Adding organic matter in farming systems - impacts and optimisation of placement/timing for best results

David Lester[1], Michael Bell[2], Cameron Silburn[3]

[1] Queensland Department of Agriculture and Fisheries, Toowoomba
[2] University of Queensland, Gatton
[3] Queensland Department of Agriculture and Fisheries, Goondiwindi

Key words

organic carbon, nutrients, nitrogen, phosphorus, 4R

GRDC codes

UQ2204-010RTX, UNE2209-001RTX, USQ1803-002RTX

Take home message

- Surface spread applications of feedlot manures and composted products at sufficient product rate can contribute another nitrogen source to soils. The rate of release will vary with the material applied and weather conditions post-application
- Nitrogen uptake by plants is driven by mass flow processes, so the more that nitrate is distributed through soil water the better the recovery of N
- Immobile nutrients in surface spread products may have less potential for plant recovery due to being stratified
- Phosphorus and potassium uptake is driven by diffusion and need wet soils for roots to operate in before plant uptake occurs
- Subsurface placement of feedlot manures and composted products at high rates can be logistically challenging. Results comparing equivalent nutrient inputs from inorganic sources with composted feedlot manure has not shown any differences to-date.

Introduction

Organic products such as feedlot manures and composts from feedlots are another way to deliver nutrients for crop production. They have different physical and chemical behaviours from inorganic fertiliser products. There may be ways in which both are used and this paper is a discussion (opinion) piece exploring some of these.

Plant nutrient uptake pathways, soil nutrient behaviours and cereal root distributions

Devising more effective nutrient application strategies may be possible with greater understanding and assessment of how nutrients behave in soil and how they are acquired by plant roots. Nutrients can be grouped based on their behaviour with soil water movement – being either mobile or immobile. Plant roots have three nutrient uptake pathways: mass flow, diffusion and root interception. Foliar nutrient uptake is not discussed in this paper. Nutrient behaviour in water and the plant uptake pathway are linked.

Mobile nutrients

Mobile elements (nitrogen, sulfur) are acquired predominantly through mass flow. As plants extract water from the soil, the nitrate in that water is acquired. When soil water moves down the profile, nitrate is redistributed with it. But in our clay soils this, movement is a lot slower than in sands or loam soils. Rules of thumb suggest that movement of nitrate is about ¼ the speed of the wetting front. If the wetting front is minimal then movement of nitrate is extremely slow. In effect, the N will stay where it is. If the soil dries out enough to allow re-wetting, movement can recommence with that water movement.

The distribution of cereal roots can be conceptualised as an inverted triangle. Depending on rooting depth, root distribution can be thought of on a 40:30:20:10 ratio. In the top quarter of your rooting depth, 40% of the cereal roots will be there. In the next quarter – i.e., from 25 to 50% down the profile – the next 30% of roots will be. If you assumed you had 1.2 m of wet soil, 70% of the roots are going to be in the top 60 m. As soil depth increases down the profile, the roots decrease. From half to three quarters down there is 20% roots, and in the bottom quarter is the final 10%. Thirty percent of the cereal root system potentially is below 60cm. Seasonal variability will influence how much activity (water and nitrogen recovery) occurs from this layer.

This is one of the factors in segmenting soil profile samples for nitrogen budgeting. It allows some insight into the relative distribution of mineral water, nitrogen and potential cereal roots.

Immobile nutrients

Immobile nutrients like phosphorus (P) are the opposite of N in many ways. Phosphorus uptake is a diffusion driven uptake pathway and occurs at physically small scales such as a few millimetres in distance. Diffusion requires areas of concentration difference – high to low – creating a gradient.

In our northern region cropping soils, most P is present in inorganic forms, but the solubility of different forms of P varies. The fraction that is readily available for plant uptake is either in the soil solution at very low concentrations or held (sorbed) onto clay and organic matter particles. The sorption and desorption processes can occur rapidly, but the net effect is that at any time there is little P available in the soil solution.

This immobile behaviour means that P stays largely where it is put. Because of the strong affinity of clays and organic matter for P, roots have to be very close to a P source/high P concentration so that P can diffuse to the root without being sorbed to other particles. Effective P uptake therefore requires either low P concentrations across large soil volumes, with roots always able to grow into soil with available P (our soils before cropping, in many cases), or concentrated patches of high P availability (bands, slots) which stay moist and where roots can concentrate in large numbers. When relying on P fertilisers, placement is a critical success factor.

Due to the immobility of P, processes like redeposition of P left in above ground plant material after harvest has enriched surface layers with plant available P. The challenge in accessing these enriched layers in the northern region is the limited time the surface soil is wet and the simultaneous presence of active roots. High evaporative losses from the soil surface, and often infrequent and high intensity rainfall events, generally limit the opportunity for plants to utilise the surface enriched layers. More commonly, lower positions (>15cm) of the soil profile are wetter for longer so this is where roots will head into. The success of deep P applications has been about putting the nutrient into positions where the plant can access them.

Potassium is an interesting blend of these contrasting characteristics. It is still held on clay and organic matter surfaces and occurs in relatively low concentrations in soil water, so diffusion drives most plant uptake. This means in our high clay soils it also is effectively immobile, although in lighter soils it moves a little further than P. What is challenging, though, is that roots don't congregate around a patch of high K like they do with P, and so it is harder to get rapid uptake of K from a band – unless you put some P with K, to act as an agent to ensure roots get interested and congregate in that area.

As a result, the behaviour of different nutrients in soil impacts how we should apply different nutrients in clay soils. We need to ensure that the application method used in each field is suitable for the nutrient being applied, and increasingly we are seeing that we may have to adopt different application strategies to achieve good crop recovery of N compared to P and K.

Nutrient application strategies – what role might organic products have?

The release rate of nutrients from inorganic or organic nutrient sources can influence how and where these products are best used. The previous section introduced the ideas of nutrient mobility and immobility. These then can be used in thinking about a nutrient application framework such as the 4R's: right source, right rate, right time, right place.

Organic products deliver nutrients in a diverse range of forms. For nitrogen, the organic material the nitrogen is in has to be microbially decomposed to release it. Rates of decomposition vary depending on how much it has already been processed (was it fresh or composted), and the weather post application (temperature and rainfall). Rates of microbial processing are then variable, but a rule of thumb for feedlot composts is 60:30:10 (Dowling pers comm). Sixty percent of the nitrogen will (in general) come out in the first 12 months, 30% in the second year, and the final 10% in the third year.

This contrasting release pattern compared to urea application for example, can be used to redistribute nitrogen into the profile over an extended period. As it rains, the applied manure/compost decomposes further releasing some nitrate as a decomposition product, and that can be moved into the soil profile with a wetting front as rainfall recharges the soil water profile.

We need that profile movement to put the nitrate into parts of the soil profile where crop plants can acquire it when needed.

For P and K in manure/composts, the story may not be as clear cut. Surface spreading the material without incorporation will further enrich the soil surface. As discussed, there is no water movement of P and K into the profile, only physical movement. While applying P and K to the surface may be beneficial from a nutrient balance perspective, it may not supplement plant availability, as the P and K applied may be in a place the roots cannot access when needed.

What about subsurface placement of organic materials?

Given the generally low nutrient concentration and the physical handling characteristics of organic materials, placing enough product at depth is a challenging undertaking. High rates of application could be surface spread, then mixed through the upper profile using more aggressive tillage machines such as double offset disks, or chisel ploughing. The depth of incorporation will still be relatively shallow at 15-20cm depth.

Subsurface banding to improve plant access to P and K in organic products becomes problematic, because of the relatively low nutrient contents and the need to deliver high rates of material to be effective.

Some research comparing a subsurface organic matter treatment (10 t/ha of composted feedlot manure delivering 280 kg N/ha and 100 kg P/ha), and equivalent nutrient input in the form of inorganic fertilisers (urea and mono-ammonium phosphate) has been done in a project investigating the amelioration of soil sodicity. Results to-date have not suggested any differences between different sources of nutrients(Lester *et al.* 2022).

Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC, the author would like to thank them for their continued support.

References

Lester, DW, Silburn, C, Birchall, C, Flavel, RJ, Guppy, CN, Maclean Bennett, J, Roberton, SD, McKenzie, DC (2022) Ameliorating sodicity; what did we learn about ameliorating sodicity constraints with a range of treatments? Yield responses to ripping, gypsum and OM placement in constrained soils. In

'GRDC Grains Research Updates. (Grains Research and Development Corporation (GRDC). Available at https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2022/03/ameliorating-sodicity-what-did-we-learn-about-ameliorating-sodicity-constraints-with-a-range-of-treatments-yield-responses-to-ripping,-gypsum-and-om-placement-in-constrained-soils [Accessed 3 November 2022].

Contact details

David Lester
Queensland Department of Agriculture and Fisheries
PO Box 2282
M: 0428 100 538
E: david.lester@daf.qld.gov.au