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Shaping profitable and sustainable farming

GUIDANCE NOTE

Minimising phosphorus losses from agricultural systems when using phosphorus fertilisers

How does phosphorus in agriculture relate to water quality issues?

Loss of phosphorus (P) to ground and surface water can be linked to deteriorating water quality. Phosphorus is an essential element for plant growth, and when the conditions are right—for example adequate light and temperature—phosphorus in waterways supports growth in aquatic weeds and algae. If excessive, this can lead to eutrophication of waterways.

The P concentration that would result in natural waters being classed as degraded, is relatively small. Some water resources are considered degraded or poor when the dissolved reactive phosphorus (DRP) concentration exceeds 0.018 mg/L. For example, about 30 g or 15 cm3 (half a matchbox full!) of P in an Olympic sized swimming pool.

How do you manage fertiliser applications to minimise their environmental impact?

The 4Rs

Applied to nutrient use on farm, it helps reduce particulate P and dissolved reactive P (DRP) or dissolved organic P (DOP) losses.

- **R**ight place
- **R**ight time
- **R**ight rate
- **R**ight form

If the 4R principles are adopted, then direct fertiliser P losses generally contribute less than 10% of total farm P losses. If managed very poorly, direct losses can be up to 85% of fertiliser P applied. The reasons for these differences in P loss outcomes when using phosphorus fertiliser, and the importance of following good stewardship practices, is the subject of this guide.

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How does phosphorus get into water?

P loss occurs primarily by two main processes.

1. P attached to soil and/or animal dung particles (particulate P) is transported across the landscape where it is at risk of entering surface water (where P can desorb into the water).
2. P dissolved in water (DRP, DOP).

Overland flow occurs where rainfall or irrigation exceeds vertical drainage, especially when soil is already saturated. Overland flow carries particulate or dissolved P across the land surface. In rolling or steeper land, particulate P loss usually makes up the greatest proportion of total P loss from any farm system.

Subsurface flow carries P dissolved in water draining through the soil matrix (leaching). It includes water movement either through the soil matrix, soil macropores or soil interflow.

Interflow is where water moves laterally without reaching ground water. Artificial drains can provide direct connectivity to receiving surface water.

In general, the higher the soil phosphorus content, the greater the P load in particulate matter, and the greater the opportunity for water moving through the soil matrix to increase the dissolved P concentration.

Although P loss is associated with natural fertility, fertiliser plays a pivotal role in raising soil fertility and if not managed well, farm P losses.

In flat land, dissolved P (DRP and DOP) can play a larger role than particulate P. Reducing DRP and DOP loss can be achieved by mitigations such as reducing the amount of P applied – especially on soils with low anion storage capacity and avoiding the application of farm dairy effluent to wet soils. While not directly related to fertiliser P, leaching of P from farm dairy effluent has also been shown to be a significant source of P loss on free draining soils.

P can also be removed from water by being adsorbed back on to soil particles or organic matter as water drains through soil. This opportunity to remove P from the soil water depends on:

a) soil attributes (e.g. soil structure, anion storage capacity, [ASC])
b) proximity and time of the soil contact.

However, dissolved P moving through macropores can effectively by-pass the soil, especially if it enters sub-surface drains, or soils are very shallow.

Components of P loss from grazed systems

There are two components of P loss from grazed systems (see Fig 1).

a) Systematic (i.e. influenced by background conditions).

b) Incidental (i.e. influenced by recent management conditions, e.g. fertiliser effects and grazing effects).

Management decisions and critical incidents will increase P exports (incidental) over and above those that would have otherwise occurred (systematic). Risk of incidental losses is greatest if drainage or surface flow events occur soon after application of soluble phosphate fertilizer, or soon after grazing (up to about 20 days). An overall increase in soil fertility can increase the systematic 'baseline' losses.

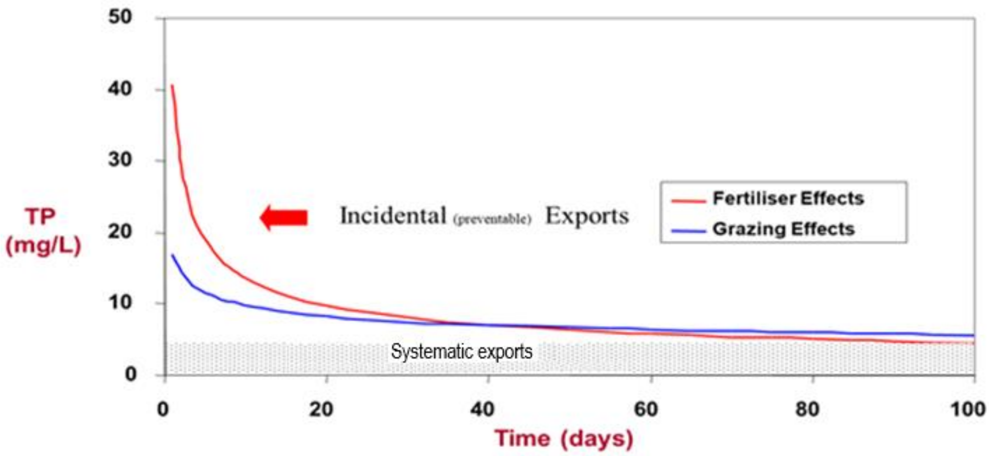

Figure 1: A diagrammatic representation of systematic phosphorus losses and fertiliser and grazing effects on phosphorus concentrations in overland flow as dissolved P.

How do losses from grazing occur?

Soil disturbance through cultivation, cattle treading and flowing water can all contribute to releasing 'particulate P' from soil. Factors that increase water velocity (e.g. slope) and turbulence (e.g. obstructions) generally increase detachment and transport rates.

'Dissolved P' sources are more complex and include the availability of soluble P (fertiliser, dung and urine), the ability of the soil in the immediate vicinity to hold P, and the time available for soil and water to mix.

Grazing increases water available P in the mixing layer at the soil surface and this is an important consideration at times of the year when overland flow is more frequent.

How do losses from P fertiliser occur?

P fertiliser applications contribute initially to the incidental losses. After time, through raised soil fertility, it can also contribute to the baseline (systematic) losses.

For this reason, phosphorus fertiliser application should target soil fertility levels no higher than the agronomic optimum. This should be managed through a soil testing programme.

When applied to soil, even in quite dry conditions, water-soluble granular fertilisers absorb water. Surface-applied superphosphate is initially wetted directly from rainfall or irrigation, by capillary uptake of water, and by vapour transfer from the soil or atmosphere.

The risk of recently applied fertilisers on P being lost to overland flow, tends to reduce relatively quickly (Figure 1). Field monitoring of rainfed and border-check irrigation systems suggest that the effects of fertiliser application and grazing on P concentration in overland flow can be half within 3 or 4 days, with 95% confidence intervals of about 3 to 8 days. (These were pastures where most P was exported in overland flow as dissolved P.)

This reduction in P exports occurs because P from water-soluble fertilisers moves into the soil, away from the mixing layer (i.e. soil surface). This, along with other soil processes, results in that P becoming less accessible to overland flow. The more time between application of soluble P and any overland flow or subsurface flow event, the less phosphorus is available for dissolved P exports.

Therefore, low water-soluble fertilisers lend themselves to use in areas with frequent rainfall or considerable sub-surface drainage and poor soil P sorption, with a low anion storage capacity (ASC< 15). This is due to an increased risk of dissolved P exports under these circumstances.

How do you reduce the particulate P losses?

Reducing the loss of particulate P is achieved by preventing soil and excretal P loss by using mitigations such as (but not exclusively):

- well-timed fertiliser applications
- precision cultivation
- appropriate stock grazing management practices to reduce treading damage
- limiting the time of stock on pasture—especially in winter
- maintaining good ground cover
- riparian planting
- use of sediment traps.

The 4R principles are central to minimising the risk of environmental impacts.

Minimising DRP/DOP losses using the 4Rs for the application of P fertiliser

In priority order, the following should be considered when applying P fertiliser.

1. Right placement

This is currently achievable with accurate GPS mapping, proof of placement, spreader control technology by ground and aerial application and irrigation management tools.

a) Identify and manage critical source areas. For example:

- where run-off occurs more frequently than other parts of the farm
- near stream margins i.e. fertiliser set back as appropriate for land-form (e.g. 10–15m on gentle slopes)
- soils with poor anion sorption capacity (ASC) i.e. <15%
- mole and tile drained soils.

Avoid or manage phosphorus applications to identified critical source areas, as appropriate to the control the risk of phosphorus loss.

2. Right timing

This is currently achievable with strategic and tactical timing, guided by an agronomy plan, operationally guided by local meteorological forecasting, and farmer knowledge of hydrophobic areas or other areas with a risk of run-off.

a) Do not apply soluble P fertiliser if rainfall likely to produce runoff is predicted within 7 days of application. Run-off can occur in winter due to saturation or in warmer months due to soil hydrophobicity.

3. Right rate

This is currently now made easier and more accurate with computerised fertiliser application technology, such as automated variable rate applicators to maintain the correct rate even as speed varies.

a) Apply only enough capital fertiliser to raise Olsen P to the agronomic optimum.

b) Apply only enough maintenance fertiliser to stay at the agronomic optimum.

c) For soils unable to retain much P, low ASC soils (<15%), i.e., podzols, organic and semi-arid soils, reduce the rate of P applied and consider alternate crops (with lower P requirement).

On irrigated soils

a) Minimise P inputs to low ASC soils (<15%).

b) Minimise P inputs to soils with shallow and/or stony topsoil.

Note: Manage irrigation to minimise bypass flow and avoid run-off.

4. Right form

Consider the use of lower water-soluble P fertiliser forms if you cannot meet all the above guidance. That is, consider applying less water-soluble forms of P fertiliser to:

a) High risk soils

- Soils with ASC <15%.
- Shallow and stony soils.
- Mole and tile drained soils.

b) Where climatic-related risk prediction is too uncertain. For example:

- prediction of intense rainfall events inducing surface runoff within 14 days of application
- prediction of soil hydrophobicity.

Conclusion

Following the 4R principles for P fertilisers can reduce P losses from grazing systems.

By understanding the processes responsible for P mobilisation, and the pathways through which P may be exported, it should be possible to mitigate the short-term risks associated with fertiliser use. This is done through diligently optimising placement, timing and rates of application along with prudent selection of compounds and formulations (appropriate for the soil and site conditions).

When applying the 4R nutrient stewardship principles, understanding the climate, hydrology and soil attributes of individual farming systems is the key to optimising production and minimising environmental impact.

Acknowledgement

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Source: http://flrc.massey.ac.nz/workshops/20/paperlist20.htm

Further information

Fertiliser Use on New Zealand Sheep and Beef Farms

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