Phosphorus – Yield responses in wheat, canola and field peas grown at different soil Colwell P and PBI levels.

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Abstract

In 40 field experiments, conducted throughout low and high rainfall cropping regions of New South Wales and Victoria, responses by wheat (33 sites), canola (4 sites) and field peas (3 sites) to applied phosphorus (P) fertiliser were measured in 2000 and 2001. Up to seven rates of P fertiliser were compared at each site. Surface soils (0-10 cm) varied from acidic sandy loams and loams, (pH $_{CaCl2}$ 4.5 – 5.8 and CEC < 10 meq/100gms) to slightly alkaline grey clays (pH $_{CaCl2}$ 5.7 – 7.8 and CEC > 20 meq/100gms). Colwell soil P levels ranged from 10 – 60 mg P/kg and the phosphate buffer index (PBI) values ranged from 47 to 137.

Median increases in relative grain yield to 20 kg P/ha across the 33 wheat sites were 17%. On low P status soils (Colwell P < 20 mg P/kg), yield responses averaged 69%, with substantial yield increases being measured up to 40 kg P/ha. On sites where Colwell soil P exceeded 30 mg P/kg, the median yield increase to 20 kg P/ha was only 7%.

On 4 soils, with Colwell P levels less than 20 mg P/kg, relative yield responses by canola to applied P were similar to those measured for wheat at comparable Colwell P levels. Thus, the critical range is extrapolated to be similar to that for wheat: 27 to 33 mg P/kg (95% confidence interval). Soil texture did not significantly affect critical Colwell P in this study. By contrast, yield responses by field peas in the order of 40% were measured at Colwell P levels between 21 and 36 mg P/kg, indicating a higher external P requirement. Based on a limited data set, the diagnostic relationship for PBI was unsatisfactory. The implications of these findings to the industry and the economics of increasing P inputs are discussed.

Key Words

phosphorus, soil P, wheat, canola, peas, phosphate buffer index

Introduction

Soil testing has slowly gained wider acceptance by Australian farmers for monitoring the fertility status of their paddocks and for adjusting annual fertiliser investment decisions (1). Interpretation of tests for soil P, as used by commercial services in Australia, relies on calibrating relationships between yield responses to P fertiliser (for a given crop) and extractable soil P status (e.g Colwell P). From these relationships, critical Colwell P (CCP) levels at near maximum (90%) crop yield are derived, and these have been summarised from a large number of Australian experiments by Moody and Bolland (2).

The Colwell and Olsen soil P tests (3) are the most widely used soil P tests in Australia, but their utility for predicting P fertiliser requirement is known to vary and depend upon P sorption characteristics of different soils (2, 4, & 5). Thus, different CCP values for a given crop may apply for different soil types or soil groups (eg 6). The recent development and use of the single point P buffering index (PBI) (4) may in the future overcome these interpretation difficulties.

In their natural state, most Australian soils are inherently low in soil P for crop and pasture production. Over the past century soil P levels have been improved in most regions by repeated applications of phosphatic fertilisers. For example, in a recent assessment of Colwell extractable P concentrations in surface soils, 40% of NSW and 51% of Victorian soil samples analysed by commercial services for farmer clients were above 30 mg P/kg. However, 38% and 29% of samples respectively had sub-optimal concentrations below 20 mg P/kg and about 10% of samples in both states were below 10 mg P/kg (7). Thus, applications of P fertiliser will continue to be essential inputs for Australian cropping systems, both to maintain soil P status of developed soils, and to rapidly improve P status in areas that have been recently developed, where substantial responses to applied P are likely (8). Importantly, in areas where soil P status is sub-optimal, crop yields are likely to be produced below their potential.

The objective of this study was to compare CCP values in different crops and soil types and to undertake a preliminary assessment of PBI for estimating P requirements.

Methods

Forty field experiments were conducted throughout NSW and Victoria during 2000 and 2001 on representative soils of previously unknown P status. Growing season rainfall varied from 180-500 mm, with a median of 307 mm. Soil types included sandy loams, loams, red earths, red-brown earths and grey and black self-mulching clays. Cation exchange capacities ranged from 5 meq/100gms, at the sandy loam sites, to greater than 30 meq/100gms on the heavy clay soils. On 13 sites, phosphate buffer index (4) values were determined and ranged from 47 to 137.

Using a cone seeder, P fertilisers were drilled in the seed row, at 4-5 cm depth for wheat and peas, and 2 cm deep for canola. Rates of applied P ranged from 0-40 kg P/ha, applied as triple superphosphate (TSP), mono-ammonium phosphate (MAP) or di-ammonium phosphate (DAP). At some sites, P fertiliser sources were compared. Most sites had at least 4 rates of applied P (0, 10 or 15, 20 or 25, and 40 kg P/ha). Where 40 kg P/ha was applied, 20 or 25 kg P/ha was drilled with the seed and the remaining P was placed at depth with the basal nitrogen (N) fertiliser. At 3 wheat and 3 canola sites established in NSW in 2000, 40 kg P/ha was applied with the seed as TSP, to eliminate any potential crop emergence problems caused by ammonia toxicity: no visual differences in plant emergence were observed between P rates at any site. Weeds were controlled by herbicides.

Basal N applications of urea were applied to adjust differences in applied N due to the P fertiliser source, and also to ensure adequate N nutrition at each site. The urea was deep banded (7.5-10 cm) and applied to all plots. In each region, common recommended varieties of each species were sown, generally at seeding rates slightly above district practice. Plots were normally 15 m in length and 1.4 – 2.0 m wide. Grain yields were determined using trial plot harvesters.

For each site, the Mitscherlich response function in the form yield (y) = $A(1-B^{\exp(-C*\text{rate of P})})$ was fitted to the relationship between grain yield (t/ha) and levels of applied P fertiliser (kg P/ha). In this function, A is the asymptotic (or maximum) yield achievable; B represents the proportional deficit in yield from maximum when no P is applied, (being zero at sites of adequate P supply and around 0.7 in very P deficient soils); and C is the curvature coefficient, which measures how rapidly the yield response curve approaches the maximum yield plateau. On P responsive sites C usually varied around 0.07, unless some other yield constraint existed. Having estimated B, relationships were then developed between B and Colwell soil P status for soils of similar surface soil texture (see Figure 1 for the 33 wheat sites). Critical ranges for all soils and for 3 broad soil texture classes were then estimated at B = 0.1 (or 90 % maximum grain yield achieved). The economic optimum rate of applied P at each site was derived using the fitted response curve and current costs and prices. This optimum ignores any residual benefits of applied P.

PBI values for 11 wheat sites were measured by the analytical method and equation proposed by Burkitt *et al.* (4). CCPM for wheat is the CCP value derived from the PBI value rather than inferred from a series of trials. It was calculated using the equation: CCPM = 15.3 + 0.039 * PBI (9).

Results

Grain yield responses were not affected by source of P fertiliser applied at any site ($p > 0.1$).

Grain yields at optimal P in wheat varied from 0.9 to 7.6 t/ha and yield responses to applied P varied from 0 to 3.4 t/ha. Across the 33 wheat sites, the median relative increase in grain yield to 20 kg P/ha was 17%. On low P status soils (Colwell P < 20 mg P/kg), yield responses averaged 69%, with substantial yield increases being measured up to 40 kg P/ha. On sites where Colwell soil P exceeded 30 mg P/kg, the median yield increase to 20 kg P/ha was only 7%.

At the 4 canola sites, each of low soil P status (Colwell P < 20 mg P/kg), seed yields ranged from 1.8 to 3.0 t/ha. Responses to applied P varied from 0.4 to 1.7 t/ha. Relative responses in canola were similar to those determined for wheat at comparable soil P status. By contrast, yield increases of about 40% were measured in 3 field pea crops on soils of Colwell soil P status between 21 and 36 mg P/kg. The economic optimum rate of P fertiliser across the 33 wheat sites averaged 24 kg P/ha. For canola and peas the optimum rate was greater, because of low soil P status at the 4 canola sites and the observed higher responsiveness of 3 field pea crops.

The curvilinear relationship in Figure 1 shows for wheat that B was generally lower for soils of higher Colwell soil P status. Conversely, large responses to applied P were gained at sites having low Colwell soil P values. Moreover, Colwell soil P values around B = 0.1 covered a considerable range between 20 and 40 mg P/kg. For all soils, the 95 per cent confidence interval for the critical range for Colwell soil P lay between 27 and 33 mg P/kg and 70 per cent of trial sites selected had Colwell P concentrations below this range. The relationship derived for clay loams appeared to produce a slightly lower CCP than for the clay and the sandy loam soils, but the differences were not statistically significant.

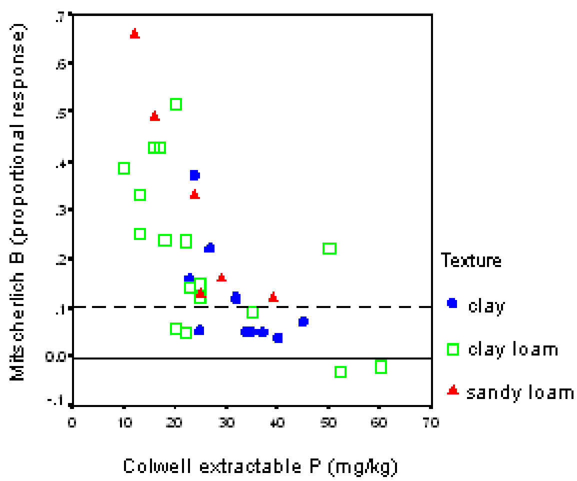

Figure 1 : Relationship between responsiveness wheat to drilled P fertiliser and Colwell soil P for different soil texture classes (0-10 cm)

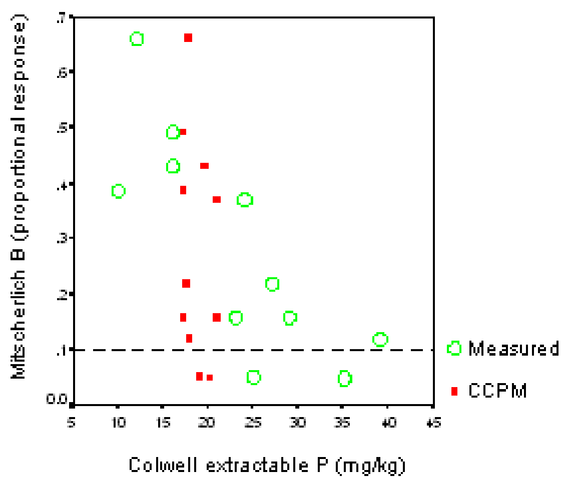

Figure 2: Relationship between responsiveness of wheat to drilled P fertiliser and CCPM at status the sites where PBI was measured

The diagnostic relationship developed for the 4 canola sites was similar to the wheat relationship (data not presented), suggesting on limited evidence that the CCP for canola may be similar to wheat, but extrapolation of the limited data for field peas (3 sites) suggests a much higher CCP in the vicinity of 44 mg P/kg.

Knowing the PBI value for some sites did not refine the relationship between B and CCPM (Figure 2). Using the PBI equation for calculating CCPM for wheat (9), the maximum CCPM value for these sites was 21 mg P/kg with a mean of 18 mg P/kg. This contrasts with the estimated CCP using Colwell P directly

(27 to 33 mg P/kg). However, the equation used was derived from a limited data set and is presently being re-evaluated for Australian soils (P.W. Moody, pers. comm.).

Conclusion

This field study has confirmed that sub-optimal soil P status still exists in cropping soils of NSW and Victoria: 32 of the 40 sites responded markedly and economically to applied P fertiliser (optimum rate of P > 10 kg P/ha and at some very low P sites up to 40 kg P/ha). These sites also had Colwell P concentrations in surface soil well below the CCP of 30 mg P/kg, with many below 20 mg P/kg. Moreover, as new land is developed for cropping in some central NSW districts, the inherently low natural Colwell P status of these soils (10) needs to be raised rapidly by “capital” investments in P fertilisers (8) to ensure sustainable yields are achieved. The experiments also demonstrated that grain yield responses to applied P were comparable using TSP, MAP or DAP, where crop N inputs were adjusted to be identical.

The investigations, across a wide range of soils, have demonstrated that Colwell soil P is a reasonable predictor of current yield response to P fertiliser. However, the CCP values defined for different crops *may* vary appreciably. This variation needs to be further assessed, since on the very limited data the estimated CCP for field peas appeared higher than for wheat and canola. Higher P applications to field pea crops may increase symbiotic N accretion (11), and so benefit following non-legume crops. Preliminary data for the new equation calculating CCPM for wheat (9), using the PBI, was inconclusive.

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