Chickpea root proliferation resulting from deep banded phosphorus in a northern NSW Vertosol

Tim Weaver[1], David Lester[2], Michael Bell[3], Bruce Haigh[4], Stephen Harden[4] and Graeme Schwenke[4]

[1]CSIRO, Locked Bag 59, Narrabri, NSW 2390, tim.weaver@csiro.au
[2]Department of Agriculture and Fisheries, Queensland. PO Box 2282, Toowoomba, QLD 4350, david.lester@daf.qld.gov.au
[3]Queensland Alliance for Agriculture and Food Innovation, University of Queensland, Gatton Campus, Gatton, QLD 4343, m.bell4@uq.edu.au
[4]New South Wales Department of Primary Industries. 4 Marsden Park Rd, Calala, NSW 2340, bruce.haigh@dpi.nsw.gov.au

Abstract
The depletion of phosphorus (P) in northern NSW and Queensland dryland cropping regions has resulted in a number of projects investigating the deep placement of P fertiliser and quantifying crop response (GRDC projects: UQ00063, UQ00078). One of these sites was established in January 2016 at Terry Hie Hie (northern NSW) with the implementation of deep placement treatments of P (0, 10, 20, 40, 80 kg/ha) ripped to a depth of 200 mm. The deep bands of P were applied in January 2016 with the intention to also examine differing widths of bands (side band, 33 cm, 66 cm). The inclusion of three widths of deep banded P is to determine the minimum distance the ripped bands can be spaced before a drop in crop response is detected. To study the effect of deep P on chickpea (*Cicer arietinum)* root architecture, clear polycarbonate tubes were installed under the plant line and between rows (passing through the deep P band) in the 33 cm banded treatment. A BTC-2 minirhizotron camera captured root images in August and November in 2016. Root tracing software was used to quantify root number, length, diameter and volume. The deep P bands had a significant effect on the root numbers, length, volume and root diameter. The root count number was higher under the plant line in August when compared to the tubes installed in the deep P band. However, the readings taken in November showed a higher number of roots in the deep P band.

Keywords
Phosphorus, Deep Placement, Bands.

Introduction
Dryland farming systems of northern NSW and southern Queensland have been mined of phosphorus from long term cropping (Bell and Lester 2012). This has created a need to research nutrient replacement methodologies to improve fertility in the sub soil with the intention to increase yield (Dalal and Probert 1997; Bell et. al. 2010; Bell and Lester 2012). Starter fertilisers are normally applied at sowing in most farming systems, however secondary roots do not access the surface applied P and become nutrient limited. The aim of this research is to deep rip phosphorus to a depth of 200 mm, providing secondary roots a concentrated P source. The role of phosphorus and its effect on roots at depth in crops has been report previously in the literature (Li et.a l. 2014). The intention of this research is to study root development under a chickpea crop and quantify root proliferation due to the addition of phosphorus at a depth of 200 mm.

Methods
Site
Root growth of chickpea was measured during 2016 winter crop at Terry Hie Hie (150°05'37"E, 29°39'35"S), NSW. The soil is alkaline $pH_{(CaCl2)}$ 7.3 to 1.5 metres with an average CEC 33.2 meq/100g. It is sodic below 0.9 m with an ESP 7.8%. It is a self-mulching, grey Vertosol. The particle size distribution to depth of 1.5 m is shown in Figure 1a and the phosphorus status prior to treatments being applied is shown in Figure 1b. The plant available water content at sowing was 166 mm to a depth of 1.5 m and is shown in Figure 2a.

Treatments
Deep P bands at 33 cm spacing to a depth of 200 mm were applied on the 22-Jan-16 at rates 0, 10, 20, 40, 80 kg/ha. PBA HatTrick[A] chickpeas were sown on the 4-Jul-16 followed by Post Sow Pre-Emergent (PSPE) Balance® 750 WG @ 100 g/ha and Simazine 1 L/ha. The crop was sown between the deep P bands 33 cm apart using Trimble® EZ-Pilot® with TMX-2050™ display for accuracy of placement and sowing. The crop

received two applications of Verdict prior to flowering at 100 ml/ha to control grasses and 3 applications of fungicides (Mancozeb) at1kg/ha prior to rainfall events (July, August, Sept).

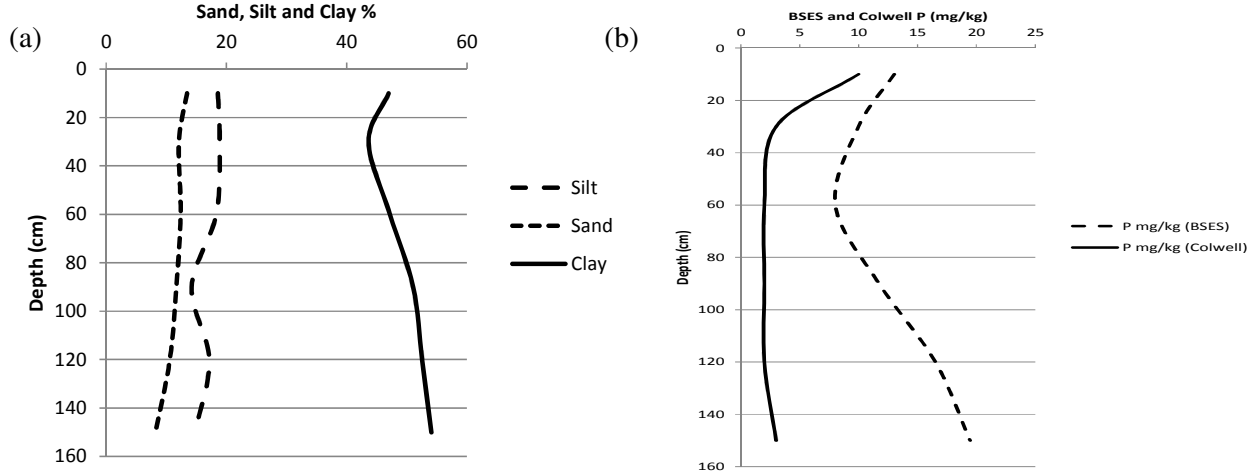

Figure 1. Sand, Silt and Clay content (%) (a) and Phosphorus (mg/kg) Colwell and BSES (b) status to depth of 150 cm at the Terry Hie Hie site where the deep bands were applied.

There was a total of 384 mm of rainfall (Figure 2b) received during the growing season and by November the crop had succumbed to a combination of waterlogging and disease and was not harvested. The maximum and minimum temperatures during the growing season were recorded (not shown). An NDVI reading (Trimble® Greenseeker®) was taken on the 16-Aug-16 with the sensor height at 75 cm and crop height at approximately 10-15 cm. A BTC-2 minirhizotron video camera and an I-CAP image capture system (Bartz Technology Corp., Carpentaria, CA, USA) was used to capture root growth during the season every 10 mm down the profile to a depth of 800 mm. Root tracing software RootFly was used to quantify images captured. Clear polycarbonate tubes were installed to a depth of 1 metre at 45^{o} in the first three reps under treatments: Farmer Reference (no ripping tyne), Control (ripping tyne no P), 10 kg Deep P/ha and 80 kg Deep P/ha. The treatments were applied at a depth of 200 mm.

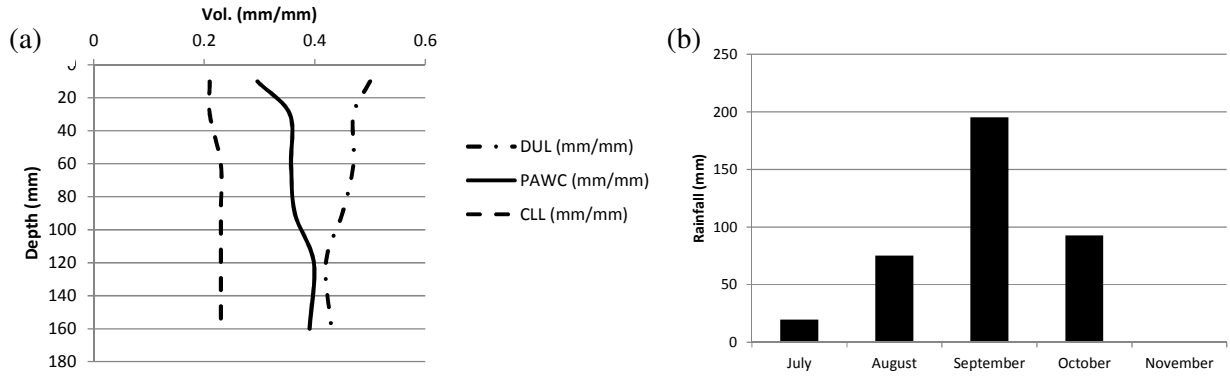

Figure 2. PAWC (mm) at sowing 4-Jul-16 (a) and Rainfall (b) during the 2016 chickpea crop at Terry Hie Hie northern NSW.

Results

Root Number

The root numbers from the August and November measurements show contrasting results (Figure 3 and Figure 5a). In August the 80 kg/ha deep banded P treatment shows high root numbers in the surface and at depth under the plant line (Figure 3a). However after several months the root numbers transfer to the band of P. There are fewer root numbers in the surface and more at depth (Figure 3d). The fossicking of roots from under the plant line to the concentrated P band also shows an increase in root numbers below 200 mm.

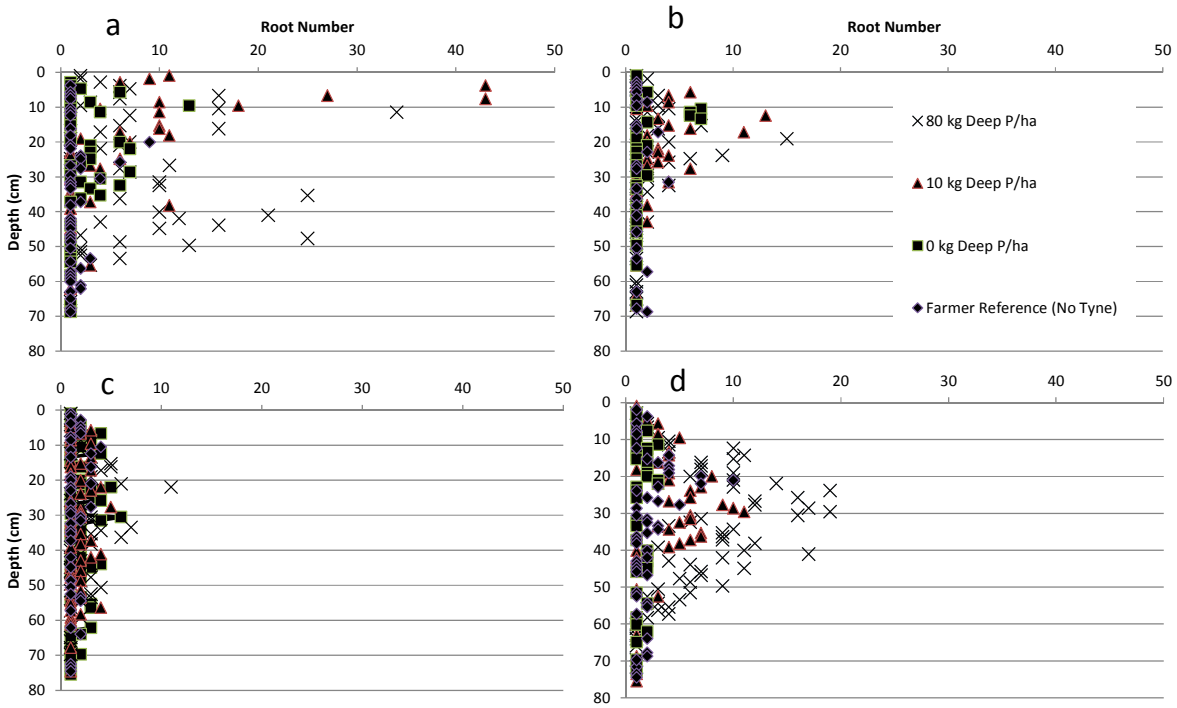

Figure 3. Root numbers to a depth of 800 mm below chickpea in the 33 cm spaced deep banded treatment (Farmer reference, 0, 10 and 80 kg P/ha). (a) under plant line (August) (b) between plant line (August) (c) under plant line (November) (d) between plant line (November).(Images were captured every 10 mm down the profile)

Crop Biomass

An NDVI reading was taken in August shortly after the first minirhizotron measurements. The biomass also supports the evidence of higher root number (Figure 3a). The NDVI index at this growth stage indicates that the 80 kg/ha of deep P in the 33 cm spaced bands was being accessed (Figure 4). The crop was sown in early July and the NDVI was measured mid-August. Under the 33 cm (between rows) spacing the chickpea roots are exploring at least 15 cm either side of the plant line at a depth of 200 mm after 6 weeks from sowing.

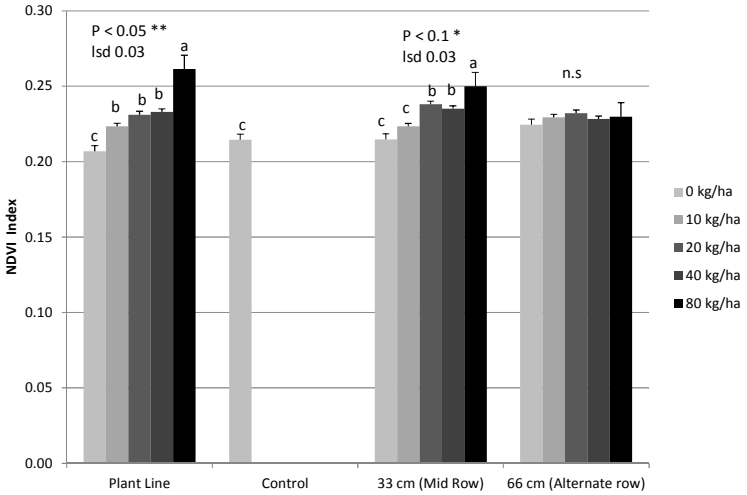

Figure 4. Normalised Difference Vegetative Index (NDVI) of Chickpea across the Deep P site at Terry Hie Hie August 2016. (Side Dress = Next to plant line, Units of P were 0, 10, 20, 40, 80 kg P/ha).

Root Length, Diameter and Volume

The root length, diameter and volume were higher under the 10 and 80 kg/ha of deep P in the 33 cm spaced bands when compared to the Farmer Reference and control treatments (Figures 5a, b, c and d). The August measurement of root volume (Figure 5c) shows that whilst root counts were higher at depth in the November (Figure 3d) the volume of the root also increased.

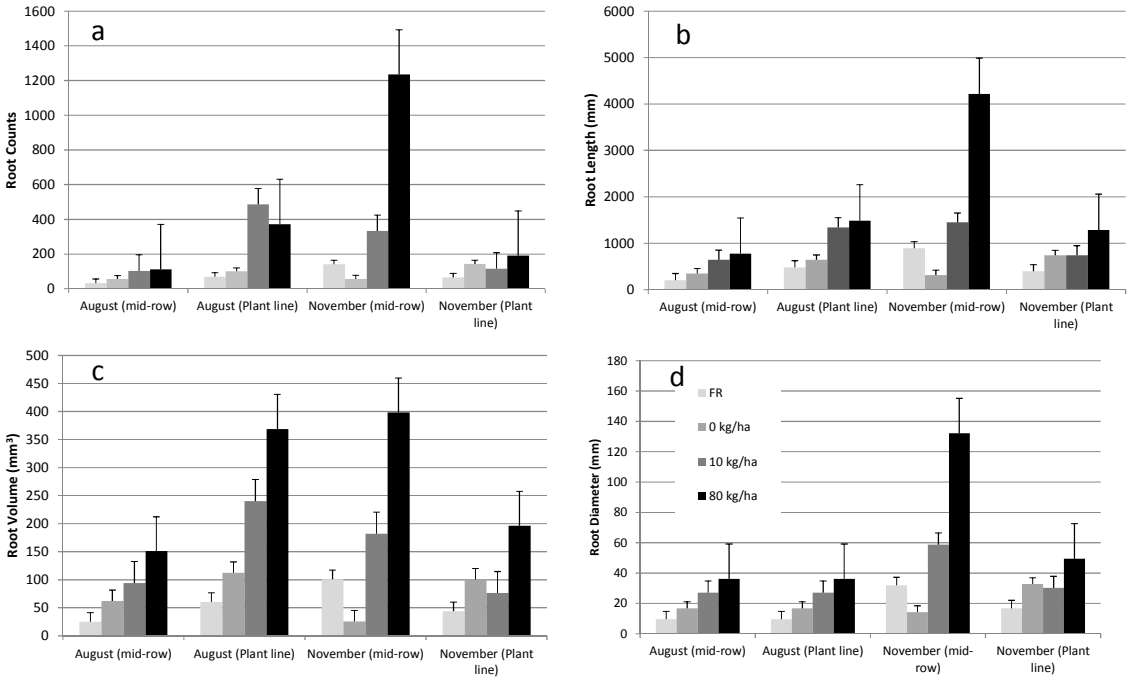

Figure 5. Sum of Root Counts to a depth of 800 mm (a), Root Length (b), Volume (c) and Root Diameter (d) measured in August and November 2016 during the chickpea crop. Treatments were Farmer Reference (FR), 0 kg Deep P, 10 kg Deep P/ha and 80 kg Deep P/ha. Tubes were installed under the plant line and between the plant line (through the deep band of P).

Conclusions

Deep banding (200 mm) of P stimulated root growth around the band. Initially root growth was stimulated in the surface from starter fertiliser P, however, after the waterlogging of the crop due to high rainfall in September and October the number of roots captured using the minirhizotron reduced (senesced) under the plant line and increased in and around the deep P band and below 200 mm. The root length and root volume also increased in the presence of deep P bands.

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