

Managing fertiliser inputs on high phosphorus status soils: incorporating soil constraints into decisions

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Key messages

- Soil acidity, water repellence and root disease have been shown to reduce crop access to soil P and where these constraints are present yield responses to fertiliser P have occurred even where soil test P levels are classed as sufficient.
- Assessment of root and soil constraints to soil P availability needs to be integral to the P fertiliser recommendation process.

Aim

To identify agronomic factors that limit the availability of soil P and which therefore need to be considered when making decisions about P fertiliser rates.

Background

Recent research has shown that the majority of soils tested from the Western Australian cropping area have a sufficient level of soil phosphorus. Weaver and Wong [1] found that 87% of soil samples from WA in 2008/09 and 2009/10 exceeded the critical value for wheat, where the critical value was defined as the Colwell extractable P level which can produce 90% or greater of the P non-limited yield.

While the overall P fertility of cropping soils in WA is above critical levels, the reverse is true for soil pH. A recent survey showed that almost 80% of soil surface (0-10cm) samples have a pH (CaCl₂) less than the critical level of 5.5 [2]. Nearly two-thirds (63%) of the samples assessed by Weaver and Wong [1] exceeded the critical values for soil P in wheat and had a soil pH below the critical level of 5.5 (CaCl₂).

A high rate of adoption of minimum- or no-tillage systems has occurred in WA. In 2008, 88% of growers were using reduced tillage systems (single pass operation) and this was expected to be 92% in the 2013 cropping season [3]. While there are a number of agronomic benefits to this system which we do not cover here, a long history (10 to 15 years) of no-tillage systems has important implications for P nutrition of crops in some soils: for example a lack of soil mixing resulting in nutrient stratification (increasing the risk that nutrients are unavailable in dry surface soils) and reduced cultural control of root diseases.

Our research in recent years has shown that positional unavailability in dry surface soil, soil water-repellence, soil acidity and root disease have a negative impact on soil P acquisition. It is likely some herbicides are having a similar effect by limiting soil exploration either directly due to root pruning or indirectly by increasing the severity of root diseases.

Discussion

How do we manage P fertiliser inputs when soil test levels are sufficient?

This question needs to be addressed within the context of current cropping systems rather than on soil test values alone. The underlying assumption to fertiliser recommendations, based on empirical models, is that Colwell P can be used to predict yield response to fertiliser P at any given site based on the average behaviour from a large number of sites where P fertiliser trials have been conducted. While the trial data used to develop fertiliser recommendation models will have included sites where constraints such as aluminium toxicity were present, these models cannot deal with such interactions specifically except by changing potential yield. There are limited trial data available to quantify the interactions between soil P availability and the constraints mentioned above, however, below we discuss the evidence we do have and its implications for P fertiliser recommendations.

Soil acidity and water repellence

Current work is showing that soil phosphorus availability to roots can be reduced at mild levels of water repellence [4]. In a field trial at Badgingarra, the absolute response in grain yield to fertiliser P is greater in the no-till control than plots that have been treated with a rotary spader or mouldboard plough. The water repellence at this site is classed as moderate (the MED and water drop penetration time for the no-till control are 1.6 and ~ 4 minutes, respectively). Data from 2011 and 2012 from this trial showed that although the water repellence at this site is not severe enough to affect germination or yield potential, it is affecting availability of soil P for uptake by plants.

Recent work has also shown that availability of soil P is reduced at low soil pH [5, 6]. In both trials, P uptake was significantly greater where lime was applied. Aluminium (Al) toxicity appears to be the best explanation for this; root length is reduced when extractable Al (CaCl_2) is greater than 5 mg kg^{-1} . Results so far have shown that lower fertiliser P rates are required to achieve maximum grain yield where the acidity constraint is removed; suggesting that where soil pH (CaCl_2) is less than ~ 4.6 current recommendation systems will overestimate plant uptake of soil P and possibly underestimate the amount of fertiliser P required.

Plant disease

Brennan [7] has shown that P fertiliser is used less efficiently where high levels of take-all were present. A response curve was fitted for grain yield in response to fertiliser P for different rotation treatments (1 to 4 consecutive wheat crops) which had induced different levels of take-all. The curvature parameter was greatest where one wheat crop had been grown, and lowest where four consecutive crops had been grown. This is significant for P fertiliser recommendations because the curvature parameter reflects the responsiveness of yield to P fertiliser: as the curvature coefficient increases the efficiency of P fertiliser use increases. The use of ammonia-based compound fertilisers (e.g. Agras, MAP, DAP) may be reducing the impact of take-all in WA, however, we expect that the same principle to apply where other root diseases occur.

Plant disease loads and variety are also an important consideration when making decisions about P fertiliser rates. For example, Bolland *et al.* [8] found that lupin varieties that were susceptible to pleiochaeta had lower yields than tolerant varieties where no P fertiliser was applied in treatments if pleiochaeta levels were high (lupin-wheat rotation & stubble burnt before sowing). For susceptible varieties (Merit, Tallerack), the P rate required for maximum yield ranged from 5 to 15 kg P ha^{-1} , and for the tolerant varieties (Myallie, Teo), the P rate required for maximum yield ranged from 0 to 5 kg P ha^{-1} .

More recent work has shown that rhizoctonia is the most prevalent root disease in the WA cropping region. Results from the Focus Paddocks project (146 sites measured in both 2011 and 2012) are showing that the incidence of rhizoctonia is greater than take-all, crown rot, and root lesion nematode. However, the severity of rhizoctonia is most often low: only 11% of sites had rhizoctonia levels of moderate or worse.

Current management practices recommended to control rhizoctonia are for deep cultivation below the seed level (at least 10 cm below the seed) in combination with a registered fungicide seed dressing. For the 2013 growing season, two new seed dressing fungicides may be available (Vibrance and EverGol Prime). Rotations using either canola as a break crop or a chemical fallow may be useful after growing cereals to reduce the inoculum levels of rhizoctonia. Additionally, ensuring adequate nutrition (N, Zn, P) at seeding for healthy and strong plant growth will also contribute to reducing the impact of root diseases in crops.

The presence of rhizoctonia may be significant for crop access to soil P. In a field trial at Wongan Hills, the maximum yield and efficiency of use of P fertiliser was lower in the continuous wheat than the lupin wheat rotation: rhizoctonia was confirmed as being present at this site and observations of root damage were generally worse in the continuous wheat plots [5]. Our results so far suggest that moderate levels of rhizoctonia can have a negative effect on crop access to soil P, and there is a negative interaction with soil acidity.

Herbicides

There is some evidence that herbicides will have an impact on soil P availability, although this is typically dependent on other factors. For example, in a field trial at Katanning (7.6 kg P ha^{-1} drilled) shoot P concentration was reduced to below the critical concentration at 27 and 57 days after sowing when 15 g ha^{-1} chlorsulfuron was applied in cv Kulin, however, chlorsulfuron had no effect on shoot P concentration in cv Reeves. While shoot P concentration was affected, no shoot or grain yield response to chlorsulfuron or diclofop-methyl was observed in this trial [9]. Chlorsulfuron can also lead to higher rhizoctonia incidence; root pruning by this herbicide can lead to lower zinc uptake which leads to a higher susceptibility to rhizoctonia [e.g. 10]. In the context of this paper, variety choice is the most practical management tool for avoiding negative effects of herbicides (chlorsulfuron in particular) on soil nutrient availability.

Implications for phosphorus strategies in crop production

There are several approaches taken by growers and advisors to managing P nutrition: for maximising yield and/or maximising gross margin, replacement of P lost in grain, insurance against mis-diagnosis of constraints and faults in the recommendation system as well as closely budgeting soil P build-up or run-down (i.e. a “target soil test” approach). Quantitatively, there may be no distinction between approaches, for example the replacement, optimal gross margin and insurance rates may all be ~ 5 kg P ha⁻¹. Where low P rates are being applied using an insurance or replacement approach, and there is a greater reliance on soil P supply, then the constraints to root uptake of soil P must be considered.

The rationale behind insurance P is to reduce the risk of P deficiency due to inadequate soil P supply. Examples of inadequate soil P supply include: soil P is overestimated by soil test results that are not truly representative of the entire paddock; drought periods that restrict the availability of soil P in the surface layer or; any of the other constraints to root acquisition of P discussed above. Figure 1 shows a summary of percent of maximum yield achieved for increasing rates of P fertiliser for 2 scenarios: where soil P levels will provide enough for 70 to 90% of maximum yield with no fertiliser applied, and where soil P is adequate for 90% of maximum yield with no fertiliser applied. This represents the situation many growers are faced with; soil test results suggest that soil P is adequate (Figure 1b), but factors may occur that reduce soil P availability (Figure 1a). Based on these data, if a decrease in soil P availability occurs due to any of the factors above, an insurance rate of 5 kg P ha (which replaces the P removed by 2 t of wheat/ha) will achieve between 82 and 91% of maximum yield in 50% of years and 10 kg P ha⁻¹ will achieve between 86 and 96 % of maximum yield in 50% of years.

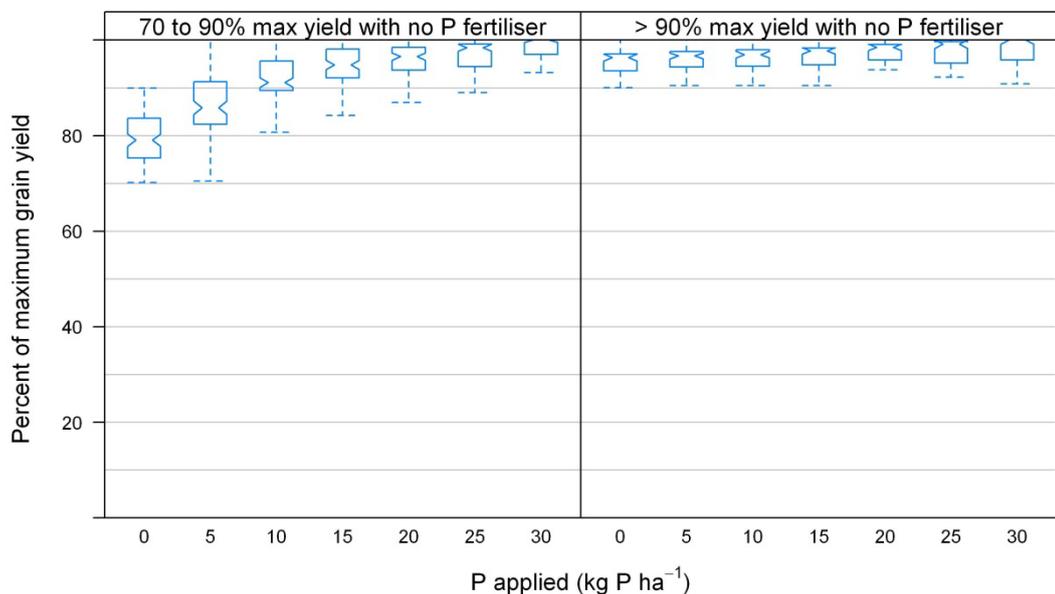


Figure 1: Percent of maximum grain yield achieved for fertiliser P applied for 2 scenarios a) soils defined as insufficient where less than 90% of maximum grain yield is achieved with no P fertiliser, and b) sufficient soils where greater than or equal to 90% of maximum grain yield is achieved with no P fertiliser. Data from the Better Fertiliser Decisions for Cropping database (bfdc.com.au). Upper and lower bounds of whiskers are 5th and 95th percentile, upper and lower bounds of box are 25th and 75th percentile and notch shows the median.

Conclusion

Knowledge of soil constraints that limit exploration of the soil by roots of crop plants is critical when making decisions about P fertiliser rates. Recent work has shown that where soil pH (CaCl₂) is less than 4.6, moderate water repellence occurs (WDPT > 4 minutes) or root disease is present, crop access to soil P can be restricted and the efficiency of use of P fertiliser is less than treatments where these constraints do not exist. Root disease levels are likely to be higher where paddocks are repeatedly cropped with cereals. These constraints are particularly relevant for growers using low rates of fertiliser P.

Key Words: phosphorus, soil acidity, water repellence, root disease

GRDC Projects: DAW00222 'More Profit from Crop Nutrition - Regional soil testing and nutrient guidelines: West'. UMU00035 'Improving profit from fertiliser through knowledge-based tools that account for temporal and spatial soil nutrient supply', DAW00213 'Putting the Focus on Profitable Crop and Pasture Sequencing'. DAW00201 'Identification and characterization of disease suppressive soils in the Western Region'.

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