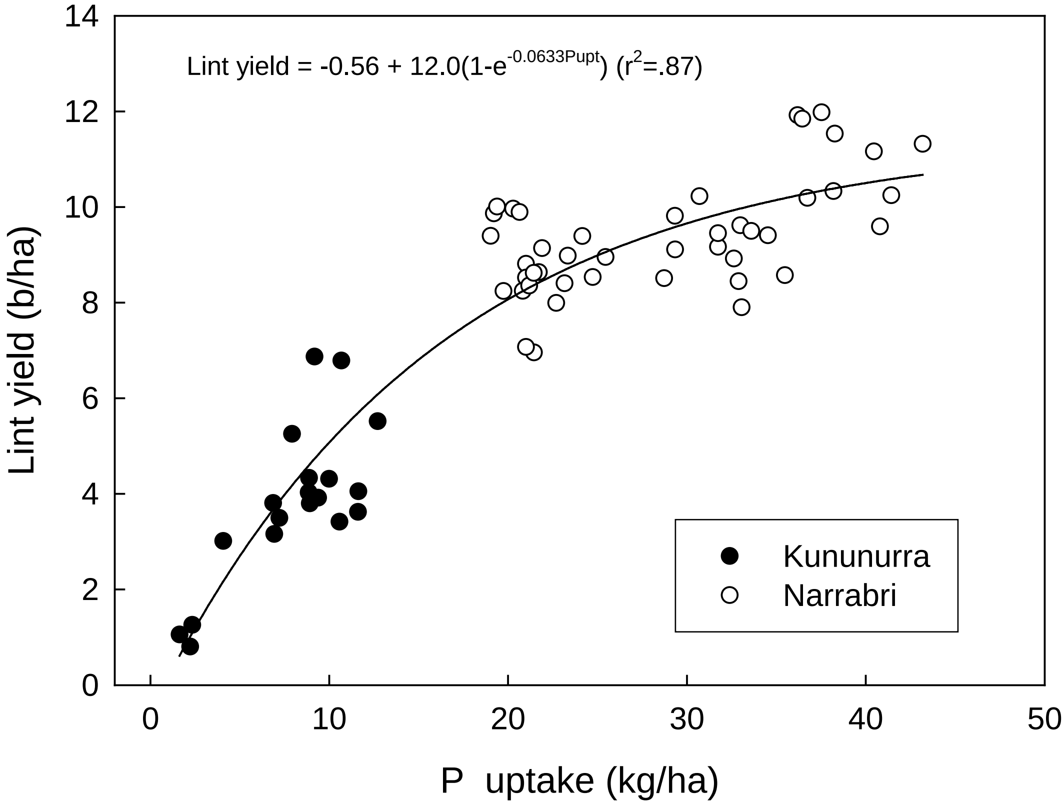
*Narrabri*

Experiments were conducted at the Australian Cotton Research Institute, Narrabri, New South Wales, Australia. Treatments differed in the management of legume and cereal rotation crops and assessed their effects upon the productivity of following cotton crops (for full experiment description, see Rochester and Peoples, 2005). Responses to fertilisers other than N and Zn had not been recorded previously at this site. The soil was a fertile alkaline dark greyish-brown cracking medium clay, classified as a fine, thermic, montmorillonitic Typic Haplustert (Soil Survey Staff, 1996). Soil samples taken prior to sowing indicated that the available P concentration (Colwell bicarbonate) was 61 mg/kg. Normally, the cultivar having highest yield potential was sown, although this differed from season to season. Cotton was sown in mid-October each year. Yield and nutrient uptake were determined as per the Kununurra site with the exception of two central rows of the eight row plots were harvested for yield determination.

## Results and Discussion

Lint yield displayed a strong relationship with the ability of the plant to take up P (Fig 1). Levels greater than 45 kg P/ha were not recorded and it appears that this is approaching the upper limits of P uptake by cotton plants, confirming the values reported in NUTRIpak. There was a distinct clustering in the data from Kununurra and Narrabri. Crops at Kununurra appeared to be limited in their ability to take up P, despite rates of up to 160 kg P/ha applied, and thus were unable to reach the yield levels attained at Narrabri. Crop yields in the order of 10 bales/ha have been recorded in Kununurra in fields with a long cropping (and P fertilisation) history (Yeates et al., 2002; Yeates et al., 2005). There was a yield response up to 60 kg P/ha in this experiment (Duggan et al, submitted), which is not unrealistic in a P deficient soil, despite the fact that no more than 15 kg P/ha was taken up by the crop. It would appear then that P uptake was limited by some unknown factor or factors at this site. Poor infection by mycorrhizal fungi can be responsible for poor uptake of nutrients that are immobile in the soil (eg P and Zn). At Narrabri there was still a distinct, positive relationship between P uptake and yield, demonstrating the importance of providing sufficient P nutrition for high yielding cotton crops in the traditional cotton growing areas of Australia.

**Figure 1.** Yield response to the uptake of P by cotton crops grown in Kununurra and Narrabri.




## Conclusion

A maximum uptake of approximately 45 kg P/ha was taken up by cotton crops. Uptake displayed a strong curvilinear relationship with yield. Lower levels of uptake were attained at Kununurra, despite high rates of P fertiliser being applied and an unknown factor prevented P uptake and thus limited yield potential. Crops at Narrabri still displayed a strong relationship between P uptake and lint yield, demonstrating the importance of P nutrition for high-yielding crops.

The NUTRIpak manual provide recommendations for P fertiliser applications based on available soil P using the Colwell bicarbonate extraction technique, as performed by most laboratories in Australia. Little response to P fertiliser is likely where Colwell-P exceeds 6 mg/kg. However, P fertiliser addition (~20 kg P/ha) will help to avoid the onset of P deficiency in soils of marginal P status (6-10 mg/kg). For soils with low available P (less than 6 mg/kg), application of ~40 kg P/ha is advised to increased soil P status. Remember, a cotton crop yielding 10 bales/ha (4 b/ac) removes 20-30 kg P/ha!

## Acknowledgments

This project was funded by both the Cotton Research and Development Corporation and the Australia Cotton Cooperative Research Centre. The authors wish to thank Stephen Yeates for his advice in conducting the experiments at Kununurra.

## References

Colwell, J.D. (1963) The estimation of the phosphorus requirements of wheat in southern New South Wales by soil analysis. *Australian Journal of Experimental Agriculture and Animal Husbandry* 3: 51-61.

Dorahy C, Rochester IJ and Blair GJ (2004). Response of field grown cotton (*Gossypium hirsutum* L.) to phosphorus fertilisation on alkaline soils in eastern Australia. *Aust. J. Soil Res.* **42:** 913-920.

Duggan, B.L., Yeates, S.J., Gaff, N. and Constable, G.A. Phosphorus fertilizer requirements and nutrient uptake of irrigated dry season cotton grown on virgin soil in tropical Australia. *Communications in Soil Science and Plant Analysis*. Submitted.

Gunn, R.H. (1969) Soils of the Kimberley Research Station, Kununurra, Western Australia. CSIRO Australia, Division of Land Research Technical Memos. 69: 28 pp.

Halevy, J. (1976) Growth rate and nutrient uptake of two cotton cultivars grown under irrigation. *Agronomy Journal*. 68: 701- 705.

NUTRIpak – A practical guide for cotton nutrition. Ed. Ian Rochester. Pub Australian Cotton Cooperative Research Centre.

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

Soil Survey Staff, 1996. Keys to Soil taxonomy, 7th edition. Natural Resources Conservation Service of USDA: Washington DC, 644 pp.

Yeates, S.J., Constable, G.A. and McCumstie, T. (2002) Developing management options for mepiquat chloride in tropical winter season cotton. *Field Crops Research*. 74: 217-230.

Yeates, S.J., Constable, G.A. and McCumstie, T. (2005) Cotton growth and yield after seed treatment with mepiquat chloride in the tropical winter season. *Field Crops Research* 93: 122-131.