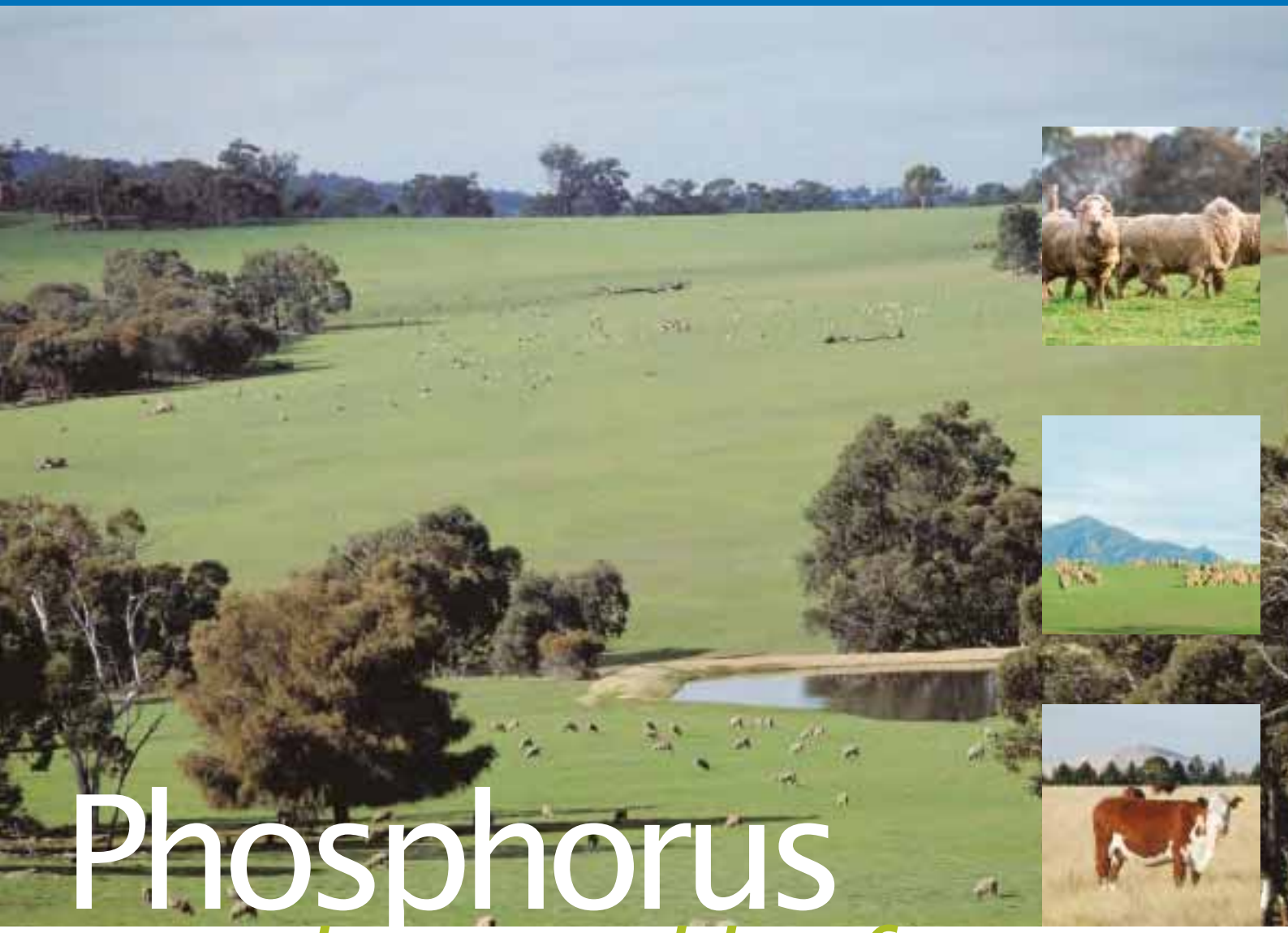


Phosphorus

for *sheep and beef* pastures

Victoria Department of Primary Industries

Department of Agriculture Government of Western Australia

australian wool *another* innovation limited

Phosphorus for sheep and beef pastures

Farm profitability is linked closely with the correct use of fertiliser.

The key to successful pasture production is the combination of well-fertilised and high-quality pastures, stocked at an appropriate grazing pressure, with livestock of high genetic merit.

Decisions about fertiliser are among the most important made on grazing properties each year. This package has been produced to help Western Australian sheep and beef cattle producers make more informed decisions about applying phosphorus fertiliser to pastures. We have used the outputs from Woolmodel©, a model developed to suit conditions in Western Australia, together with information from other Australian research to make this process easier.

This package assists producers to:

- decide how much phosphorus to apply to particular paddocks
- decide what type of phosphorus fertiliser to use
- plan a soil phosphorus monitoring program
- decide which paddocks have the greatest need for fertiliser.

Contents

Abbreviations

cm	centimetre
DSE	dry sheep equivalent
g	grams
ha	hectare
kg	kilogram
mg	milligram
mm	millimetre
K	potassium
N	nitrogen
P	phosphorus
ppm	parts per million
S	sulphur
t	tonne
µm	micron
WA	Western Australia
yr	year

The key message of this package is that the old rule of thumb of one kilogram of phosphorus per dry sheep equivalent can be greatly refined to improve profitability, reduce the potential for damage to waterways and the wider environment.

The annual amount of phosphorus per dry sheep equivalent (kg P/DSE) needed to maintain productivity varies from 0.72 to 2.42 kg P/DSE, depending on rainfall, soil type and grazing enterprise.

NOTE

Recommendations in this brochure assume that all major and trace elements are in adequate supply and high soil acidity has been corrected. It is crucial to ensure the soil can provide an adequate supply of all essential nutrients to get the full benefit from applied phosphorus. A deficiency of one nutrient will limit the potential response to all other nutrients.

Phosphorus in grazing systems

Phosphorus is essential for all living things. It is required for respiration, photosynthesis, energy expenditure, cell division and growth, and the uptake and movement of nutrients. In animals, phosphorus is a major constituent of bones, teeth and the central nervous system.

The phosphorus in a grazed paddock moves continuously between the soil, plants and animals (Figure 1).

Some phosphorus may be lost from the grazing system through soil reactions and the movement and management of livestock. If insufficient fertiliser phosphorus is applied to balance these losses, the soil phosphorus status of the paddock will fall. Eventually productivity will also fall.

Soil losses

Phosphorus in dung and plant litter is unavailable to plants until the organic matter is mineralised (broken down) by micro-organisms in the soil.

Phosphorus in the soil will react with iron and aluminium to form insoluble compounds. This phosphorus is known as fixed or sorbed phosphorus. It cannot be used directly by plants but over time may become available through weathering of the soil particles.

Other losses of phosphorus occur by leaching (especially in acid sandy soils), run-off following heavy rain immediately after fertiliser application, and soil erosion.

The amount of phosphorus lost due to soil factors varies with soil type and increases with rainfall.

To maintain an adequate soil phosphorus status, the phosphorus lost from each paddock through soil and animal processes must be replaced

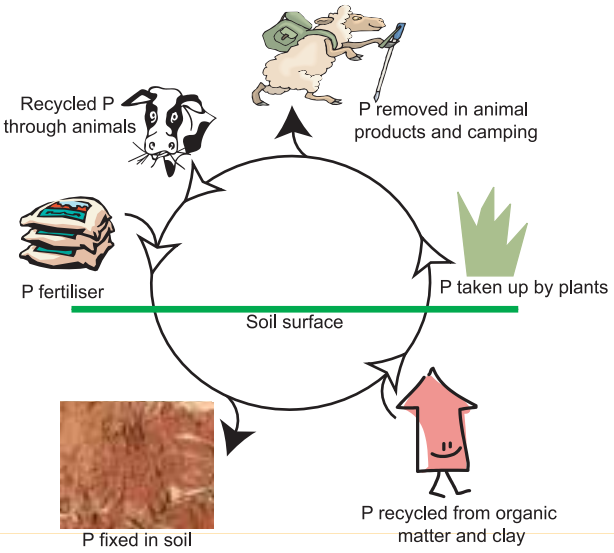
Animal losses

A high proportion of the phosphorus consumed by livestock returns to the soil in dung and urine, but much of it is transferred to stock camps within the paddock, leading to a net loss of phosphorus from the main part of the paddock. Stock camps are more pronounced on hilly terrain and set stocked areas, and less pronounced on flat areas or where paddocks are rotationally grazed.

Some phosphorus is exported from the grazing system when animals, meat, milk or wool leave the farm.

If insufficient phosphorus is applied, the phosphorus status of the paddock will fall and eventually productivity will also fall

Figure 1. A simplified phosphorus (P) cycle showing the continuous movement of phosphorus in the animal grazing system and potential loss pathways. After Cornforth and Sinclair (1982).



Research leads to better decision making

Grazing studies show a close relationship between inputs of phosphorus and profitability.

This has led to recommendations for maintenance fertiliser applications based on a kilogram of phosphorus per dry sheep equivalent (kg P/DSE). This approach is better than previous methods, which were based on results from soil tests. Recommendations based on a rate of phosphorus per DSE ensure paddocks with the highest stocking rates receive the most fertiliser, rather than all paddocks receiving the same fertiliser rate irrespective of stocking rate.

Widespread recommendations across farms and districts of a single kg P/DSE rate are incorrect because the amount of fertiliser required will also depend on soil type, the animal enterprise and potential productivity of the system.

The principle applied in this decision support package is to apply sufficient phosphorus fertiliser to account for all losses from the grazing system. These losses increase as stocking rates increase, and are also greater when more phosphorus is removed from the grazing system as animal product.

This package uses the Woolmodel©, developed in Western Australia, to calculate the kg P/DSE to achieve maximum profit for a range of soil conditions and rainfall. The predictions from Woolmodel apply to wool production from wethers only.

Research elsewhere in Australia and New Zealand has shown the phosphorus requirement for maximum profit varies with the animal enterprise. The phosphorus requirement for wethers is less than for breeding stock. Systems producing prime meat (lambs or beef) require the most phosphorus to support the high growth rates of stock and high removal of phosphorus from a meat production system. Predictions of the phosphorus required for breeding stock or prime meat production in this package are based on differences between these systems and wool production from wether systems. We have used results from New South Wales to do this.

Grazing studies show a close relationship between inputs of phosphorus and profitability

How much phosphorus is needed?

This package enables recommendations for application rates of phosphorus (kg P/DSE) to be tailored for individual paddocks on each farm.

To make decisions on how much phosphorus fertiliser to apply to an individual paddock on your farm, to support the desired production level and maintain adequate soil phosphorus levels, you will need to know:

- soil type
- average rainfall
- annual stocking rate expressed as DSE/ha
- animal enterprise
- phosphorus content of the fertiliser

The amount of phosphorus required per DSE can be determined using the Ready Reckoner attached to this package or using the tables on page 6. An example of how to use the tables is given opposite.

Instructions for using the Ready Reckoner

1. Select the relevant soil phosphorus fixing class based on your soil type.

2. Move the black arrow above the window to opposite your average annual rainfall within that class.

3. The appropriate kg P/DSE required to maximise profit is shown in the window opposite each stocking rate.

4. Calculate the amount of phosphorus to apply per hectare by multiplying the kg P/DSE by the average annual stocking rate for the paddock or farm.

5. If your stocking rate or rainfall differs from the table then use intermediate or average values of kg P/DSE.

An example calculation

The soil type in your paddock is a yellow-brown gravely sand (jarrah/banksia gravel). The farm is located in a 600 mm rainfall zone.

➨ ***Table 1 indicates that your soil type has medium phosphorus fixing capacity***

Stocking rate is best determined using one of the commercially available farm management computer programs that calculate the yearly stocking rate from paddock records. A computer spreadsheet to calculate stocking rate from paddock records is available from the WA Department of Agriculture.

Alternatively, the DSE values for different classes of livestock are shown in Table 2. Use paddock records and Table 2 to determine your stocking rate. If individual paddock information is not available use average stocking rates for the farm.

For the example calculation, assume the paddock runs 50 kg wethers at 5 head/ha.

➨ ***Using Table 2, stocking rate is calculated to be 1.0 DSE x 5 animals/ha which equals 5 DSE/ha.***

Having determined the phosphorus fixing capacity for your paddock, and taking into account the 600 mm rainfall and 5 DSE/ha stocking rate, use Table 3 to determine the appropriate phosphorus rate per DSE for your paddock.

➨ *1.24 kg P/DSE is the recommended phosphorus requirement*

The amount of fertiliser to apply per hectare can be determined using the following equation:

$$\textbf{Fertiliser requirement} = \frac{100 \times \text{kg P/DSE} \times \text{DSE/ha}}{\%P}$$

If single super (with 9% phosphorus) is used, the fertiliser application rate will be:

➨ $\frac{100 \times 1.24 \times 5}{9} = 69$ **kg single super/ha**

Table 1. Phosphorus fixing capacity according to soil type.

Phosphorus fixing capacity	Soil type	Description
Low	Gravel	Bleached (grey) gravelly sands (jarrah/banksia gravel)
	Sands	Grey-brown sands (paperbark sands) Deep, sandy duplex soils (more than 30 cm sand over clay)
Medium	Loams	Grey-brown loams (marri/paperbark loams)
	Gravels	Yellow-brown gravelly sands (jarrah/banksia gravels) Bleached (grey) gravelly sands
	Sands	Yellow-brown sands (jarrah sands) Shallow, sandy duplex soils (less than 30 cm sand over clay)
High	Clay	Brown to black clays (Bungham clays)
	Loams	Red to yellow-brown loams (karri/marri loams) Loamy duplex soils (wandoo/marri/flooded gum loams)
	Gravels	Yellow-brown gravelly loams (jarrah/wandoo gravels) Red-brown gravelly loams (marri/karri gravels)

Adapted from Agriculture WA bulletin 4302

Table 2. Dry sheep equivalent (DSE) values for different classes of livestock, at different liveweights.

Sheep	30 kg	40 kg	50 kg	60 kg
Dry ewes or wethers (maintaining weight)	-	0.9	1.0	1.2
Last month of pregnancy (singles or ***twins***)	-	1.2 / ***1.4***	1.4 / ***1.6***	1.6 / ***1.9***
Lactation (singles or ***twins***)	-	2.6 / ***3.7***	2.7 / ***3.9***	2.9 / ***4.4***
Weaners (growth rate 100 g/day)	1.1	1.3	-	-
Average (year) ewe	-	1.5	1.6	1.8

Beef cattle	400 kg	500 kg	600 kg
Dry cows or store steers (maintaining weight)	6	7	8
Dry cows or store steers (growth rate 0.5 kg/day)	8	11	12
Dry cows or store steers (growth rate 1.0 kg/day)	11	13	15
Last 3 months of pregnancy	8	9	11
Cows with 0-3 month calves	13	14	17
Cows with 3-9 month calves	19	21	24
Average (year) cow	15	16	19

Table 3. Predicted phosphorus application rate (kg/DSE) for maximum profit of wethers[1] for a range of conditions.

Phosphorus fixing capacity	Stocking rate (DSE/ha)	Annual Rainfall (mm)			
		400	*500*	*600*	*700*
Low	3	0.94	0.84	0.78	0.72
	5	1.02	0.96	0.88	0.78
	8	*	1.14	1.00	0.88
	12	*	*	*	1.00
Medium	3	1.28	1.24	1.16	1.08
	5	1.38	1.36	1.24	1.14
	8	*	1.52	1.38	1.24
	12	*	*	*	1.36
High	3	*	2.14	1.96	1.78
	5	*	2.24	2.04	1.84
	8	*	2.42	2.18	1.94
	12	*	*	*	2.08

1 For breeding stock add 0.1 to the recommended kg P/DSE and for prime meat production add 0.2 to the recommended kg P/DSE.

* indicates that either the stocking rate is too high to sustain the stock without supplements, or that gross margins will fall if the stocking rate is increased to this level.

Testing and monitoring soil phosphorus

Soil tests for phosphorus are used to assess the ability of a soil to supply phosphorus to plants. These tests also give a measure of the quantity of biologically active phosphorus in grazing systems.

In Western Australia, soil phosphorus is measured using the Colwell extraction method. The result is generally referred to as a Colwell P and expressed as milligrams of phosphorus per kilogram of soil (mg/kg).

When the Colwell P falls below about 20 mg/kg, annual and perennial ryegrasses fail to persist and the proportion of poor quality grasses (such as Guildford grass and silver grass) and broadleaf weeds increases. Table 4 shows the acceptable ranges (medium status) for Colwell P taking into account soil buffering capacity.

Apart from measuring phosphorus for maintenance requirements, the most effective way to use soil tests, is for measuring ***trends*** in nutrient status from one year to the next. Results from soil testing can be variable and influenced by many factors including sampling time, location and depth.

Soil sampling

To get the most reliable results and detect a trend from a soil test, it is necessary to:

- Take soil samples from the same places within a paddock at the same time each year.
- Take samples between November and March, before the start of the growing season.
- Mark your sampling path across the paddock by painting fence posts white, or by marking a landmark. More detailed instructions are given in soil sample kits.
- Take at least 30 sub-samples along the sampling path at regular intervals (e.g. each 10-15 paces). Avoid taking samples from stock camps, under trees, at watering points or along headlands.
- Take samples with a sampling tool which removes a 10 cm deep core of soil - the concentration of phosphorus in the soil falls off rapidly with depth, so it is vital to collect all samples at the same depth; and make sure that the bottom end of the sample doesn't fall out of the sampler as it is removed from the soil.

Monitor paddocks

Between 10% and 20% of paddocks on a farm can be designated as monitor paddocks and tested every two years. Monitor paddocks should represent a cross section of hay/silage, high stocking rate and low stocking rate paddocks. Other paddocks can be tested every 5 to 10 years.

Regular soil testing will prevent excessive quantities of fertiliser being used in future years. Changes in the trend of soil phosphorus values should be used to revise whether you have a low, medium or high phosphorus fixing soil. For example, if a medium fixing soil has been used, and the soil phosphorus level falls over time, try using a high soil fixing class for that paddock or soil type.

Other information

In addition to soil phosphorus levels, soil tests can give other valuable information about a soil, such as status and trends of other nutrient or changes in soil acidity.

In addition to phosphorus, the nutrients most likely to be deficient in Western Australia are sulphur, potassium, nitrogen and trace elements, copper, molybdenum and zinc.

Sulphur status should be confirmed with a tissue test, which can also be used to assess and monitor trace element status.

Soil tests also report ***reactive iron*** and ***phosphorus retention index*** which are used to determine the buffering capacity of soils, i.e. the ability of the soil to 'lock up' phosphorus. These tests help determine the phosphorus requirement for a soil.

Guidelines for lifting soil phosphorus levels

A clay loam soil needs about 5 kg/ha of phosphorus in excess of maintenance (i.e. in excess of the kg P/DSE shown in Table 1) to increase the Colwell P by 1 mg/kg.

Slightly lighter textured soils require only 3 kg phosphorus in excess of maintenance to increase Colwell P by 1 mg/kg.

Soils that fix large amounts of phosphorus, such as red clays, need as much as 7 kg/ha of phosphorus in excess of maintenance to increase Colwell P by 1 mg/kg.

The most efficient way to use soil tests is to use them to measure trends from one test to the next

Photo courtesy of Department of Agriculture WA

Photo courtesy of Department of Agriculture WA

The following generalisations apply to all soils:

- The higher the phosphorus status of a soil, the greater the amount of fertiliser phosphorus required to maintain that status.
- The higher the phosphorus status of a soil, the bigger will be the drop in phosphorus if no fertiliser is applied.
- For well-utilised paddocks with a high phosphorus status, omitting to fertilise can lead to shortages of feed in winter if a high stocking rate is to be maintained.
- At medium ranges of soil phosphorus (Table 4) there is need for maintenance levels only of phosphorus fertiliser.

For productive pasture systems, the desired Colwell P should take into account the soil buffering capacity

Table 4. Phosphorus status (Colwell P - mg/kg) for different soil buffering capacities

Reactive iron (ppm)	P retention index	Low mg/kg	Medium mg/kg
1 - 200	< 2	< 8	7 - 13
201-400	2 - 7	< 15	15 - 20
401 - 800	7 - 15	< 20	20 - 25
801 - 1600	16 - 35	< 25	25 - 30
> 1600	> 35	< 30	30 - 35

Adapted from Agriculture WA bulletin 4302

Phosphorus fertilisers

Phosphate rock is the main source of phosphorus used in the manufacture of fertilisers in Australia and overseas. This material is insoluble in water, and therefore the phosphorus it contains is unavailable to plants.

Superphosphates are the most common fertilisers used to supply phosphorus to sheep and beef pastures. Superphosphates are produced by reacting phosphate rock with acids, changing the phosphorus in the rock to a form that is water soluble and available to plants.

Some phosphatic rocks, called reactive phosphatic rocks or RPRs will react with wet acid soil, releasing the phosphorus in a form that plants can use. Research in Western Australia has shown that RPRs are not an economic alternative to existing phosphate fertilisers. More information on the use of RPRs on Australian pastures is available on the internet at: **http//www.latrobe.edu.au/rpr**

The type of phosphorus fertiliser to use depends on the phosphorus and sulphur status of the soil, and to some extent soil type.

Phosphorus status

If soil phosphorus levels are low or below adequate, the most efficient phosphorus fertiliser to use to increase phosphorus status is triple superphosphate. In most cases, single superphosphate is the most efficient fertiliser to maintain fertility.

Sulphur status

Where a soil test indicates a high level of available sulphur, the use of low sulphur fertilisers such as triple superphosphate is warranted, especially if these are the cheapest source of phosphorus. If sulphur levels are low, single superphosphate, with 11% sulphur, or a sulphur enhanced product is the best to use.

Single superphosphate is the most efficient fertiliser to maintain fertility, whilst triple superphosphate is the most efficient to increase soil phosphorus levels

Likelihood of acidification

For soils prone to acidification, particularly those with a light-textured topsoil and organic carbon less than 2.5%, the pH of the soil must be monitored. When soil pH($CaCl_2$) falls below 5.0, pH balance should be restored with applications of lime.

Publications providing more information about the management of soil acidity are listed in Further reading on page 14.

Fertiliser for hay and silage paddocks

Large quantities of nutrients are removed when hay or silage is made. Pasture hay contains about 0.25% phosphorus and 2% potassium, so a 2.5 t/ha hay crop removes about 6 kg P/ha and 50 kg K/ha.

If the fodder is not fed back onto the paddocks from which it was made, the nutrient status of the paddock will decline.

A fertiliser program on hay and silage paddocks should aim to replace the phosphorus and potassium in the hay or silage, *in addition* to phosphorus removed through livestock (kg P/ha) and *in addition* to any phosphorus required to bring the soil phosphorus up to maintenance levels.

Regular soil tests should be taken in summer/early autumn to monitor fertility of hay and silage paddocks.

Removing hay and not feeding it back will also gradually acidify the soil. About 75 kg/ha of lime is required to compensate for the effect of removing a 2.5 t/ha hay crop.

Photo courtesy of Mal Brown

Priorities for phosphorus fertiliser use

The phosphorus application program over the whole property will be a staged process taking into consideration logistics and economics.

The values in Table 3 will help decide the optimum amount of phosphorus to apply to different paddocks, or major soil types within the farm, thereby maximising the investment for each kilogram of phosphorus applied.

It is possible to further prioritise phosphorus applications based on paddock use, pasture composition and soil tests.

The information below is based on practical experience of factors that drive responses to phosphorus fertiliser.

Proposed use

Paddocks with the greatest need for phosphorus are those that run pregnant, lactating or fattening stock, or where hay or silage is to be made. Phosphorus fertiliser improves pasture nutritive quality, as well as pasture production, and stock will respond profitably to high quality herbage.

Anticipated stocking rate

The need for phosphorus fertiliser increases as the stocking rate increases and more pasture production is required.

If available pasture contains more than 10% old pasture (on a dry matter basis) in August, the pasture is under-used or over-fertilised. Alternatively, poor quality pasture may be preventing stock eating all that is available.

Pasture type

Paddocks can be classified into different categories depending on their potential response to phosphorus fertiliser. For a given soil test value, it is likely that the paddocks with the best pasture composition will give the highest response to phosphorus fertiliser.

Spreading the same amount of fertiliser per hectare over the whole property is unlikely to give the best return for the money invested

Four different pasture types are listed in order of priority for phosphorus fertiliser applications:

1. **Re-sown pasture:** applying fertiliser on re-sown pasture protects the investment already made. It is essential to apply adequate nutrients following pasture renovation.
2. **Good pasture:** pasture that consists mainly of sown grasses and annual or perennial legumes.
3. **Moderate pasture:** sown grass and clover is present, but there is also Guildford grass or silver grass. Capeweed and barley grass may also be present.
4. **Poor pasture:** run-down pasture where sown species are inconspicuous, and the sward is dominated by Guildford grass and silver grass. Sub clover, if present, is stunted with small dark-green leaves indicating nutrient deficiency.

Pastures dominated by Guildford grass, silver grass, brome grass or native grasses respond less to fertiliser than improved pastures

Phosphorus status of paddock

The lower the soil phosphorus status the greater the likely response to phosphorus fertiliser, provided other nutrients are non-limiting and the pasture is not run down.

If the soil phosphorus level is not known, consider the amount of phosphorus applied in the last four years or the soil test results from similar paddocks. It is best, however, to soil test the paddock.

Other soil-related factors

Excessive salinity, high aluminium, excessive acidity, waterlogging or a lack of water-holding capacity will limit the extent to which pastures will respond to phosphorus.

Responsible fertiliser use

A well-fertilised and well-managed improved pasture is responsible land management. The benefits from dense, subterranean clover based pastures on fertile soils are:

- improved ground cover
- reduced water run-off
- higher water use than low fertility sites

Most soils readily 'fix' applied phosphorus, where it remains in the top few centimetres of soil. However, even small amounts of phosphorus can contribute to environmental problems in waterways, impacting on flora and fauna habitat and, ultimately the marine environment. Algal blooms in waterways and estuaries have already been caused by excessive use of phosphorus fertilisers in Western Australia.

Dissolved phosphorus can easily leach down into the watertable in sandy soils or it can move across the soil surface if the soil is saturated with water.

On clay soils the phosphorus becomes attached to clay particles and is washed with the clay into nearby waterways.

Research into the effects of phosphorus is continuing at several sites with the aim of lifting productivity and minimising environmental impacts.

Best practice in applying phosphorus fertiliser can minimise nutrient loss and reduce any impact on the environment.

Current best practices for fertiliser application are:

- Avoid applying fertiliser when ground cover is less than 70%, or land is over-grazed, or affected by drought or fire
- Do not apply phosphate fertilisers near dams, streams, rivers or drains - the phosphorus will move to lower parts of the landscape and pollute water
- Avoid high stock densities in areas near drains in winter - stock will pug the soil and cause clay to move when heavy rain occurs
- Do not apply fertiliser if heavy rain is forecast within four days
- Avoid applying fertiliser to waterlogged soils or soils likely to flood soon after application
- Locate fertiliser storage areas away from potential run-off areas.

Best practice in applying phosphorus fertiliser can minimise nutrient loss and reduce any impact on the environment

Phosphorus fertiliser is best applied in autumn to paddocks with at least 70% ground cover

Further reading

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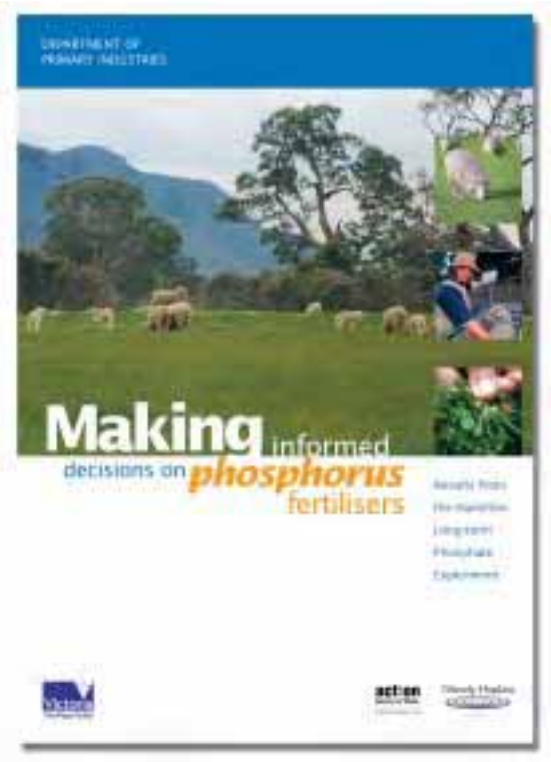

A summary of the results from the Hamilton Long-term Phosphate Experiment is reported in the publication: *Making informed decisions on phosphorus fertilisers* and is available from:

Primary Industries Research - Victoria
Department of Primary Industries
Private Bag 105,
Hamilton Vic, 3300

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