Shoot and root growth and potassium concentration of maize as affected by potassium fertiliser placement

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Abstract
Banding of fertilisers is becoming a necessary part of conservation tillage. Unfortunately, when nutrients are placed in a band there is the possibility of insufficient root contact for optimum uptake. For nitrogen (N) and phosphorus (P), this issue is addressed through the well understood plant response of root proliferation. In contrast, there has been little work done on fractional fertilising of potassium (K), and the existing work indicates that K does not promote root proliferation. A pot trial with treatments consisting of six different fractional soil volumes fertilised with K was set up to determine the effect of fractional fertilisation of K on the plant uptake of K, root morphology and shoot biomass. Root proliferation occurred in treatments with a band application of fertiliser and with 6.25 and 12.5% of soil volume fertilised. There was no effect from fractional fertilisation on plant uptake of K or shoot biomass production. Plants were able to adapt to the resource environment and achieve adequate uptake of K regardless of the soil volume fertilised.

Key Words
Potassium, root proliferation, potassium fertiliser, *Zea mays*

Introduction
Conservation tillage has been widely adopted in the South Burnett, (Queensland, Australia) for the agronomic benefits it confers. One adverse effect of this adoption is the stratification of K in the soil profile, which, combined with K depletion, is leading to the appearance of K deficiency in crops (Bell *et al.* 1995). Clearly a means of supplying K which overcomes stratification, whilst preserving the benefits of conservation tillage, is required. One option is to band K fertilisers, possibly at depth. However, banding K may not result in sufficient K uptake, as placing fertiliser in a small soil volume will supply few roots since the mobility of K in soil can be limited. White (2002) and Bell *et al.* (1995) showed that K in Ferrosols in the South Burnett region is immobile, resulting in banded K fertilisers remaining where they are placed, reducing the soil volume containing sufficient K for plant uptake.

Plants respond to enriched nutrient patches in two ways; a morphological response (root proliferation) or a physiological response (increased uptake rate). An increase in the uptake rate of P, N and K in enriched zones has been shown by a number of authors (Robinson 1994), but this may be insufficient to meet the plant nutrient requirements; up to 50% of maize roots required access to K in solution for sufficient K uptake (Claassen and Barber 1977). The effectiveness of banding N and P fertiliser is, in part, attributable to the root proliferation. There are numerous reports of root proliferation in response to N and P (Hodge *et al.* 1999), and indicating that proliferation is dependent on the strength of the enriched zone relative to background fertility (Hodge 2004). Little work has been done on the ability of K to promote root proliferation. Most published studies have been in solution culture, have used maize (*Zea mays*) as the test species, and have found that K does not promote root proliferation (Brouder and Cassman 1994; Claassen and Barber 1977).

Information on the effect of K placement on root growth and morphology is important for evaluating the smallest soil volume that can be fertilised with K, without decreasing K uptake to a level that will give less than maximum yield. The objective of this work is to determine optimum placement of K for greatest recovery of K by the crop.

Methods
A pot trial consisting of six treatments (four replicates), was set up as a completely randomised design. Treatment 1 (control), had no added K. The other five treatments had 1.36 g of K/pot as KCl, mixed with different volumes of soil; for Treatment 2 as a band placement, while the other treatments had K mixed with 6.25%, 12.5%, 25% and 50% of the total soil volume (Treatments 3, 4, 5 and 6 respectively). The pots (300 mm diam.) were filled with 15 kg of a low K, Brown Ferrosol soil from the South Burnett. The soil was

ground to less than 2mm to allow consistency of packing and ease of washing roots. Basal nutrients (N-140 mg/kg, P-470 mg/kg, Ca-28 mg/kg, Mg-28 mg/kg, Zn-5 mg/kg, Cu-5 mg/kg, B-1 mg/kg and Mo-0.189 mg/kg) were added before the appropriate soil volumes for each treatment were separated and mixed with KCl. The fertilised soil volumes were positioned in the middle of the pots and were the depth of the soil profile for the 25 and 50% of soil volume fertilised with the dimensions of the other volumes shown in Figure 5. The fertilised soil sections were separated from the rest of the soil in the pot with loose weave shade cloth. This allowed easy separation of the soil section for collection of roots. Four germinated *Zea mays* seeds were planted, two on each side of the fertilised soil sections, which once established were thinned down to two, one each side of the fertilised soil section.

At 40 days after planting the trial was harvested with measurements of fresh and dry weights of the whole plant top as well as roots of each soil section. The fresh weights of the roots were used to determine root length by using linear correlations developed from previous work using the same *Zea mays* seeds. Plant tissue K concentrations of the shoots were also determined. Differences between the treatments in plant tissue K concentrations, shoot dry weights, root length densities within fertilised zones and total root lengths were determined using one way ANOVAs calculated using Minitab (Anon 2004).

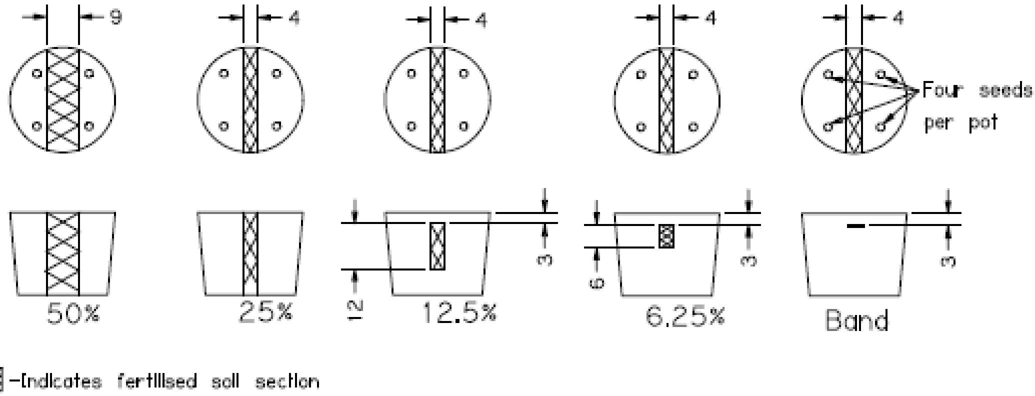

Figure 5: Arrangement of fertilised soil sections in the soil profile. Dimensions are shown in cm.

Results and discussion

Fractional fertilisation of the soil had no significant effect on the total root length ($p = 0.290$) (Table 11). However, fractional fertilisation had a significant effect on the root distribution ($p = 0.001$), with Treatment 3 (6.25%) producing the greatest root length density in the fertilised soil section (Table 11). Root proliferation was also apparent in Treatment 4 where 12.5% of soil volume was fertilised (Table 1 and Figure 2). Proliferation can not be attributed with certainty to K, but may have been a result of an indirect effect, for example as a result of preferential adsorption of K^+ over NH_4^+ increasing NH_4^+ in solution in the band and promoting root proliferation. No proliferation occurred with 25 or 50% of the soil fertilised.

The soil factors that dictate the promotion of root proliferation are the soil volume fertilised and the ratio of the nutrient concentration in the fertilised zone to the nutrient concentration in the unfertilised zone. In this pot trial the same quantity of K fertiliser was applied to different soil volumes, resulting in ratios of K concentrations in the fertilised zone to the K concentration in the unfertilised zone of 113, 18, 9, 4.5, and 2.26 for Treatments 2 to 6. Root proliferation was promoted when the ratio of the K concentrations in the fertilised zone to the K concentration in the unfertilised zone is greater than 9 (Treatments 2, 3 and 4). Root proliferation does not appear to be promoted when the ratio is equal to or less than 4.5 (Treatments 5 and 6).

Table 11. Total root length and root length density in fertilised and unfertilised soil.

Treatment (% soil volume fertilised)	Mean root length density (mm/g of soil)		Mean root length (cm)	
	Fertilised soil section#	Unfertilised zone	Fertilised soil section*	Total
1	N/A	3.2	N/A	4867
2 (band)	5.88[ab]	4.24	88[a]	6379
3 (6.25)	7.95[a]	3.87	745[b]	6193
4 (12.5)	5.10[bc]	3.56	957[b]	5634
5 (25)	2.80[cd]	3.83	1050[b]	5663
6 (50)	2.22[d]	4.20	1706[c]	4853

#*Numbers in the columns with the same letter are not significantly different at 95% confidence intervals.

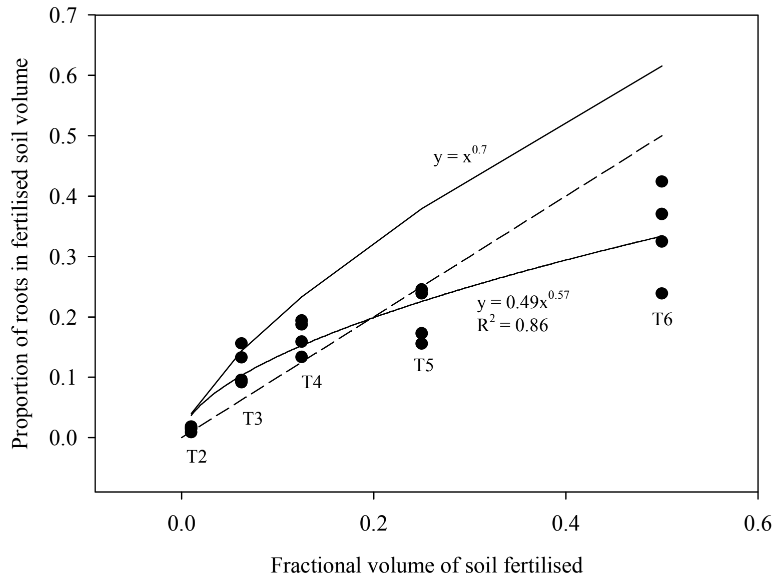

Figure 2. Effect of fraction of soil treated with K on the fraction of the roots in K-treated soil with the line of best fit for treatments 2 to 6. The other line shown, $y = x^{0.7}$, is the relationship for maize in N fertilised soil (Anghinoni and Barber 1988). The dashed line is a 1:1 line and is what would be expected if there was no response to K.

There were no foliar symptoms of K deficiency, and only a small visual difference in growth (Treatment 1 was shorter). The shoot dry weights showed no significant difference between the treatments ($p = 0.776$). However, there was a significant treatment effect ($p < 0.0009$) for tissue K concentration; Treatment 1 having a significantly lower value than other treatments. The Treatment 1 tissue K concentration of 1.05% is below the critical value for whole shoot at 42 days after sowing of 1.75 to 2.08%, (Reuter and Robinson 1997). With Treatments 2 to 6, where K was applied, there was no significant difference in the plant uptake of K. In all of these treatments adequate K was absorbed with plant tissue K concentrations ranging from 1.97% to 2.4%.

The band applied treatment had a lower root length density and a smaller root length in the concentrated soil section than the other treatments (Table 1). As this treatment also had the same plant uptake of K, there would have been physiological plasticity (increased uptake rate) to make up for the lower root length in and around the fertiliser band. The soil solution K concentration must have been sufficiently high to increase uptake rate to a point that replaced the smaller root volume in and around the fertiliser band.

Root proliferation in the treatments with 6.25 and 12.5% of the soil volume fertilised resulted in a root length in the fertilised soil that was less than but not significantly different to the root length in the fertilised soil volume of the treatment with 25% soil volume fertilised. The treatment with 25% of the soil volume fertilised also showed no root proliferation in the fertilised section (Table 1 and Figure 2). This indicates that the root volume in the fertilised section provided sufficient contact with the applied fertiliser for adequate K uptake.

The objectives of this pot trial were to determine the effect of fractional fertilisation of K on the plant K uptake and the root morphology. From this data, the soil volume to fertilise with K for optimum plant uptake of K and maximum shoot biomass could be determined. The effect of fractional fertilisation of K was to increase the plant uptake of K. If the soil solution K concentration and surrounding exchangeable K were insufficient for the soil to buffer the increased uptake rate to allow adequate plant uptake, then root proliferation was promoted until a root length was achieved to allow adequate uptake with both increased plant uptake rate and root proliferation. In essence, the *Zea mays* plants were able to adapt to the resource environment and achieve adequate uptake of K. Thus, there was no effect of fractional fertilisation on plant uptake of K or shoot biomass production.

It then follows that there is no optimum soil volume to fertilise for optimum K uptake and shoot biomass growth. However, if consideration is given to the energy expenditure required with physiological and morphological plasticity, then the optimum soil volume to fertilise would be 25%, the lowest soil volume treatment with no root proliferation. Although it should be noted that in this trial there was no adverse effect on shoot biomass up to the 40 days after sowing growth stage from the energy expended, with plasticity responses (increased uptake rate) to fractional fertilisation. This optimum soil volume to fertilise can be compared with 12.5% for the uptake of P by soybean (Borkert and Barber 1985) and 50% for the uptake of P by maize (Anghinoni and Barber 1980). This shows the variability that is involved with fractional fertilisation.

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