ENSURING YIELD BENEFITS THROUGH INFORMED FERTILISER DECISIONS

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

Deep placed phosphorus (P) has become an important consideration for growers when planning a fertiliser strategy, with the growing recognition that it can offer long term yield benefits in many environments and growing conditions.

The challenge

Declining native soil fertility poses a significant challenge to the future sustainability and profitability of Australian farming systems.

Traditionally, P has been considered as a nutrient applied at planting in the seeding furrow which supplies a small but critical amount of P to plants. However, as the crop develops it begins foraging for the bulk of its nutrients deeper in the soil profile, particularly if moisture is available.

Over the years, reserves of nutrients such as P and potassium (K) in the 10cm-30cm layers of the soil profile have been depleted by crop growth demands and generally haven't been replaced adequately. Even when fertilizer inputs have been matched to crop removal, placement of these nutrients has often been too shallow. Nutrients such as P and K are effectively immobile in all except the sandiest of soils, moving sparingly, if at all, through the soil profile with water.

Northern no-till cropping systems tend to be particularly affected by this phenomenon. The clay soils restrict leaching of P and K, and the reliance on stored soil moisture rather than in-crop rainfall encourages crop roots to explore deeper into the moist subsoil to extract available nutrients. However the north isn't unique, with no-till and intensive cropping systems in southern cropping regions also seeing soil P levels becoming concentrated in the topsoil and reducing at depth.

The main crop plants require around 8-12kg of P and approximately 50-70kg of K for optimal crop growth in an average season, and research has shown that yields can be constrained by as much as 20 to 30 per cent if P or K is limiting in the 10cm-30cm soil layer.

To maintain productivity and improve the return on fertiliser input investment, growers are being forced to reconsider their approach to fertiliser management, particularly in terms of rate, timing, product and placement.

Given the relatively high initial application and P fertiliser costs, deep P applications are a longer-term investment and the fundamental decisions facing growers relate to `how much P and how often'.

The response

Since 2012, the Grains Research and Development Corporation (GRDC) has been investing in research to

assess crop response to P fertiliser in terms of rates, products and placement with trials conducted at 35 locations from central Queensland to central New South Wales.

Professor Michael Bell, UQ Researcher. Photo: GRDC

The research team is led by Professor Mike Bell from the University of Queensland and is a collaborative effort between the Queensland Department of Agriculture and Fisheries (DAF) and NSW Department of Primary Industries (NSW DPI).

Given that responses to deep P applications are impacted by factors such as soil type, seasonal conditions and soil moisture availability, crop demand, crop species, product type and sub-soil constraints, a significant part of this research has focused on the logistics and crop response of placing P at depth for crops grown in different environments and growing conditions.

The data has assisted researchers to develop diagnostic indicators of when to use starter and deep P fertilisers, provide guidelines for effective application methods to address P limitations and undertake economic assessments of the profitability of deep banding within a cropping system. This work has contributed to the release of a deep P calculator, developed jointly by the GRDC, Queensland DAF and CSIRO, which helps growers calculate the return on investment of various application rates of phosphorus in different crop rotations.

Over the years the field research has delivered some interesting results, particularly with regards to the residual value of deep placed P and the nutrient interaction effects (typically with N, and in some cases with K).

While large crop responses have been recorded at many locations, responsiveness has been impacted by seasonal moisture availability (on yield potential and root activity), P placement (starter versus deep P, band spacing, amount of soil disturbance), P rate, time of application and product choice.

However, the risk of adverse seasonal conditions limiting the response to deep banded P has been somewhat countered by the residual value of deep P applications. The residual value has generally proved excellent, with some sites still recording yield benefits four to five years after application.

The trial work has focussed on rates of P fertiliser ranging from 0 to 60 kg P/ha applied in deep bands (at ~20cm depth), typically at band spacings of 50cm, along with an untilled Farmer Reference treatment as a measure of the current baseline condition.

Deep P applications were made using either mono-calcium phosphate (TSP), or more commonly mono-ammonium phosphate (MAP). A basal nutrient application of N, sulfur and zinc (Zn) was added to the deep application to balance the rates of N added as MAP and lower the risk of other nutrient limitations constraining P responses. In soils with low K, that was also added to the basal application.

All main plots were then split to annual 'with' or 'without' starter P fertiliser applications at planting at rates ranging from 6 to 10 kg P/ha. This is allowing the researchers to assess whether yield responses are due to the starter P, the deep P or an interaction between both.

Crop choice at each site was dependant on the host farm's crop rotation and the residual benefit of the different rates of applied P was tracked through subsequent growing seasons.

In most cases, grain yield has been higher with a starter P application than without, suggesting growers should continue with their normal starter P program irrespective of deep P application.

The research also found that all crops responded to deep P when subsoil P (in the 10-30cm layer) was

low. A range of responses to deep P were recorded for similar soil P concentrations, ranging from small through to large yield increases. As an example, failing to apply deep P resulted in yield penalties of 10-25 per cent for a Colwell P in the 10-30cm layer of 2 mg/kg.

This variation is attributable to a combination of other yield constraints such as a lack of water or low N availability, or an ability to access P from relatively enriched topsoil layers such as in wet years.

Across much of the trial work, crop yield responses to deep P applications have been significant, highlighting the potential for growers to boost profitability both on an individual crop basis and across the farming system.

Six of the eight trial sites in central Queensland have proved responsive to deep P applications with grain yield increases ranging from an additional 14 per cent to 100 per cent compared to the no deep P treatment over periods of three to five years after deep P application.

It's a similar story in southern Queensland where deep P applications have produced statistically significant yield responses in 26 out of 35 crop seasons, with the longest running sites now in their fifth crop season after deep P application. The cropping program has been dominated by winter crops at these sites (27 of 33 crop-seasons), with wheat and barley responding positively in all 15 site-years and chickpea in 6 out of 12 crop seasons. Sorghum has responded in four out of the six site-years. Whether these differences in response frequency relate to seasonal moisture availability, soil P status or inherent differences in the ability of crops to utilise deep P bands is being explored in other projects and additional experiments.

The impact

As with any research, the on-farm adoption of deep P placement will hinge on its ability to deliver productivity and profitability gains.

With upfront costs of around ~$100/ha for 20kg P, it is important to identify how many crops it takes for the deep P investment to be repaid, and how long this investment will continue to generate additional income.

Of the 11 sites using deep applications of MAP in Southern Queensland, eight had repaid the investment in 20P and returned increased profit within two years, and five of those had managed to do so in the first year. The 20P treatment at Jimbour West, which had five crops between winter 2014 and winter 2018, has returned almost $800 per hectare in increased profit over this time.

However, economic returns will vary dramatically between sites, depending on seasonal conditions and the production environment.

Before embarking on a deep P program, growers should:

- Determine paddock variability for yield and use the data to prepare a soil sampling program.
- Assess the fertility and constraint status of the soil profiles.
- Evaluate crop responses to fertiliser applications designed to address those yield constraints using an appropriate program of strip-trials and on-farm exploration to validate the diagnosis of nutrient constraints.

There are four suggested treatments to explore the effects of a deep P application before starting a larger program:

- Treatment 1 is current practice or "do nothing", which benchmarks current system performance;
- Treatment 2 involves the physical tillage of soil to a depth or roughly 20-25 cm, which simulates the deep placement operation without any fertiliser application. While not a long-term solution, simply loosening soils can sometimes allow better root exploration of those profile layers and more efficient uptake of scarce soil P resources.
- Treatment 3 is tillage with additional nitrogen. In many sites, nitrogen status is in equilibrium with the existing 'normal' yields from that field, and if deep P improves field yield potential, extra N has to be

applied to achieve the higher yield target. Applying additional N alone in this treatment allows growers to separate responses from tillage, extra N, and extra N and P.

- The last treatment is deep P application. Given that MAP is the most effective form of P and soil Zn is often also low, an application of 100-150 kg/ha of an ammonium phosphate product with zinc is typically used. Suggested rates for use in strip trials are 20-30 kg P/ha of an ammonium phosphate-based product. To maximise the chances of plant roots encountering the applied P early in the growth stage, band spacings of 50 cm or less are recommended.

Validation

Central Queensland agronomist and co-principal of Acres Rural in Rolleston, Jeff York, has seen some exceptional responses to deep placed P but said applications weren't appropriate in all situations and needed to be based on soil tests results.

"Generally, we are seeing a response to deep P applications where we would have expected to. In 2018, we had one site where a wheat crop yielded an additional 73 per cent due to the application of deep P. The conditions were also conducive to a response – the crop was planted on minimal moisture, had around 20mm of rain after emergence and from then on relied on stored soil moisture," he said.

"From our perspective, there's a number of important messages from the research to date including that nutrient interaction is extremely important – N, P and K need to be in balance to generate a worthwhile response, and that the responses from starter P and deep P are individual.

"When there's very little in-crop rainfall, which is quite common for winter crops in central Queensland, the surface layer dries out and the plant is unable to access non-mobile nutrients trapped in the dry surface soil. This forces the crop to forage for nutrients deeper in the soil profile which can generate a stronger response to deep P.

"The deep P research work that's been undertaken to date has demonstrated that in certain situations, deep P applications can be a very worthwhile investment, particularly in a higher yielding year.

"However, with high upfront costs and a residual value spanning several years, growers need to consider it as a longer-term capital expenditure investment."

The outlook

Deep P research will continue to be a priority for GRDC within its crop and soil nutrition investments to further industry's understanding of the productivity and profitability impact on an individual crop and farming system basis.

Research collaborations are also likely to see the deep P work extended within GRDC's production regions.

Research into the different P products, application timing, rate and placement will build on the extensive trials undertaken to date and address on-going knowledge gaps in areas such as the timeframes for deep P re-application under different nutrient limits and seasonal conditions, methods to directly account for fertiliser P recovery and export and importantly, why growers experience variable crop responses to deep P applications from one year to the next. The research recognises that the link between product placement and root synchrony is fundamental to understanding plant response.

One of the current projects (UQ00082) is aimed at addressing questions about the relative responsiveness of different crop species to fertiliser application and specific application strategies. Responses to different profile nutrient distributions for both existing and emerging nutrient constraints, and the type of fertiliser application strategies to address them, are a key focus. This project will deliver updated nutrient response data in the Better Fertiliser Decisions database for a wide range of crop species and nutrient responses, strengthening the link

between soil test results and likely response to applied nutrients.

Another project (UQ00086) is investigating the most effective form of P fertiliser to maximize P bioavailability in the short and longer term (e.g. mono-calcium and mono or di-ammonium phosphates - MCP, MAP and DAP, respectively) when applied in bands in soils with differing clay contents. This will help provide clear guidelines on the suitability of different P products for use in specific soil types. It is also looking at any potential risks from placing a blend of fertiliser products in a concentrated band, with this issue especially important in areas where subsoil P and K are both low.

Work is also being undertaken into the longevity of deep P responses with the recent establishment of a trial program to assess the impact of a fresh application of 30 kg P/ha against the original deep applications made three to five years ago.

References and resources

Deep P calculator
http://www.armonline.com.au/deepp/#!/

GRDC podcast *Deep placement of P and K*
https://grdc.com.au/news-and-media/audio/podcast/deep-placement-of-p-and-k

GRDC codes: UOQ1207-001RTX, UOQ1505-001RTX