PHOSPHORUS AVAILABILITY FACT SHEET

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

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Understanding phosphorus availability in soils and its effect on plant root structure

Photo: University of South Australia

University of South Australia's Dr Euan Smith collecting data to better understand phosphorus availability.

KEY POINTS

- Soils across cropping areas in Australia may be deficient in phosphorus (P) and require phosphorus fertiliser application to secure productivity
- Plant-available phosphorus in soils can be determined using diffusive gradients in thin films (DGT) devices that GRDC-supported researchers are using to calculate the movement and availability of phosphorus from fertilisers
- Phosphorus diffusion and phosphorus availability are controlled by both the fertiliser's formulation and the soil's characteristics
- The research shows limited movement and availability of phosphorus in highly calcareous soils
- Near hotspots of locally available phosphorus, plant roots respond by strongly proliferating
- This root proliferation may facilitate the uptake of other nutrients

Measuring phosphorus availability

Phosphorus (P) is one of the main nutrients required for plant growth and productivity. Australia's agricultural soils are heavily affected by phosphorus deficiencies due to the weathered nature of the landscape. If not addressed, either through the application of fertilisers or other soil management practices, these soil deficiencies can markedly decrease crop yields and farm profitability.

To enhance fertiliser efficiency, it is essential to understand how phosphorus availability is affected by soil characteristics, fertiliser formulations and the crop's root distribution in the soil.

Conventional techniques to measure phosphorus availability provide limited information on the spatial availability of phosphorus in soil as related to crop root architecture. As part of a GRDC investment, researchers at the University of South Australia and the University of Queensland used techniques that mimic plant uptake — diffusive gradients in thin films (DGT) devices (Figure 1) — to study the diffusion and availability of phosphorus fertilisers in the laboratory and under paddock conditions.

They combined this technique with synchrotron analysis to investigate the effect of fertilisers and soil properties on the distribution of available phosphorus in soils and the effect this has on the crop root structure. The Australian Synchrotron provided extremely high-intensity X-rays, allowing the researchers to examine the plants and soil at the molecular level.

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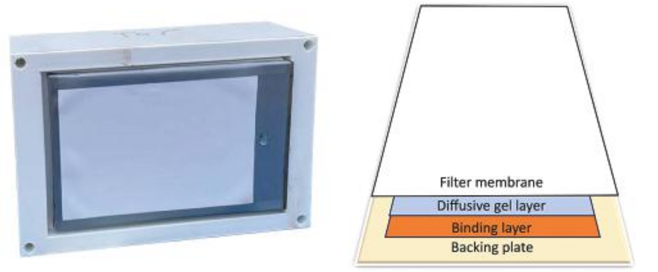
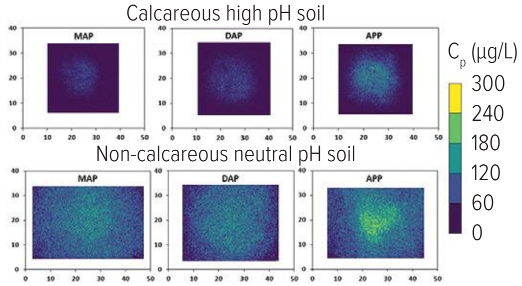
Figure 1: The paddock DGT device developed by researchers from the University of South Australia.



The soil-available phosphorus is absorbed by a binding layer that is covered by a diffusive gel and a filter membrane (right). All three layers are attached to a backing plate.

Source: University of South Australia

Figure 2: The 2D diffusion of phosphorus captured by a DGT device and analysed by X-ray microscopy fluorescence.



The top shows the limited diffusion in the strongly phosphorus-fixing calcareous soil, and the bottom shows the more extensive phosphorus diffusion in the pH neutral non-calcareous soil for three different phosphorus fertilisers (MAP, DAP and APP). The axes indicate the scale (mm).

Source: Moens et al. (2024)

Not all phosphorus fertilisers are equal

The uptake of nutrients by plant roots is achieved by diffusion of nutrients from the fertiliser into the soil in a form amenable for uptake. The diffusion is dependent on the fertiliser type and soil properties. Using DGT devices combined with synchrotron techniques, the researchers showed the diffusion of available phosphorus from different phosphorus fertiliser formulations in different soils (Figure 2).

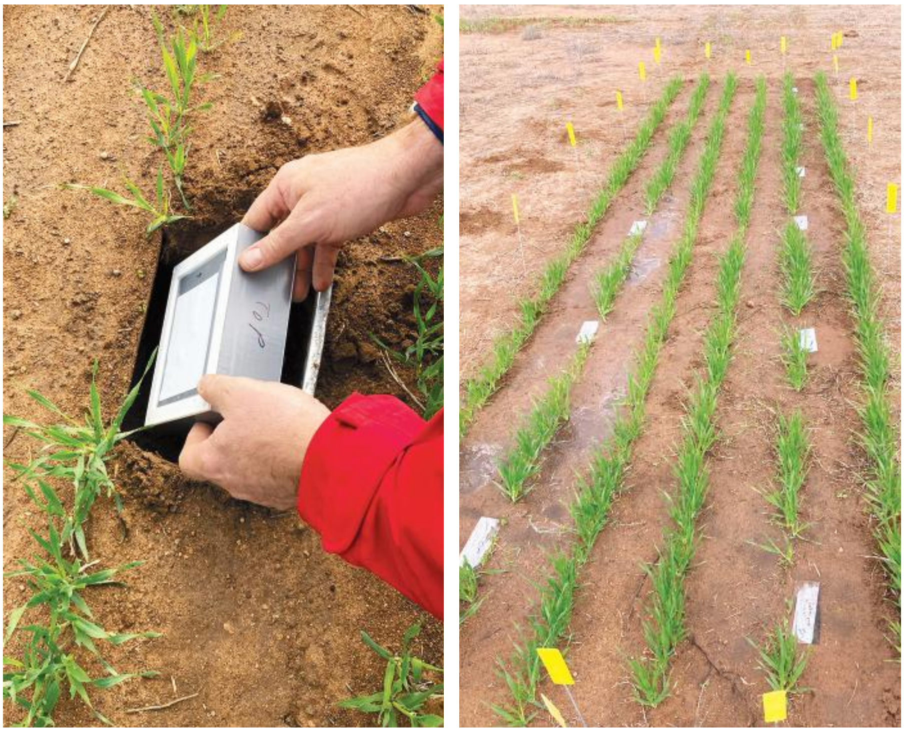
Applying a DGT device to the soil mimics the plant uptake process and allows a visual and quantitative comparison of which fertilisers provide the most phosphorus available to plants. Three different fertilisers were assessed: ammonium polyphosphate (APP), monoammonium phosphate (MAP) and diammonium phosphate (DAP). Results from the DGT devices showed:

- the diffusion of phosphorus was inhibited in the strongly phosphorus-fixing calcareous soil compared to a neutral pH non-calcareous soil; and
- the concentration of available phosphorus in the MAP and DAP fertilisers was similar, but APP had a higher concentration of plant-available phosphorus in both soils.

Application of phosphorus DGT in the paddock

DGT devices provide useful information on phosphorus availability in the soil and the localised phosphorus status under controlled (laboratory) conditions. As part of the GRDC investment, DGT devices were developed to provide similar visual and quantitative information when deployed in the paddock (Figure 2).

Figure 3: DGT devices used in the paddock to evaluate soil phosphorus status at six weeks after sowing. Barley plants have been removed to facilitate placement of DGT devices.



Source: University of South Australia

Further information on the application and use of the field-testing DGT can be found on page 3, Useful resources.

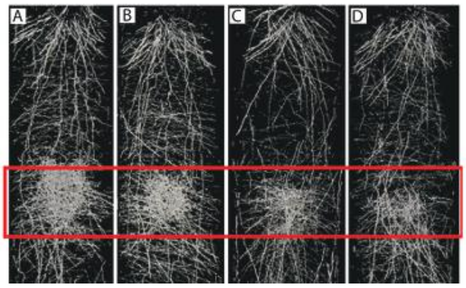
Phosphorus availability and root architecture

The lower phosphorus diffusion from the fertiliser granules in some soils has a direct impact on the plant root structure.

Banding applications of phosphorus fertilisers are commonly undertaken during seeding. In some circumstances, deep banding (15 to 30 centimetres) of fertiliser may be applied to utilise high soil moisture conditions. Placement of phosphorus fertilisers at a greater depth enhanced the plant root density. phosphorus fertiliser granules placed at 20cm showed elevated wheat root density compared to the surrounding soil profile (Figure 3).

The increased root density was not dependent on the source of applied phosphorus (MAP or DAP) but there was a difference in the total wheat root length density in a Kandosol (acidic soil, from Queensland) compared to a Calcarosol (alkaline soil, from South Australia) (Figure 4). The fertiliser application enhanced root proliferation around the phosphorus band much more in the Kandosol compared to the Calcarosol.

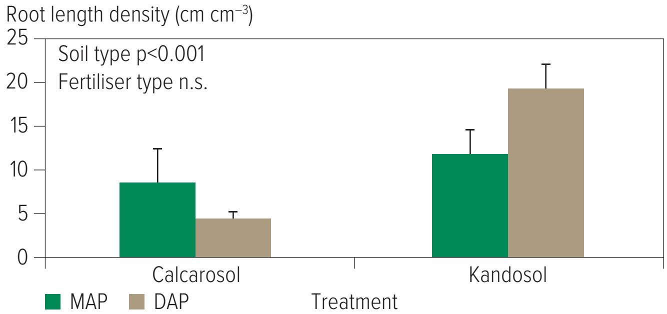
Figure 4: Root systems of wheat plants grown in the Calcarosol (A, B) and in the Kandosol (C, D) soils.



The two different phosphorus placements are, from left to right, DAP (A and C) and MAP (B and D), for each soil. The soil cores were examined with synchrotron techniques to a depth of 30cm (columns were 9cm in diameter).

Source: modified from van der Bom et al. (2024) submitted to *Plant Physiology*

Figure 5: Effect of MAP and DAP fertilisers on root length density on wheat plants grown in Calcarosol and Kandosol soils. Root length densities were measured in close vicinity of the phosphorus fertiliser band.



Source: modified from van der Bom et al. (2024) submitted to *Plant Physiology*

Implications for phosphorus fertiliser management

The research showed that phosphorus fertiliser selection and depth of placement strongly influenced root structure. The diffusion of available phosphorus away from the fertiliser granule is controlled by the fertiliser source and soil type and, therefore, the nature of fertiliser application should be tailored to soil type. In highly calcareous soils, phosphorus availability was particularly limited, and APP performed better than DAP and MAP.

Irrespective of the fertiliser applied, root density is much higher in the fertiliser banding region but the response in calcareous soils is more limited, possibly due to the reduced phosphorus availability from precipitation of calcium phosphate. Nutrient uptake is higher in high-density root zones and fertiliser granule placement can be managed to take advantage of soil moisture and other nutrient applications.

USEFUL RESOURCES

GRDC Fact Sheet (2012): *Crop nutrition: Phosphorus management* (Northern region).

GRDC Update Paper (2020): *Nutritional strategies to support productive farming systems.*

GRDC Update Paper (2022): *P dynamics in vertosols – factors influencing fertiliser P availability over time and the implications for rate, application method and residual value.*

GRDC Fact Sheet (2023): *Fertiliser deep banding.*

Find GRDC Fact Sheets and Update Papers on the GRDC website: grdc.com.au.

REFERENCES

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MORE INFORMATION

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