

Why fluid fertilisers are highly effective in calcareous soils

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Introduction

Alkaline and alkaline-calcareous soils represent a significant proportion of the World's arable landmass and are commonly utilised for cereal production in Australia. In South Australia 16600 km² of cereal cropping land on the Eyre Peninsula is calcareous, with some topsoils having CaCO₃ contents as high as 90% (Coventry et al. 1998; McKenzie et al. 1999). Vast areas of alkaline soils also exist in the South Australian and Victorian Mallee (Coventry et al. 1998) and in cropping districts in New South Wales (Milthorpe 1991; Walker 1991), Western Australia (Brennan 1991) and Queensland (Duncan 1967). Phosphorus fertilisers have been applied to alkaline and calcareous soils for many years. However, P deficiencies remain an important limitation to crop productivity in many of these regions (Holloway et al. 2001).

Initial trials on the Eyre Peninsula showed that fluid P fertilisers outperformed granular P fertilisers on Grey and Red Calcarosols (Holloway et al. 2001). Subsequently, more than 100 field comparisons, in South Australia and Victoria, have shown that fluid P fertilisers can be substantially more effective than granular P fertilisers on calcareous and alkaline soils. Laboratory studies were undertaken to determine whether yield responses were due to fertiliser placement effects,

differences in soil moisture, fertiliser pH or diffusion and fixation processes in the soil (Lombi et al. in press).

This paper summarises the results of the field and laboratory studies and outlines the main factors responsible for the high efficacy of fluid P fertilisers on alkaline and calcareous soils.

Field Trials

Early field trials in South Australia showed that fluid P fertilisers could stimulate yield increases in wheat (*Triticum aestivum* L.) above those achievable using granular fertilisers. Trials at Yandra 1999, compared the Relative Agronomic Effectiveness (RAE) of fluid TGMAP and granular MAP, on dry matter production and grain yield of Frame wheat (Holloway et al. 2001). The RAE of two fertilisers can be compared by determining the amounts required to produce the same yield (Bolland and Barrow 1988; Palmer et al. 1979). Therefore, the RAE of fluid P for any given yield (t/ha) can be expressed as:

$$\text{RAE}_{\text{yield}} = \frac{\text{Rate of granular P (kg P/ha)}}{\text{Rate of fluid P (kg P/ha)}} \quad [1]$$

For example, at a commercial rate of 8 kg P/ha, fluid fertiliser produced 23% more grain than the granular product (Holloway et al., 2001). To produce equivalent yields, more than 60kg of granular P would have been required (Figure 1), which equates to a RAE of more than 7.5 for the fluid product. That is, 7.5 times more granular P fertiliser was required to produce grain yields of 0.68 t/ha. These results confirmed that the fluid MAP was considerably more effective than the granular MAP at the Yandra site.

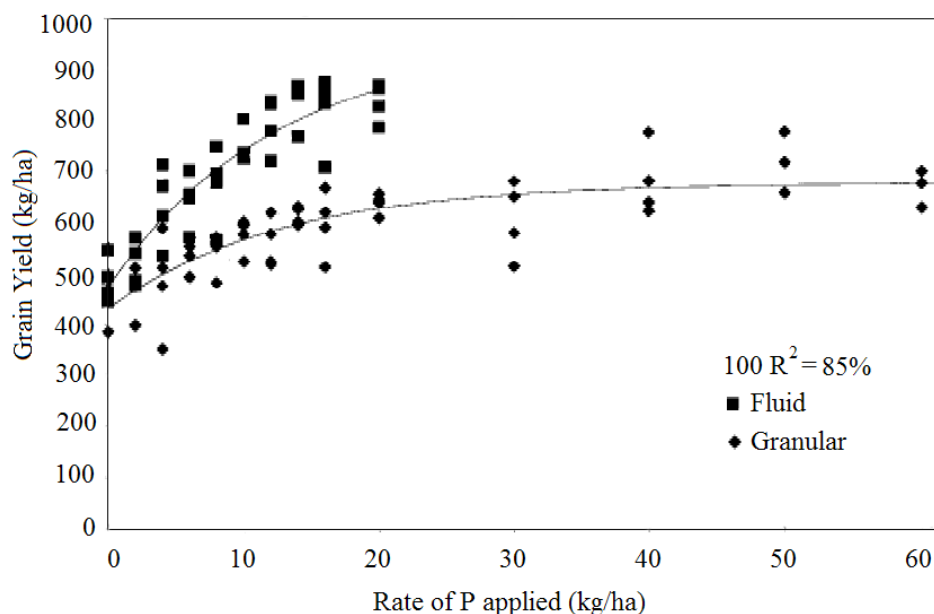


Figure 1. Relationship between grain yield of Frame wheat, rate and form of P fertiliser applied at Yandra, 1999. Redrawn from Holloway et al., 2001.

Since 1999, more than 100 comparisons between fluid and granular P fertilisers have been undertaken across 3 major soil types on the Eyre Peninsula. More than 75% of comparisons on calcareous soils demonstrated significant ($P < 0.05$) yield increases with fluid P fertilisers (Table 1). No significant yield increases have been measured on Red Loam soils, though 4 out of 11 comparisons showed a yield decrease with fluid P fertilisers (Table 1).

Table 1. Numbers of field comparisons on Eyre Peninsula that showed significant ($P < 0.05$) yield increases or decreases with fluid, compared to granular, P fertilisers.

	Number of Comparisons	Yield +	Yield -	No difference
Grey Calcareous	50	45	-	5
Red Calcareous	40	23	-	17
Red Loam	11	-	4	7

In 2003, field trials were established in Victoria's Mallee and Wimmera districts to assess crop response to fluid P. The two Mallee trials were undertaken on a Calcarosol and a Sodosol. The site in the Wimmera district was on an alkaline Vertosol. Fluid P fertilisers (APP and phosphoric acid) produced significantly ($P < 0.05$) more dry matter at mid-tillering than the granular fertilisers at all three sites. However, the superior dry matter production only translated into increased grain yield on the Mallee Sodosol, where phosphoric acid increased grain yield by 45% over DAP and by 67% over TSP, at equivalent rates of P. Yield may have been depressed at the other two sites because of the dry seasonal conditions post-anthesis.

Laboratory Studies

Laboratory studies were undertaken to determine whether the yield responses to fluid P fertilisers were due to placement effects during application, the additional water applied with fluid fertilisers, differences in fertiliser pH or fixation and diffusion processes in the soil.

Holloway et al. (2001) showed that crop response to fluid P was not caused by fertiliser placement effects. After mixing granular (TSP, MAP and DAP) and fluid fertilisers (Phosphoric Acid, TG-MAP, and APP) homogeneously with the soil, Holloway (2001) found that dry matter production of wheat was significantly increased with the fluid P treatments. In addition, each treatment was irrigated to 90% water-holding-capacity. Therefore, the response to fluid P was due to neither 'placement' nor 'water' effects. Fluid fertilisers are applied to fields at rates approximating 120L/ha, which is equivalent to only 1.2×10^{-5} mm of additional soil moisture; not enough to stimulate crop growth. These results suggested that chemical and/or physical factors may be responsible for the high efficacy of fluid P fertilisers on alkaline and calcareous soils.

Lombi et al (in press) investigated the mobility and solubility of fluid and granular P fertilisers in alkaline and calcareous soils. The procedures used to measure P mobility have been fully described elsewhere (Lombi et al. in press). A brief description of the method follows. Plastic petri-dishes were filled with 3 different soil types (Grey Calcarosol, Red Calcarosol and Vertosol) to a common bulk density. The soils were moistened to field capacity and 3 granular fertilisers (MAP, DAP and TSP) and 3 fluid fertilisers (TGMAP, APP and phosphoric acid) were applied to the centers of the petri-dishes. Soils were incubated for 5 weeks, following which, concentric rings of soil were removed around the point of fertiliser application. In addition, the dissolution of MAP granules in the Grey and Red calcarosols was monitored in a parallel experiment, run over 12 weeks.

Major findings from this work were that:

- Over 60 % of P remained within 7.5 mm of the fertiliser granules after 5 weeks in each soil (Figure 2);
- Fluid P diffused further than granular P in the Calcarosols. The largest amount of fluid fertiliser P was recovered from the 7.5-13.5 mm sections (Figure 2);
- The distribution of P in the alkaline non-calcareous Vertosol did not differ significantly between granular and fluid forms (Lombi et al., in press; data not shown).
- The amount of P remaining in the MAP, DAP and TSP granules after 5 weeks corresponded to 13, 9.5 and 18 % of the total P initially present in the granules, respectively (Lombi et al. in press).

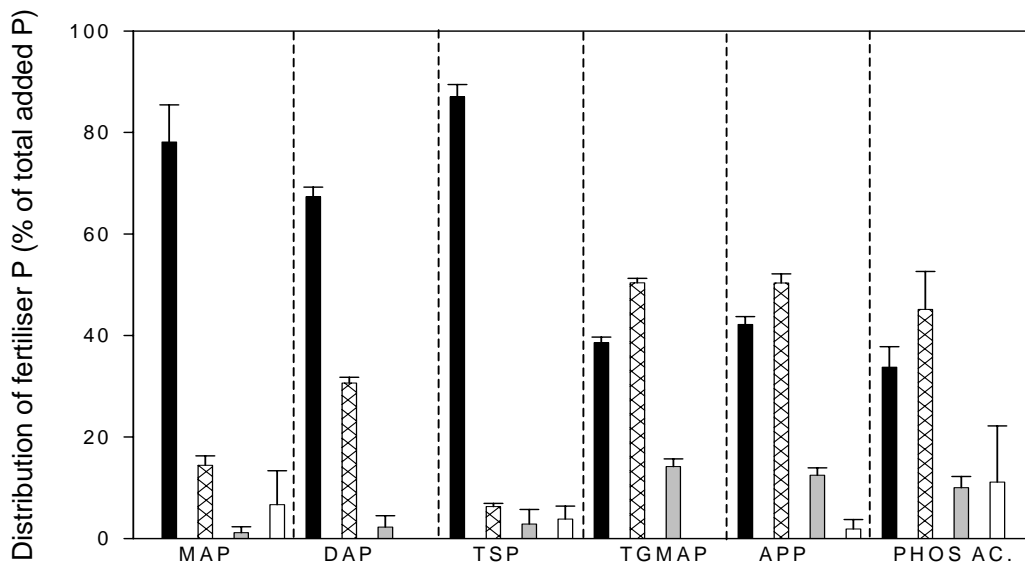
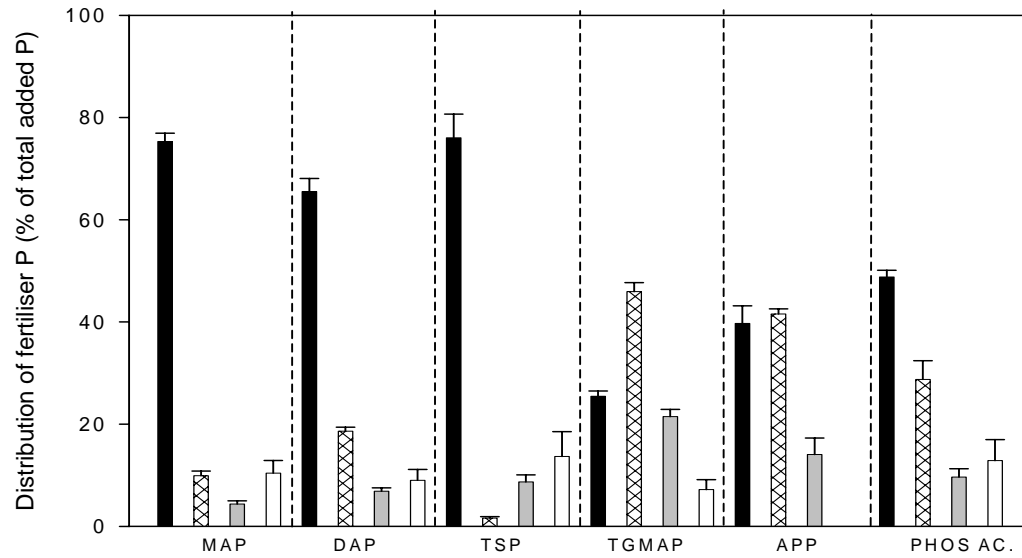


Figure 2. Diffusion of fertilizer P in (a) Grey Calcarosol (b) Red Calcarosol Adapted from Lombi et al., (in press). ■ 0-7.5mm, ▨ 7.5-13.5mm, ▩ 13.5-25.5mm, □ 25.5-43mm.

In the parallel experiment, most of the P release from MAP granules occurred on the day that the fertiliser was applied to soil (Figure 3). Up to 12% of P remained within the MAP granules after the 12-week diffusion period (Lombi et al. 2004). In addition, the concentration of calcium ions in the MAP granules increased rapidly following their addition to the calcareous soils (Figure 4). These results suggest that P release

might have been precluded by the rapid diffusion of calcium ions into the MAP granules. These conclusions were supported by Lombi et al. (2004) who showed that sparingly-soluble crandallite minerals $[\text{CaAl}_3(\text{PO}_4)_2(\text{OH})_5 \cdot (\text{H}_2\text{O})]$ were the dominant residual P phase in the MAP granules. Alternatively, the high soil alkalinity may have prevented dissolution of the citrate-soluble P fraction contained within the granules (Lombi et al. 2004). These effects probably account for the relatively poor efficacy of granular P fertilisers in calcareous and alkaline soils.

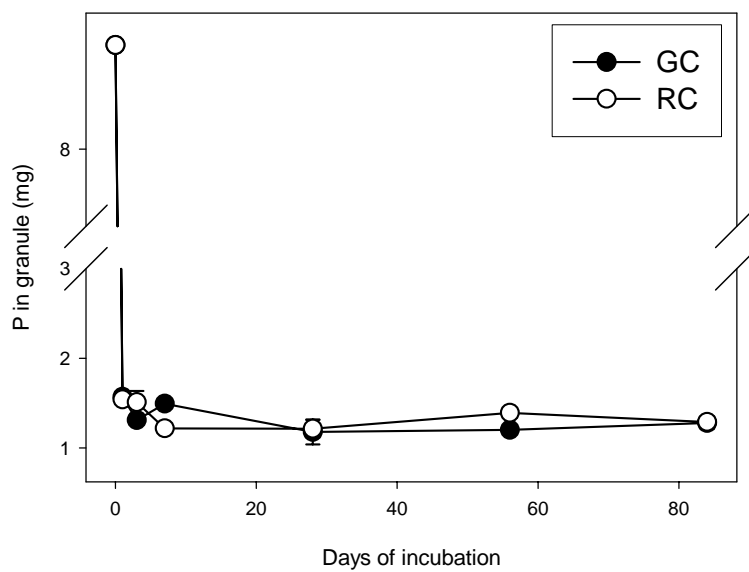


Figure 3. Release of P from MAP granules on Grey (GC) and Red (RC) Calcareous soils.

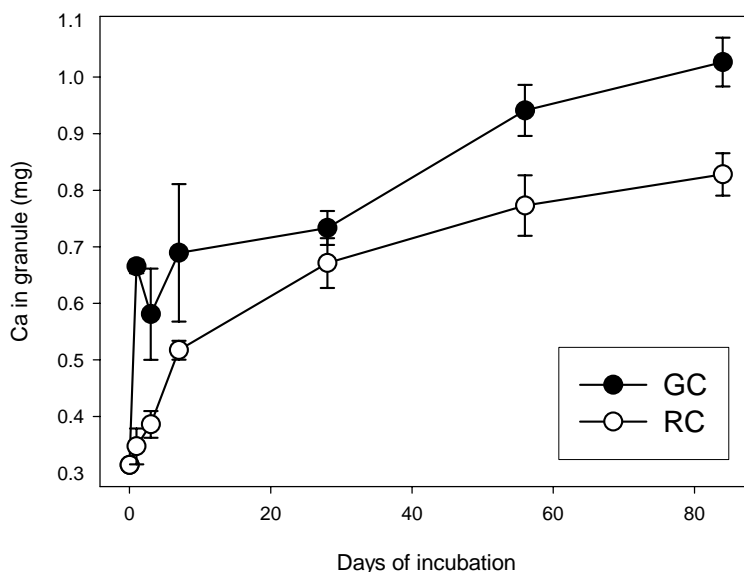


Figure 4. Ca diffusion into MAP fertiliser granules on Grey (GC) and Red (RC) Calcareous soils.

Conclusions

On alkaline and calcareous soils, fluid P fertilisers increased grain yield and dry matter production of wheat (*Triticum aestivum* L.) above those achievable using granular MAP, DAP or TSP fertilisers. On the Eyre Peninsula, fluid TGMAP was at least 7.5 times more effective than granular MAP (Holloway et al. 2001). Laboratory investigations explained some of the disparity between the two products by showing that at least 12% of P remained within MAP granules 12-weeks after they were applied to calcareous soils. In addition, P from fluid sources diffused further through calcareous soils than P from granular products. Fertiliser placement or soil moisture effects could not explain the high efficacy of fluid P fertilisers. These results have shown that fluid P fertilisers could provide a valuable alternative to granular products on the alkaline and alkaline-calcareous soils of Southern Australia.

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