How effective are fluid phosphorus fertilisers in the Wimmera and Mallee region of Victoria?

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Abstract

The use of fluid forms of phosphorus (P) fertiliser has received widespread interest in the grains industry in recent years. To assess the relative efficacy of fluid versus granular forms of P on wheat production in Victoria, field trials were conducted in 2003 and 2005 on the major alkaline soil groups used for grain production in the Wimmera and Mallee regions. The trial period was characterised by below-average growing season rainfall (maximum of 283 mm), with little stored water present at sowing. There were large dry matter responses during early seedling growth to P application (range 45 to 334%) in all trials. Fluid forms of P fertiliser generally produced greater growth responses than granular forms at mid tillering (range 9 to 96%) but this dry matter response was not always related to increases in tissue P concentration. Fluid P forms produced significantly ($P < 0.05$) greater maturity biomass in 4 of the 6 trials, averaging 10% more biomass than granular forms (range 0 to 35%). Five of the 6 sites produced a significant ($P < 0.05$) grain yield response to P application, but fluid fertilisers produced greater grain yield than granular forms in only 3 of these trials (range 6 to 45%). Although fluid fertilisers offer some agronomic advantages, their relative price compared to granular forms will be the chief determinant of their adoption by grain growers.

Key Words

Alkaline soils, soil water, wheat, granular forms

Introduction

Phosphorus deficiency is a key limiting factor to agricultural production in Australia (Donald 1964), especially on the alkaline soils that dominate dryland grain production regions of Victoria. Previous studies on other alkaline (but more calcareous) soils on the Eyre Peninsula of South Australia have demonstrated that fluid forms of P fertiliser often produced significantly greater yield responses than the granular forms traditionally preferred by farmers (Holloway et al 2001). The superior performance of the fluid fertiliser forms on calcareous soils has been attributed to greater solubility, lability and diffusion of P compared to granular forms under laboratory conditions, but the advantage was much less pronounced on alkaline non-calcareous soils (Lombi et al. 2004), such as those that dominate cropping in Wimmera and Mallee regions of Victoria. Glasshouse trials involving a large range of neutral-alkaline soils, including both calcareous and non-calcareous soils from South Australia and Victoria (McBeath et al. 2005) indicated that fluid P forms produced greater dry matter responses in wheat compared to granular forms on the majority of soils that were P responsive. Glasshouse environments however provide only a preliminary indicator of plant responses to particular factors, especially nutrients (Passioura 2006) and hence there is a need to assess responses under field conditions. We therefore undertook a study to examine whether fluid fertiliser forms of P could provide yield benefits to wheat compared to granular P forms under field conditions in Victoria.

Methods

Field trials were established in 2003 at Walpeup (Calcarosol; 325 mm annual rainfall) and Birchip (Sodosol; 375 mm) in the Mallee and at Kalkee (Vertosol; 420 mm) in the Wimmera. Following very dry seasonal conditions in 2004 (data not presented), trials were established at three sites in 2005: Birchip (same paddock but different part to that used in 2003); Kalkee (in an adjacent paddock to that used in 2003 but on the same soil type) and BCG-Birchip (Calcarosol, similar to that used at Walpeup in 2003). Key soil variables and growing season rainfall are listed in Table 1. The trial was designed as a randomised complete block at each site with 4 replicates comprising 6 rates of P (0, 4, 8, 12, 16 and 24 kg P/ha) and 2 forms of fertiliser (fluid or granular). For each form of fertiliser, 2 types were tested: Fluid P as either ammonium polyphosphate (APP) or phosphoric acid (PA) and Granular P: as either di-ammonium phosphate (DAP) or triple superphosphate (TSP). Granular P forms were banded with the seed whereas fluid P was applied in a total volume of 200 L/ha in a continuous stream at approximately 0.5 cm below the seed. The wheat cultivar Yipti was sown at all sites in 2003 and *cv*. Chara at Birchip and *cv*. Yanac at Kalkee sown in 2005. Plots were 14 m long and comprised 8 rows at 19.2 cm row spacing. Due to differences in nitrogen content of the different fertiliser products, varying rates of granular urea was applied at sowing to ensure that all plots received the equivalent of 50 kg N/ha at all sites. A basal application of Zinc (applied as Supra-Zinc) was also applied to the soil immediately prior to sowing and appropriate weed and disease control applied as needed. Dry matter (2 quadrats each comprising 4 x 1 m rows) was determined at mid tillering and again at maturity along with grain yield following drying at 70^{o}C for 48 hours prior to weighing. Tissue P concentration of the grain and straw at maturity was assessed on ground (< 0.5 mm sieve) tissue following oven drying by digesting in acid and analysed for P using Inductively Coupled Plasma Atomic Emission Spectrometry (ICP).

Results

Growing season rainfall in 2003 was below average at all three sites, with a particularly dry finish (Table 1). There were significant dry matter (at mid tillering) and grain yield responses to P at all three sites, ranging from 68% at Kalkee to 334% at Walpeup, reflecting the low plant available-P status (Colwell-P range 7 to 17 mg/kg soil) of the field sites. Generally the two fluid fertiliser forms of P (APP and PA) produced significantly ($P < 0.05$) more dry matter at mid tillering than the 2 granular forms (DAP and TSP), especially at Birchip (96%) and Kalkee (23%) (data not presented). Phosphoric acid produced greater dry matter response than APP and DAP more dry matter than TSP at all sites, especially at the lower rates of applied P. Shoot tissue P concentration at mid tillering increased when P was applied but P form (fluid versus granular) generally had no significant effect ($P > 0.05$) (data not presented). However, the greater dry matter production from the fluid treatments translated into higher grain yield at only one site, Birchip, where PA produced up to 1.0 t/ha (45%) more grain than DAP and 1.3 t/ha (67%) more grain than TSP at an equivalent rate of P (Figure 1). However at higher P rates (≥ 16 Kg P/ha), DAP performed similarly to the fluid forms.

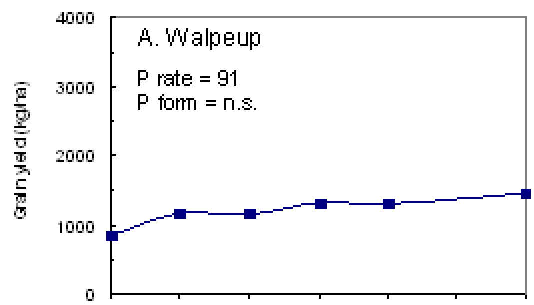
In 2005, rainfall at all three trial sites was characterised by extremely dry autumnal conditions (Decile 1) and a late break (mid June for Mallee sites; late June for Wimmera site) with good rainfall in early June. July to September rainfall was below average (Decile 3) but rainfall following anthesis was above average (Table 1). Similar to 2003, there were significant dry matter responses at mid tillering to increasing rates of P fertiliser application at all three sites, with the greatest response (P_0/P_{24}: 145%) recorded at Kalkee (data not presented). Fluid forms of P fertiliser (APP and PA) produced greater dry matter responses at mid tillering than two granular forms tested (DAP and TSP) by up to 58% at low to moderate rates of applied P (4 to 16 kg P/ha) at two of these sites (BCG-Birchip and Kalkee). Shoot P concentrations at mid tillering were low (0.26 to 0.32%) but were significantly increased ($P < 0.05$) by the application of fluid P compared to granular P at all 3 sites (data not presented). Phosphorus application (regardless of type) produced a significant grain yield response at the BCG-Birchip site but had no major effect at Birchip. Fertiliser form had no consistent effect at either of the two Mallee sites. At the Kalkee site, both fluid P forms out yielded the granular forms by an average of 0.24 t/ha (or nearly 10%) at low rates (4 to 12 kg P/ha) of applied P (Figure 2).

Table 1: Plant available P status (Colwell P) and growing season rainfall (mm) for trials conducted at

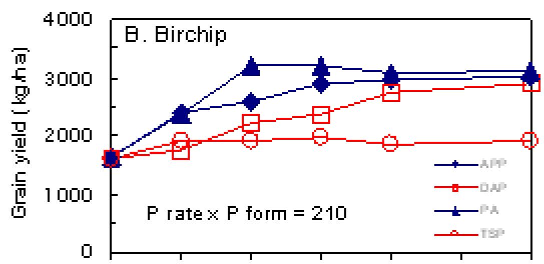
Walpeup, Birchip and Kalkee (2003) and Birchip, BCG-Birchip and Kalkee (2005).

Site	Soil P (mg/kg)	PBI (MIR)	$CaCO_3$ (% MIR)	Growing season rainfall (mm)	September-October rainfall (mm)	Mean grain yield (t/ha)[1]
			2003			
Walpeup	7	n.d.[2]	1.1	160	55	1.21
Birchip	12	224	1.6	181	51	2.06
Kalkee	17	0.0	1.3	283	75	2.74
			2005			
Birchip	21	46.5	2.4	245	88	1.83
BCG-Birchip	39	124	4.6	225	77	1.78
Kalkee	20	37	1.1	244	93	2.63

[1] At highest rate of applied P ; [2] n.d. (outside detection range of MIR)



A.



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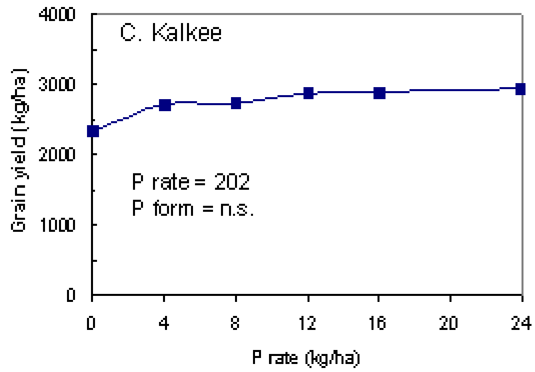

C.

Figure 1: Grain yield of wheat in response to application of fluid (APP, PA) and granular (DAP and TSP) fertilisers at (A) Walpeup, (B) Birchip and (C) Kalkee in 2003. Numbers represent l.s.d.(5%).

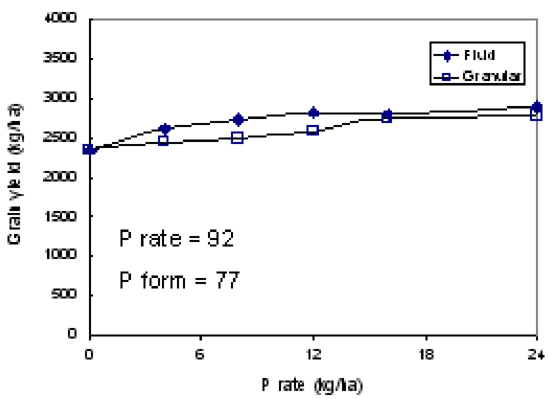

Figure 2: Grain yield of wheat in response to application of either fluid (APP and PA pooled) or granular (DAP and TSP pooled) fertilisers at Kalkee in 2005. Numbers represent l.s.d. (5%) for P rate and P form (fluid versus granular).

Discussion

Field trials conducted in this study suggest that fluid fertiliser forms of P offer the potential to improve the growth and grain yields of grain crops on the alkaline soils of Victoria but the extent of this improvement can vary significantly. One challenge to the broader adoption of fluid fertilisers is our current inability to identify under what circumstances fluid fertilisers produce superior grain yield compared to granular forms. A previous study (McBeath et al 2005), conducted in a controlled environment and where soil water remained non-limiting, found that fluid fertiliser forms of P generally produced greater dry matter responses by wheat at the seedling growth stage compared to current granular forms on 30 soil types collected from the major grain growing regions of Victoria and South Australia. In the current study fluid P forms also generally produced greater dry matter responses (but not necessarily tissue P concentration) than granular forms. However these dry matter responses, even when present at maturity, often did not translate to greater grain yield. This type of growth response to P (as opposed to N) is unusual, as generally early dry matter responses of this magnitude will be maintained throughout the season. This suggests that some other factor may be influencing fertiliser responsiveness.

The greater ability of fluid forms of P to improve the growth of wheat is believed to result from both decreased rates of chemical ‘fixation’ of P in the soil and a greater diffusion rate of P away from the point of application compared to granular forms (Lombi et al 2004). This result suggest that either certain soil chemistry (which affect P ‘fixation’) or moisture (which strongly influences diffusion rates) may have controlled the relative efficacy of fluid P fertilisers in this study. Previous experimentation indicated a strong trend for fluid forms to perform best at low (< 5.5), and high (> 8.5) soil pH and where levels of calcium carbonate are high (McBeath et al 2005). However this trend was not repeated in our field trials as the soil pH were greater (although Colwell P was lowest) at the Walpeup site, where the comparative yield response to fluid P was lower than at Birchip and Kalkee. Furthermore, although 1 trial (Birchip in 2003) recorded large grain yield responses to fluid P, the average response across all 6 trials was less than those found on the Eyre Peninsula (Holloway et al 2001) where carbonate levels are generally much greater than Victorian soils. Soil chemical properties can vary significantly over relatively small distances in the Mallee. Although the relative response to P application varied spatially, there was no evidence that responsiveness to P fertiliser form varied spatially across soil zones identified with EM38 mapping (Nuttall et al. pers comm).

Trials at Birchip and Kalkee in 2003 and 2005 were located on the same general soil type (eg. alternative sides of the fence or different parts of the paddock) to permit an assessment of seasonal (rainfall) effects on response to fertiliser form. The relative efficacy of P fertiliser form did vary markedly with year (e.g. 45% grain yield advantage of fluids at Birchip in 2003 vs. no or little response in subsequent years), but there was no conclusive evidence that differences in the amount of soil water in the profile at sowing or the amount falling as rain (regardless of its timing) during the growing season was responsible for this differential response. Although wheat in the two trials at Kalkee yielded on average more compared to the other sites (Walpeup, Birchip, BCG-Birchip), the Kalkee trial in 2003 experienced severe water stress during grain fill (post-anthesis rainfall of 6 mm). The trial at Birchip also experienced a dry finish, but not to the same extent. Recent experimentation by Lombi et al. (pers comm) suggest that the relative efficacy of fluid versus granular forms of P fertilisers may be strongly influenced by soil moisture conditions in the period immediately following application and subsequent effect on dissolution and precipitation rather than an effect on crop physiology. This aspect is currently being assessed in the laboratory.

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