NSW DPI

Fertilisers for Pastures

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Natural Heritage Trust
Helping Communities Helping Australia
A Commonwealth Government Initiative

Hawkesbury-Nepean CMA Catchment Management Authority

NSW DEPARTMENT OF PRIMARY INDUSTRIES

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Much of the information is derived from a recent major project (DAN 088) *Optimising Phosphorus Fertiliser Use on Dairy Farms – NSW* conducted on the dairy farm at Elizabeth Macarthur Agricultural Institute, Camden and funded by NSW Department of Primary Industries, Dairy Australia, Incitec-Pivot and Canpotex. The findings have been combined with results from other fertiliser trials carried out over many years.

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Mike Keys, Rebecca Lines-Kelly, Amanda Mather, Carol Rose, Tony Ross, Angus Gibson, Nick Sherwood, Bill Inglis and Georgia Davies.

NOTE

Livestock health disorders
Pasture improvement through the use of fertilisers may be associated with an increase in the incidence of certain livestock health disorders. Livestock and production losses from some disorders are possible. Management may need to be modified to minimise risk. The disorders known to occur that may be associated with fertiliser use are listed in the relevant sections of this publication. Consult your veterinarian for further advice.

Native Vegetation
The Native Vegetation Act (2003) may regulate some pasture improvement practices where existing pasture contains native species. Inquire through your local Catchment Management Authority office for further details.

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Introduction

This booklet is a guide to help landholders make better fertiliser decisions for their pastures. Much of the information comes from a major grazing project on the Camden district dairy farm at Elizabeth Macarthur Agricultural Institute. The findings have been combined with results from other fertiliser trials.

The information targets the higher rainfall (over 750 mm) districts of eastern NSW, grazing mostly beef cattle, dairy cattle or horses under relatively high stocking rates. It is also suitable for farmers grazing goats, sheep, alpaca and donkeys. The pastures in this region are generally rainfed with some properties using supplementary irrigation.

In this zone, many of the soils are weathered and low in nutrients. The soils may have other features that also limit pasture growth eg shallow depth, acidity and salinity. An assessment of these factors is a necessary part of making better fertiliser decisions.

The need for fertilisers is closely related to the intensity of production. Dairy farms require high inputs due to high grazing intensity and continuous product removal. On the other hand, pastures grazed at lower stocking rates such as a beef breeding enterprise or horses, have a much lower need for fertilisers.

A very wide range of products is available, from conventional, factory-made fertilisers to the raw, organic alternatives derived from animal manure or food processing wastes. Some products contain a mixture of both materials.

This book covers the basics of soil testing and outlines the effect of acidity, salinity and sodicity on soil fertility. There is information on individual nutrients, cation exchange capacity, trace minerals and nutrient budgets. There are sections on using organic materials as fertilisers, on how to use plant and animal symptoms to detect nutrient disorders and on animal health issues involving fertiliser.

BENEFITS OF CORRECT FERTILISER USE

Correct fertiliser use can:

- increase pasture production
- improve pasture quality
- increase seasonal pasture availability
- improve tolerance of pastures to grazing and drought
- reduce weed levels due to pasture competition
- improve pasture water use efficiency
- potentially increase stocking rate
- help to reduce runoff and erosion

WHEN THERE IS TOO MUCH NUTRIENT

An excess of one or more nutrients does not increase pasture growth and is a waste of dollars spent on fertiliser.

Excess nutrients from holding yards, laneways, feedpads, effluent paddocks and stock camps increase the nutrient load in runoff. Runoff from high nutrient areas should be diverted onto pasture.

Bare ground generates more runoff than well-vegetated paddocks and most nutrients are carried by eroded soil particles. Once they reach creeks and farm dams, some nutrients are released into the water and can promote the growth of undesirable water weeds and algae.

Nutrient leaching beyond the rootzone can contaminate ground water and also wastes money.

NSW state government legislation prohibits the pollution of water with excess nutrients. In the Warragamba water catchment, nutrient movement into waterways is a significant issue.

Some fertilisers and recycled materials contain unwanted elements such as cadmium or fluorine. If applied in excess, these elements can contaminate pasture or livestock.

FERTILISER FACTS

For optimum pasture growth all essential nutrients must be present in sufficient amounts. If any nutrient is deficient, pasture growth will be limited by this deficiency, even if all other nutrients are in abundance.

Soil testing is a vital part of fertiliser use. Savings can be made by using fertilisers only when and where they are needed.

Best returns from using fertiliser will be from your better quality land. Using fertiliser on steep country with shallow, infertile soils is less likely to be economic.

Changes in grazing management, stocking rate and fodder conservation may be needed to capture the benefit of increased pasture growth.

Some fertilisers and farming practices can gradually acidify the soil, particularly the poorer sandy ones.

If used correctly, fertilisers can decrease the amount of pollutants in runoff and leaching by increasing the pasture groundcover and utilising available nutrients.

Algal blooms can be caused by excessive fertiliser use.

ENTERPRISE	FERTILISER ISSUES
Low intensity beef production	▶ underuse of fertilisers eg phosphorus ▶ native soil acidity
Horse industry Alpaca, sheep, goats	▶ fertilisers to enhance persistence of desirable pasture species ▶ consider nutrients imported in feed
High intensity dairy production beef production horse agistment and breeding	▶ determining where soil nutrients are in excess or deficit ▶ balancing nutrients when fertilisers are applied at high rates ▶ soil acidification ▶ decreasing nutrient runoff to waterways ▶ accounting for nutrients in imported feed which are distributed in dung and urine
Landholders with saline and other poor soils	▶ is it economic to add lime, gypsum or fertiliser?

Important fertiliser issues affecting grazing enterprises

MAKING A DECISION

1. Is the land suitable for livestock production? Consider features such as slope, topsoil depth, vegetation and base fertility.
2. Can increased pasture growth be profitably utilised?
3. Is salinity a problem?
4. Is acidity a problem (topsoil and subsoil)?
5. Is the soil pH_{Ca} below 4.6? Will aluminium affect the plants you wish to grow?
6. If the salinity, pH and aluminium need to be changed, will it be economic to do so? If not, alternative pasture species need to be considered.
7. What nutrients are limiting to production and how much is needed to correct any deficiency?
8. Which fertiliser is the most cost effective way of increasing the limiting nutrients in the soil?
9. Would some livestock nutrient requirements be best supplied by feed or mineral supplements?

Correct fertiliser use can lead to higher stocking rates.

Most nutrients are carried by eroded soil particles, especially from bare ground.

Diagnosing nutrient disorders in soils and pastures

Poor pasture and animal performance can be caused by many factors, including mineral disorders. Soil, plant and animal tests can help identify most mineral disorders and guide fertiliser use.

SOIL TESTING

Soil testing in the laboratory is the main way to determine the fertility of a soil. Testing costs are small compared with the savings that can be made by more efficient use of fertilisers and other soil amendments.

A complete soil test supplies over a dozen pieces of information, some of which are valid for a substantial length of time. Soil tests are also carried out to prevent the under or oversupply of nutrients, monitor changes in nutrient levels over time and help decide which areas to fertilise.

It is important that soil tests are performed by a laboratory accredited by the National Association of Testing Authorities (NATA). Rural fertiliser suppliers often act as agents for laboratories providing soil tests. Many rural suppliers have soil test kits available. They may either lend sampling equipment or a staff member may sample for the landholder.

NSW Department of Primary Industries offices also provide kits for soil analysis.

LANDSCAN™ courses (available through NSW DPI) can also assist landholders with soil tests and interpretation of results.

Taking a surface soil sample

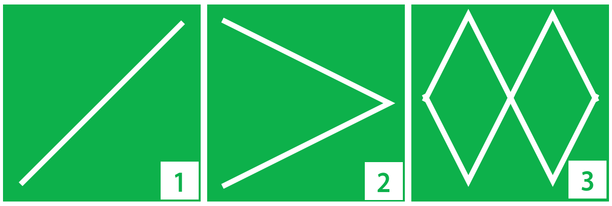
Look at the soils in the area you intend to sample. Take a separate soil sample from each soil type (eg clay, loam or sand) and from paddocks that have been managed differently because these factors affect fertiliser needs.

A minimum of 20 cores per area should be collected and these are mixed in one bag. The more cores taken the more reliable the sample.

In pastures, soil samples are collected from 0–10 cm depth. Deeper samples may need to be taken to investigate subsurface acidity and salinity.

Once the samples have been collected, it is important to have them analysed quickly to avoid changes caused by moisture and temperature.

A map and written plan of the soil sampling area is essential for interpreting results and any subsequent testing. It is recommended that soil cores be collected along a fixed transect (eg 1&2). This method allows for re-testing and better monitoring of changes in fertility than zig-zag or random sampling (eg 3).



To obtain representative samples, do not sample from unusual sites such as

- stock camps
- manure (dung pats) and urine patches
- gateways and tracks
- water troughs
- feedout areas
- old fertiliser stockpiles
- areas where the soil has been greatly disturbed eg to build a dam
- paddocks that have had fertiliser applied, other than nitrogen, within the last three months

Tools required for soil sampling

- soil corers (can be borrowed from rural supply store)
- buckets
- new plastic bags (usually part of any sampling kit)
- labels or barcodes
- recording sheets, preferably with barcodes matching those on bags
- water proof pens and pencils

Soils can be tested at any time that is convenient as long as fertiliser has not been applied in the last 3 months (except nitrogen). Moist soil is softer and easier to sample, but avoid waterlogged soil.

Soil tests can be arranged through your local fertiliser supplier.

Find out how long it will take for results to be returned so the timing of fertiliser applications can be planned.

Results can be discussed with staff of NSW Department of Primary Industries and other trained specialists in order to check the recommendations given in the soil test report. Information on previous and intended landuse and any previous test results will help with this process.

VISUAL SYMPTOMS

Many nutrient disorders cause symptoms in plants. By the time symptoms develop, yield is reduced.

Some visual symptoms are characteristic of a particular disorder. Others may indicate more than one problem, for example symptoms of nitrogen deficiency are similar to those of sulfur or potassium deficiencies. It is advisable to use soil, plant or animal testing if deficiency or toxicity symptoms are apparent before fertiliser is applied.

TESTING PLANT TISSUES

Analysing plant material can identify nutrient deficiency or toxicity disorders and is efficient for trace elements. Consult a specialist to find out how to take the samples. Record the plant species, stage of maturity and sampling date when submitting samples.

Advice on mineral analysis of plant samples and interpretation of results can be organised through your local NSW DPI office.

ANIMAL SAMPLE TESTING

Some mineral deficiencies and excesses can be determined using serum, biopsy and autopsy samples. Animal testing is useful to indicate deficiencies of magnesium, selenium, copper and zinc.

Your local veterinarian will carry out tests to determine potential nutrient disorders in livestock.

Do not use animals being fed with supplements to identify nutrient deficiencies.

Pale green pasture showing urine patches. This pasture could be nitrogen, potassium or sulfur deficient. Testing is required to identify the problem.

FERTILISER TEST STRIPS

A fertiliser test strip is simply a strip of fertiliser spread in an otherwise unfertilised paddock. An alternative is a window plot, where fertiliser is not applied to a small area within a fertilised paddock.

Test strips and window plots can be a useful way of evaluating alternatives to conventional fertiliser.

If pasture in the strip performs better than the rest of the paddock, it may be worthwhile to apply the nutrient on a wider scale.

It is only possible to see a greater than 20% improvement in pasture production. Smaller responses can only be determined by measuring the pastures.

For best results:

- choose a uniform site with species likely to respond
- label and identify position of strips
- make sure no other nutrient is deficient

Responses to test strips may vary with season and not be immediately apparent.

Representative soil sampling is needed to obtain reliable soil test results.

Soil acidity

pH is a measure of how strongly acid or alkaline a substance is. Soil pH measurements are made in a 1:5 solution in water (pH_w) or calcium chloride (pH_{Ca}) or as a field test using test papers.

Problem acid soils have a pH_{Ca} below 5. Excessively alkaline soils (over pH_{Ca} 8) are rare in the high rainfall zone. Optimum plant growth generally occurs around pH_{Ca} 6, with some plant species more tolerant of pH extremes.

In their natural state, most coastal and tablelands soils in NSW are mildly to strongly acid. The acidity itself is not toxic, but it releases high concentrations of aluminium and sometimes manganese that are toxic to many desirable pasture and crop species.

Lime corrects acidity and decreases aluminium and manganese toxicity. Lime also acts as a soil conditioner, supplies calcium and helps to increase microbial activity and the availability of some nutrients.

Dolomite and gypsum may also have beneficial effects on acid soils (see calcium and magnesium sections). Sewage ash has a liming effect.

Lime is more effective if incorporated into the soil to a depth of 10 cm. If planning to sow a new pasture or forage crop and lime is required, incorporation into the seed bed gives immediate benefits.

If surface spread, lime moves slowly into the profile. It moves faster into sandy soils and down cracks in cracking clays.

The effectiveness of liming materials depends on two factors:

1 **neutralising value (nv)** – this refers to the amount of soil acids it can neutralise ie its ability to change pH. Pure calcium carbonate has a nv of 100%. Agricultural lime has a nv of 95–98%. Products such as dolomite have a nv ranging from 92–102% but usually below 95%.

2 **fineness** – fine lime works faster but is difficult to spread. Lime that feels gritty will only slowly react with the soil and may not be good value for money.

FERTILISER INTERACTIONS

Liming can cause freshly applied nitrogen, either as fertiliser or manure, to be lost as gas. Do not apply lime and nitrogen fertilisers at the same time.

Liming affects the availability of trace minerals, increasing molybdenum but decreasing some other trace minerals. Trace mineral deficiencies may need to be corrected, especially on sandy soils.

FARMING PRACTICES THAT ACIDIFY

Farming tends to increase the acidity of a soil. Product removal, growing legumes and nitrogen fertilisers cause the soil to become more acid.

Fertilisers that strongly decrease soil pH include ammonium phosphate, ammonium sulfate, mono ammonium phosphate, diammonium phosphate and elemental sulfur. Urea, ammonium nitrate and anhydrous ammonia are less acidifying.

The amount of lime needed to correct the acidifying effect of these fertilisers is given in the nitrogen and sulfur sections.

CORRECTING ACIDITY

Liming is likely to be beneficial if your soils have a pH_{Ca} below 4.6. At levels above this, it is advisable to consider the aluminium content of the soil to determine the cost effectiveness of adding lime (see table page 6).

The amount of lime needed to raise the pH_{Ca} will depend on the current pH and soil texture. The table below is a guide for the amount of lime required to adjust the pH to 5.2. A test to determine the lime requirement for soils is available.

SOIL TEXTURE	LIME (95% NV) REQUIRED (T/HA) TO LIFT pH_{Ca} OF THE TOP 10 CM FROM:		
	4.0 to 5.2	4.3 to 5.2	4.7 to 5.2
sand	2.4	1.2	0.5
loam	3.9	2.1	0.9
clay	7.1	3.8	1.6

Amount of lime (t/ha) needed for different soil pH and textures

Liming is effective to counteract surface acidity but it is not always economic or practical.

PLANT TOLERANCE TO ALUMINIUM TOXICITY

Aluminium toxicity is the most important factor limiting pasture growth in soils where pH_{Ca} is less than 5.0. The best indicator is the exchangeable aluminium as a percent of the total cation exchange.

High aluminium and manganese levels decrease plant growth and slow the decomposition of organic matter and the fixation of nitrogen in legumes.

The management of aluminium toxicity, subsurface acidity and perhaps surface acidity will likely require the use of acid tolerant pasture and crop species.

The table below lists some plants by their tolerance to acidity and aluminium, for example lucerne should have an aluminium content near zero, while cocksfoot will tolerate levels above 10%.

If it is uneconomic to use high rates of lime over large areas to correct pH and aluminium toxicity, then alternate strategies, such as using tolerant pastures or a change in land use (eg forestry) can be considered.

TOLERANT	MODERATELY TOLERANT	SENSITIVE
cocksfoot	maize	lucerne
ryegrass	white clover	barley
oats	wheat	medics
triticale	phalaris	clare sub clover
paspalum	sub clover	
chicory		
lotus		
serradella		
kikuyu		

Tolerance of plant species to acid and aluminium

IF pH_{Ca} IS > 4.6 & Al_{EX}% IS	EXPECTED RESPONSE TO LIME
near 0%	none
1–5%	lucerne will respond and there may be a molybdenum deficiency
5–10%	aluminium sensitive crops and pasture grasses will respond
10–15%	moderately tolerant pasture plants will respond and a marginal economic response may occur in more tolerant species
15–20%	a greater economic response lime in acid tolerant species
>20%	highly tolerant species will respond

Predicting lime response in plant species using exchangeable aluminium (Al_{ex}%). Below pH_{Ca} 4.6 there will almost always be a response to lime.

Field test kits are useful to determine soil pH levels.

Farming practices that make soils more acid include hay and silage production, nitrogen fixing pastures, product removal and some fertilisers.

Soil salinity

Salinity is a measure of total soluble salts in a soil. A saline soil is one with enough free salts to harm plant growth. Sodium chloride is the most common form of salt. Salinity is widespread in Australia and occasionally a problem in coastal catchments.

CAUSES

- erosion of topsoil, exposing saline subsoil
- rising ground water, bringing salt up to the root zone
- clearing deep rooted plants, causing a rise in the water table
- parent rock material containing salts eg marine shales
- sea spray
- sea water replacing fresh water in ground water
- overuse of effluent, manures and soluble fertilisers

FIELD INDICATORS

- trees dying for no apparent reason
- annual and perennial pastures are less productive, they can thin and die out
- increase in pasture species that are salt tolerant, especially in boggy areas
- salt crusts (puffy and white) in severely affected areas
- areas left bare by stock licking the salt

LABORATORY TESTING

Salinity levels are tested using the electrical conductivity (EC) of soil samples mixed with distilled water. This is usually done in a 1:5 soil/water extract.

The higher the salinity, the greater the EC.

PLANT SENSITIVITY

The tolerance of pasture and crop species to salinity varies considerably.

The salt sensitivity of plants relates to the electrical conductance of a saturated soil extract (ECe). A conversion factor is used to calculate ECe from EC. It depends on soil texture and is listed in the bottom table.

ECe = EC x soil factor

When checking for salinity of the soil and plant suitability, make sure you are using the correct value in the test report.

ELECTRICAL CONDUCTANCE (ECe)			
3	4	6	10
MOD SENSITIVE	MOD TOLERANT	TOLERANT	HIGHLY TOLERANT
maize	kikuyu	oats	barley
cocksfoot	lucerne	wheat	puccinellia
clover – white & rose	paspalum	couch	tall wheat-grass
	phalaris	ryegrass	
	clover – berseem & sub	tall fescue	
		clover – persian & balansa	

ECe levels above which yields can be reduced for different plant species

The impact on growth also depends on soil type, stage of plant growth (seedlings are most susceptible) and variety or cultivar grown.

Rehabilitation of saline soils requires changes in agricultural practices including

- increased use of perennial pastures
- use of salt tolerant species
- planting trees in recharge areas
- drainage

TEXTURE	NOT SALINE	WEAKLY SALINE	MODERATELY SALINE	STRONGLY SALINE	SOIL FACTOR
sandy loam	< 0.11	0.11 – 0.23	0.23 – 0.45	> 0.45	14
loam	< 0.12	0.12 – 0.35	0.35 – 0.79	> 0.79	10
clay loam	< 0.18	0.18 – 0.42	0.42 – 0.85	> 0.85	9
clay	< 0.24	0.42 – 0.56	0.56 – 0.94	> 0.94	7

EC ds/m (1:5) and soil texture relating to salinity and the factor to convert EC to ECe

Soil sodicity

Sodicity is a measure of available (or exchangeable) sodium in relation to other exchangeable cations. Sodic soils are often structureless, have poor water infiltration, low root penetration, reduced trafficability when wet and are highly erodible. Sodic subsoils are more common than sodic topsoils.

Similar structural problems sometimes arise when exchangeable magnesium is in excess. Soil structural problems caused by sodium are much more common.

CAUSES

The sodium in soils originates from

- parent material, especially salt-rich bedrock
- sea water and salt spray
- farming practices, including irrigation with sodium-rich water

LABORATORY TEST

The soil test used to determine sodicity is Exchangeable Sodium Percentage (ESP). Soils with an ESP greater than 5% are generally regarded as sodic. If the soil is saline, a modified test is required to determine ESP.

FIELD INDICATORS

Sodic soils

- have lumps of soil that disperse (fall apart and become milky) in pure water
- are structurally unstable when wet
- set hard when dry
- generally have a high clay content
- are often exposed by erosion of topsoil

REHABILITATION

The principle when treating sodic soil is to replace excessive sodium with calcium by using lime or gypsum.

The addition of organic amendments (retained stubble, green manures, composts and organic fertilisers) in combination with inorganic products such as gypsum, lime or dolomite will overcome the dominance of sodium in the clay particles, and will improve the soil structure.

RATES OF SOIL AMENDMENTS

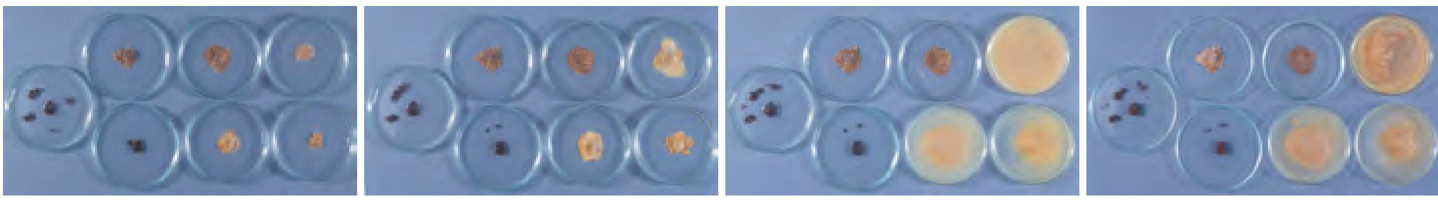
If treatment is economically justified, common rates required are:

- gypsum 2.5–5 t/ha
- lime for soils with a pH_{Ca} below 4.8 2.5–5 t/ha
- dolomite 2.5–5 t/ha
- mixtures of gypsum, lime and/or dolomite 2.5–5 t/ha
- poultry litter 10–15 m^3/ha

The choice of amendment will depend on the cost and the need to raise pH and supply magnesium.

CAUTION
Do not use dolomite if the ratio of exchangeable calcium : magnesium is less than 2:1 because magnesium can be in excess

Spreading gypsum, lime or dolomite on sodic soils will improve soil structure.



initial | 10 minutes | one hour | 24 hours

Sodic soils disperse in water. Seven soils ranging in sodicity are tested to determine their ability to stay intact.
The soils on the left are more stable than those on the right, which have dispersed.

Nitrogen

OVERVIEW

The most common nutrient that pastures respond to is nitrogen. Urea and ammonium fertilisers need to be broken down to nitrate, the plant available form of nitrogen.

Surface soil tests are a poor indicator of nitrate. Soil cores need to be deep (60 cm, preferably 90 cm) and samples need to be kept chilled to get useful results . This is generally not practical.

PRINCIPLES FOR MANAGEMENT

There are three approaches to supplying nitrogen to pastures

No fertiliser nitrogen

- pasture nitrogen is supplied from legumes (clovers, medics) which fix nitrogen from the air
- useful for low stocking rates

High fertiliser nitrogen

- nitrogen is applied after every grazing or every second grazing while pasture is growing
- useful for high stocking rates
- should be used if legume content is below 25%

Strategic fertiliser nitrogen

- pasture nitrogen is supplied from adequate legume populations when the soil temperature is above 10ºC at 10 cm depth but
- fertiliser nitrogen is applied to fill short term feed gaps during cool periods

Nitrogen fertiliser will increase the growth of pastures.

When applying nitrogen to pastures, it is important to consider the following factors.

Pastures need to be actively growing. This will depend on the temperature and maturity of the plant.

Soils should not be waterlogged, but contain sufficient moisture for growth of pasture and to dissolve the fertiliser.

The fertiliser is best applied within three days of grazing or slashing. Urea can be applied to dairy pastures immediately prior to strip grazing.

INDICATORS OF RESPONSIVE PASTURES

Pastures deficient in nitrogen are patchy and often a pale green-yellow colour with more vigorous growth over urine patches.

Responsive pastures contain mostly grass and have a low legume content.

Responses to nitrogen are most economic in late autumn and early spring when it is warm enough for plant growth and nitrogen release from fertiliser but too cold for nitrogen fixation.

Soils that are sandy and leached, low in organic matter and those with a long history of cropping are most likely to be nitrogen deficient.

MANAGEMENT

Small frequent applications of fertiliser nitrogen will keep environmental and animal health problems to a minimum and prevent waste of fertiliser.

The quantity of fertiliser nitrogen to apply varies with strategy:

- for high use up to 400 kg N/ha/year (40 kg/ha post grazing)
- for strategic use up to 100 kg N/ha/year (40 kg/ha used in split spring and autumn applications)
- do not apply more than 60 kg/ha of fertiliser nitrogen in a single application

Unlike fertiliser nitrogen, the nitrogen in poultry litter is released slowly and it can be applied as a single application.

Apply urea on soils which are expected to increase their moisture content. Do not apply to waterlogged or dry soils as nitrogen can be lost to the atmosphere.

INTERACTIONS

Pastures heavily fertilised with nitrogen can become sulfur deficient.

Avoid liming soils that have recently had nitrogen applied to avoid nitrogen loss to the atmostphere.

Legumes will fix less nitrogen if they receive fertiliser nitrogen.

AVOIDING HEALTH PROBLEMS

Nitrate poisoning, ammonia toxicity and bloat can occur in pastures fertilised with nitrogen. The following guidelines should be used:

- do not graze pastures between 2 and 14 days after nitrogen fertilisation
- never give starved, unadapted or dry stock unrestricted access to highly nitrogen fertilised pastures
- supply a bale of roughage hay in the paddock when feeding lush, nitrogen fertilised pastures.

Veterinary surgeons can test pastures for nitrate.

High dietary nitrogen intake can reduce the uptake of magnesium in the rumen.

ENVIRONMENTAL ISSUES

Repeated applications of nitrogen can lead to contamination of ground and surface water if the nitrogen is not used within the rootzone of the plant.

Nitrate is very mobile in soils. It can leach quickly out of the rootzone or be washed downslope following substantial rain or irrigation. When this happens, a fresh application may be needed.

Nitrate leaching is a major cause of soil acidity. Nitrogen fertilisers increase the acidity of the soil. The lime required to counteract acidity is shown in the table below.

MOST COMMONLY USED NITROGEN FERTILISERS

In pastures, urea is most commonly used.

Mono ammonium phosphate and di ammonium phosphate fertilisers could be cost effective if phosphorus also needs to be applied.

If poultry litter is used to provide all of the nitrogen that the pasture needs, a build up of phosphorus will occur over time. It is best to use litter to supply the phosphorus requirements and then apply nitrogen fertiliser at suitable intervals after spreading.

MAKING A FERTILISER DECISION

Stocking rate, pasture utilisation and legume content of the pasture need to be considered.

Some nitrogen fertilisers (urea) need to be applied to moist soils. The timing of application should coincide with rain or irrigation.

FERTILISER	kg/ha FERTILISER TO APPLY 40 kg NITROGEN/ha	kg OTHER NUTRIENTS APPLIED	kg LIME REQUIRED TO NEUTRALISE ACIDITY FROM APPLYING 40 kg NITROGEN
urea	88		72
mono ammonium phosphate (MAP)	364	80 phosphorus	216
di ammonium phosphate (DAP)	224	44 phosphorus	144
ammonium sulfate	195	47 sulfur	216
poultry litter (average analysis)	1540 (3.9 m^3)	28 phosphorus 16 potassium 9 sulfur 38 calcium 8 magnesium	0

Common nitrogen fertilisers, the amount needed to provide 40 kg nitrogen, other nutrients provided and the amount of lime needed to neutralise the acidity caused by the fertiliser

Highly productive systems require higher nitrogen inputs than farms with lower production.

Phosphorus

OVERVIEW

Phosphorus is frequently a limiting nutrient to the growth of pasture. Generally, soils in Australia are depleted in phosphorus due to weathering and erosion. Agriculture removes phosphorus from the soil in farm products.

The minerals in soils have the ability to bind to phosphorus. Some soils (basalt derived clay) bind strongly to phosphorus, others (sands) less so.

The ability to bind phosphorus is known as the phosphorus sorption capacity of a soil. Soils with a high phosphorus sorption require more fertiliser because more of the phosphorus applied is bound in a form not available for plant growth.

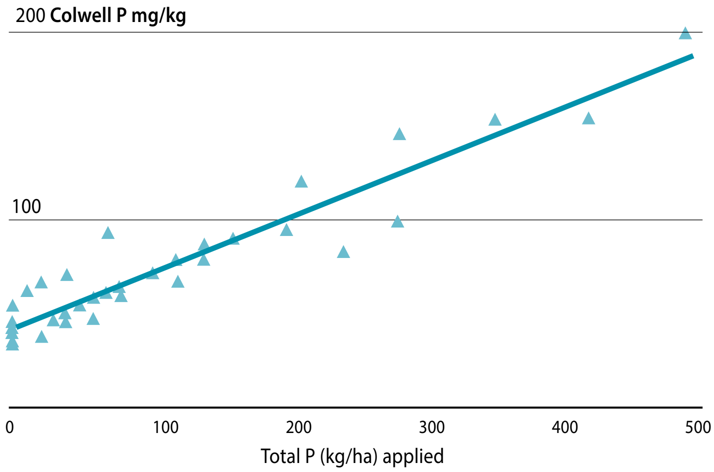
Annual soil testing is an effective guide to monitor changes in available phosphorus when in the early stages of a fertiliser programme.

PRINCIPLES FOR MANAGEMENT

Soil tests can estimate the amount of phosphorus available to plants. The graph below demonstrates the relationship between total fertiliser applied (kg/ha) and the soil test results over 3 years from a grazing trial at Camden on a low-medium sorbing soil.

Large quantities of phosphorus are removed by hay cutting and strip grazing. Amounts lost by leaching and runoff are small.

Phosphorus only moves 1 to 5 mm from the point of application. When sowing a new pasture, banding the fertiliser is more efficient than broadcasting.



Increase in the Colwell test after applying phosphorus fertiliser to a low-medium sorbing clay-loam soil over 3 years at Camden

INDICATORS OF RESPONSIVE PASTURES

Symptoms of phosphorus deficiency are difficult to identify. Leaves appear dark green and leaf tips turn brown then die.

In animals, the symptoms include poor reproduction performance and depraved appetite (pica) where animals are seen to chew on dirt, sticks and bones.

Soil tests are the most cost effective and useful way to identify paddocks that will benefit from phosphorus fertiliser. Do not sample the soil within three months of a phosphorus fertiliser application.

The most responsive pastures are legumes and temperate species such as ryegrass, cocksfoot and phalaris.

Some native grasses will respond to phosphorus fertilisers, especially those with a higher nutritive value such as microlaena and danthonia.

MANAGEMENT

Phosphorus fertilisers can be applied to dry soil and should not be applied if there is a reasonable risk of storms causing runoff. Split applications are preferable when using heavy rates.

Highly productive temperate pastures require a soil test Colwell P of at least 75 mg/kg, for medium production the result should be 50 mg/kg.

Low Colwell P levels may create favourable conditions for weeds and less productive pasture plants.

On different soils, the phosphorus test result changes at different rates after fertilisation.

For clayey soils, more phosphorus fertiliser is needed than for sandy soils. Refer to the following table to help calculate the amount of phosphorus (kg) required for optimum pasture growth.

SOIL TYPE	PHOSPHORUS (kg) REQUIRED TO LIFT SOIL TEST RESULT BY 10 mg/kg		
	COLWELL	BRAY	OLSEN
Camden dairy P trial	31	52	83
clay	66	–	130
loam	33	–	90
sand	10	–	50

The approximate amount of phosphorus (kg) needed to lift the Colwell, Bray or Olsen soil test result by 10 mg/kg

INTERACTIONS

Liming strongly acidic soils can make phosphorus more available to plants.

AVOIDING HEALTH PROBLEMS

Phosphorus fertilisers contain cadmium and fluorine in small amounts. If superphosphate or ground phosphate rock is applied to damp pasture immediately before grazing, there is a small risk of ingestion of these potentially toxic elements when grazed.

ENVIRONMENTAL ISSUES

Phosphorus moves from pasture to water mostly from bare ground. It is important to maintain ground cover and design the property to minimise soil loss.

Phosphorus fertiliser should not be applied to holding yards, dairy laneways and effluent treated paddocks. Phosphorus accumulates in these areas, similar to paddocks receiving repeated application of poultry litter.

MOST COMMONLY USED PHOSPHORUS FERTILISERS

The most commonly used phosphorus fertilisers are single and triple superphosphate, mono ammonium phosphate, di ammonium phosphate, ground phosphate rock and poultry litter.

The phosphorus in ground phosphate rock has a very low availability except in strongly acid soils.

MAKING A FERTILISER DECISION

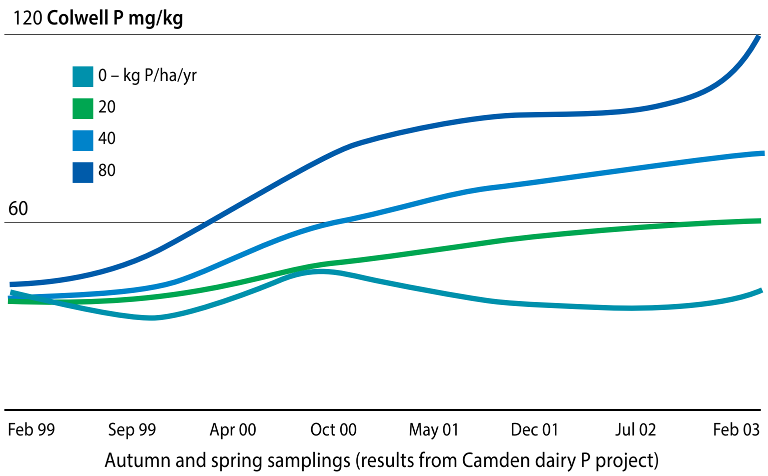
The choice of fertiliser depends on price and the need for additional nutrients. Phosphorus fertiliser applications need to be guided by soil test results.

Phosphorus costs are high (around $3.50/kg) and a decision on the rate required to reach the desired test result needs careful consideration.

On farms with high production, eg dairy, hay production, six monthly or annual applications of fertiliser may be necessary.

On paddocks where soil test phosphorus levels are adequate, maintenance applications of fertiliser can be made less frequently. Application of phosphorus fertilisers is not necessary in areas where Colwell soil test results exceed 85 mg/kg.

Phosphorus binds strongly to soil so losses are high from bare ground.



Heavier rates of phosphorus fertiliser application will reach a desired level of soil phosphorus quicker than lower rates

FERTILISER	kg FERTILISER TO APPLY 10 kg PHOSPHORUS/ha	kg OTHER NUTRIENTS APPLIED
single superphosphate	114	22 calcium 13 sulfur
triple superphosphate	50	8 calcium 1 sulfur
mono ammonium phosphate (MAP)	45	5 nitrogen
di-ammonium phosphate (DAP)	50	9 nitrogen
ground phosphate rock	67	23 calcium
poultry litter (average analysis)	500 (1.3 m^3)	13 nitrogen 5 potassium 3 sulfur 13 calcium 3 magnesium

Common phosphorus fertilisers, the amount needed to provide 10 kg of phosphorus and other nutrients supplied

Potassium

OVERVIEW

A large store of potassium is available in most soils. Potassium deficiency usually arises when plant removal is high. Hay and silage production removes large amounts of potassium from the soil.

Potassium is relocated around the farm in dung and urine and should be replaced in areas of depletion.

If overused, chloride forms of potassium fertiliser can contribute to high salt levels in the soil.

There are animal health implications from potassium excess, especially in cattle in late pregnancy and early lactation.

PRINCIPLES FOR MANAGEMENT

Use soil tests to measure potassium levels in different parts of the farm. Potassium tends to accumulate in areas close to the centre of operations eg night and springer paddocks in dairies and feedout areas.

Large potassium losses due to hay and silage removal need to be replaced. Nutrient budgets can be used to predict the amount of fertiliser needed.

Spreading effluent and manure over a large area will prevent a potassium surplus in grazing paddocks.

Plants will take up potassium from the soil in amounts higher than needed. This is known as luxury consumption.

Potassium levels in the plant reduce as it matures. Pastures should not be grazed within 28 days of potassium fertiliser application.

Nutrient budgets need to take into account feed imports and product exports as well as fertiliser and effluent use.

INDICATORS OF RESPONSIVE PASTURES

Pastures with a high legume content are the most responsive.

Soils most likely to be deficient in potassium are

- sandy and light textured
- low in organic matter
- with a history of crop and hay removal

The deficiency symptoms in plants are scorched leaf margins and localised mottling.

MANAGEMENT

Adequate exchangeable potassium values are 0.3–0.6 me/100g. The table below is a guide to rates of potassium fertiliser, according to soil test result and production system.

Pasture analysis results exceeding 4% potassium can indicate excessive soil potassium levels. Fodder conservation and cropping can be used to reduce potassium levels in the soil.

To reduce the risk of luxury consumption and associated health disorders, avoid applying potassium fertilisers in early spring and at calving in seasonal herds.

Split autumn and late spring applications are recommended in high rainfall areas or when high rates are applied.

Potassium fertilisers should be applied to moist soils.

ENTERPRISE	EXCHANGEABLE POTASSIUM me/kg			
	<0.2	0.2–0.3	0.3–0.6	>0.6
dairy cows <2/ha	40	25	10	0
dairy cows >2/ha	60	40	20	0
irrigated lucerne	60	40	20	0
irrigated pasture	45	30	15	0
dry pasture	30	15	0	0

Kg potassium required per hectare according to enterprise and exchangeable potassium soil test result

INTERACTIONS

High levels of soil potassium reduce magnesium uptake by plants.

AVOIDING HEALTH PROBLEMS

Pastures grazed soon after application of potassium fertilisers have an increased animal health risk. High plant potassium levels are associated with grass tetany and milk fever in cattle. Refer to animal health section for preventative measures.

ENVIRONMENTAL ISSUES

The potassium in most fertilisers is highly mobile. However once applied, it readily becomes attached to soil particles and is converted to a less mobile form that does not leach. There is little loss in plant availability.

MOST COMMONLY USED POTASSIUM FERTILISERS

The cheapest and most commonly used potassium fertiliser on pasture is potassium chloride (muriate of potash). Potassium nitrate and potassium sulfate are also used but are more expensive.

Dairy effluent and manures contain relatively high levels of potassium. These need to be used with care to avoid salinity and animal health problems.

Poultry litter contains useful amounts of potassium but is not a suitable choice if potassium is the principal nutrient required.

Fodder harvesting and conservation can be used to reduce excessive potassium in soils.

MAKING A FERTILISER DECISION

Soil test results are the most useful tool for deciding on the use of potassium fertiliser.

Nutrient budgets can also be used to indicate paddocks that may need fertiliser.

Fertiliser blends which contain potassium are useful if other nutrients are required.

FERTILISER	kg FERTILISER TO APPLY 10 kg POTASSIUM/ha	kg OTHER NUTRIENTS APPLIED
potassium chloride (muriate of potash)	20	
potassium nitrate	26	8 nitrogen
potassium sulfate	24	5 sulfur
poultry litter (average quality)	1000 (2.5 m^3)	26 nitrogen 18 phos. 6 sulfur 25 calcium
dairy effluent irrigation (average quality)	5 mm	5 nitrogen 1 phos.

Common potassium fertilisers, the amount needed to provide 10 kg of potassium and other nutrients supplied

The typical posture of a cow with milk fever, note the "S" bend in the neck.

Sulfur

OVERVIEW

Sulfur deficiency is becoming more common due to the increased use of fertilisers that contain only small amounts of sulfur.

Cultivation increases the availability of sulfur to plants, so pasture systems are more likely to show deficiency than cropped soils.

Plants use sulfur in the sulfate form.

PRINCIPLES FOR MANAGEMENT

Soil tests will determine the sulfur status of the farm. In some cases, it may be necessary to analyse plant tissue to determine the sulfur level, especially in cold, wet conditions.

Nutrient budgets can also be used to determine the need for sulfur, especially in areas where high analysis fertilisers (urea, mono ammonium phosphate and di ammonium phosphate) have been used.

INDICATORS OF RESPONSIVE PASTURES

Sulfate leaches readily from lighter soils with low organic matter. These soils are the most likely to be deficient in sulfur.

Leaves of deficient plants appear light to pale green in colour. Symptoms are more obvious in legumes. The appearance is similar to nitrogen deficiency, so a test to confirm the deficiency is advisable before fertiliser is applied.

MANAGEMENT

The adequate level of extractable sulfur in a soil test is 5–8 mg sulfur/kg.

The nitrogen:sulfur ratio in plant tissue should be in the range 10:1–15:1. Higher nitrogen values could create problems in plant and animal nutrition.

SOIL TEXTURE	EXTRACTABLE SULFUR (mg/kg) in KCl_{40}			
	<5	5–10	10–15	>15
sand	20	15	10	0
sandy loam	15	10	5	0
clay loam	10	5	0	0

Kg of sulfur required per hectare, according to soil texture and content of extractable sulfur (KCl_{40} test)

INTERACTIONS

The most important fertiliser interaction with sulfur is nitrogen. Nitrogen to sulfur ratios can be measured in plant tissue.

AVOIDING HEALTH PROBLEMS

High levels of sulfur can interfere with copper absorption by livestock.

A nitrogen to sulfur ratio in the diet should not exceed 12:1 for cattle and 14:1 for sheep.

Sulfur deficient plants accumulate nitrate which may cause nitrate poisoning in livestock.

Sorghum forage crops are low in sulfur and stock grazing these may require additional feed supplements.

ENVIRONMENTAL FACTORS

Some sulfur fertilisers have an acidifying effect on the soil eg elemental sulfur and ammonium sulfate.

If your test result for sulfur is extremely high (>100 mg/kg) and the soil close to sea-level, it could indicate the presence of an acid sulfate soil at depth.

MOST COMMONLY USED SULFUR FERTILISERS

Single superphosphate is the most common fertiliser to supply sulfur to pastures.

Gypsum supplies sulfur and calcium.

Elemental sulfur is not as soluble as other forms, however all of the sulfur becomes available over time. Cold weather slows the conversion of the sulfur to sulfate by microbes.

Sulfur coated urea will supply both sulfur and nitrogen. This product should not be used at every nitrogen application.

MAKING A FERTILISER DECISION

Sulfur fertiliser is unlikely to be needed if there is a history of superphosphate use.

Care needs to be taken in the interpretation of soil tests as some climatic conditions can affect the sulfur result

- cold weather slows the conversion of sulfur held in the soil organic matter to a form available to plants
- following heavy rain, the available sulfur level falls due to leaching, but it can increase during dry conditions due to evaporation

On sandy soils, elemental sulfur or a mixture of sulfate and elemental sulfur should be used to reduce the risk of leaching during high rainfall events.

To overcome immediate deficiencies of sulfur, sulfate forms of fertiliser should be applied.

Sulfur deficiency symptoms can resemble deficiency symptoms of other nutrients.

FERTILISER	kg FERTILISER TO APPLY 10 kg SULFUR/ha	kg OTHER NUTRIENTS APPLIED	kg LIME REQUIRED TO NEUTRALISE ACIDITY FROM APPLYING 10 kg SULFUR
superphosphate	91	8 phosphorus 18 calcium	
gypsum	69	13 calcium	
ammonium sulfate	42	9 nitrogen	47
ammonium phosphate sulfate	95	14 nitrogen 11 phosphorus	84
elemental sulfur	10		30
poultry litter	1670 (4.2 m^3)	43 nitrogen 30 phosphorus 17 potassium 42 calcium 8 magnesium	

Common sulfur fertilisers, the amount needed to provide 10 kg of sulfur, other nutrients supplied and the amount of lime needed to neutralise the acidity caused by the fertiliser

Calcium

OVERVIEW

Calcium deficiency is rare in plants except on very sandy soils and some highly organic soils.

Calcium is the major component of lime, dolomite and gypsum.

The level of calcium in the diet is one of the factors affecting animal health disorders such as grass tetany and milk fever. It influences the cation-anion balance and calcium-phosphorus balance.

Calcium is important to soil structure. Soils with a high proportion of exchangeable calcium are crumbly and conducive to plant growth.

High levels of oxalate in summer grasses such as kikuyu, setaria, pangola and panics, can tie up calcium and lead to animal health disorders (eg Big head in horses).

PRINCIPLES FOR MANAGEMENT

Soil calcium levels fall following prolonged use of high analysis fertilisers which do not contain calcium (urea, mono ammonium phosphate and di ammonium phosphate).

Legumes contain 3–4 times more calcium than grasses. This is important when considering plant requirements and losses when removed as hay or silage.

Care is required when feeding livestock to ensure that calcium supply is in balance with other nutrients particularly magnesium, phosphorus and potassium.

Legumes contain high levels of calcium, so removal as hay or silage can lead to its depletion.

INDICATORS OF RESPONSIVE PASTURES

Pastures will show symptoms for acidity and aluminium toxicity before calcium deficiency becomes evident, especially on clay and loam soils.

Cereal crops grown on very sandy soils may show calcium deficiency symptoms which include stunted growth, dark green foliage and grey tips on older leaves.

Soils with exchangeable calcium levels less than 5 me/100g may respond to calcium even though the pasture does not appear deficient. (see table below)

MANAGEMENT

Soils that are acid and low in calcium can be adjusted by liming. (see pH section)

Lime is useful to counteract acidity caused by product removal and use of nitrogen and sulfur fertilisers.

Irrigating with hard water will also raise calcium levels. A water test will help where a nutrient budget is being used to work out fertiliser needs.

CATEGORY	EXCHANGEABLE CALCIUM me/100g
very low	0–2
low	2–5
adequate	5–10
high	10–20
very high	>20

Exchangeable calcium levels in soils

INTERACTIONS

Lime increases the availability of molybdenum and reduces the risk of aluminium and manganese toxicity. It can also decrease the availability of copper, zinc and boron, especially on sandy soils.

AVOIDING HEALTH PROBLEMS

Calcium is vital to animal health. It prevents the development of serious disorders in cattle.

Reproductive efficiency can be impaired if the calcium:phosphorus ratio of the diet is outside the range 1.5 to 2:1.

In breeding animals, a balance of calcium with other nutrients is essential prior to giving birth.

ENVIRONMENTAL IMPACT

Calcium is abundant in nature and there are no environmental issues associated with its use.

Ground water often contains large amounts of calcium.

MOST COMMONLY USED CALCIUM FERTILISERS

Calcium carbonate (agricultural lime), calcium magnesium carbonate (dolomite) and calcium sulfate (gypsum) are widely used.

Calcium is contained in many other fertiliser and biological products. These include superphosphate, poultry litter, blood and bone, sewage ash and ground phosphate rock.

MAKING A FERTILISER DECISION

If the soil is acid, liming will overcome calcium deficiency.

If the soil is not acid and a calcium deficiency or depletion of calcium is evident, relatively low rates (500 kg/ha) of lime or gypsum can be used.

If the soil is also deficient in phosphorus, superphosphate can be used to supply phosphorus and calcium.

FERTILISER	kg FERTILISER TO APPLY 10 kg/ha	kg OTHER NUTRIENTS APPLIED
calcium carbonate (lime)	25–29	
calcium magnesium carbonate (dolomite)	48–63	7 magnesium
calcium sulfate (gypsum)	50–83	10 sulfur
calcium nitrate	53	8 nitrogen
single superphosphate	53	5 phosphorus 6 sulfur
triple superphosphate	65	12 phosphorus 1 sulfur
ground phosphate rock	27–33	5 phosphorus
poultry litter	400 (1.0 m^3)	10 nitrogen 7 phosphorus 4 potassium 2 sulfur 2 magnesium
blood and bone	67–125	5 nitrogen 7 phosphorus
sewage ash	30	2 phosphorus

Common calcium fertilisers, the amount needed to provide 10 kg of calcium and other nutrients supplied

Magnesium

OVERVIEW

Magnesium is an important nutrient in the control of milk fever and grass tetany in cattle. Pastures with high levels of potassium can increase the problem.

High levels of nitrogen in plants can induce a magnesium deficiency in the animal.

Use of magnesium feed supplements may be necessary, especially in early spring when uptake of magnesium by plants is low.

In general, magnesium deficiency is uncommon for pasture growth except on very sandy soils.

Magnesium is relatively mobile and can move slowly away from the rootzone in water draining through the soil.

Soil structural degradation leading to a greater erosion hazard and additional runoff can occur in soils with very high magnesium levels.

PRINCIPLES FOR MANAGEMENT

Use soil tests to identify areas of the farm that are deficient in magnesium or have excess potassium.

Plant tissue tests can be used to identify the need for magnesium supplements for livestock.

INDICATORS OF RESPONSIVE PASTURES

Acid sandy soils are those most likely to be deficient in magnesium.

Deficiency symptoms in plants include pale areas between leaf veins and brown burnt areas on older leaves.

Animals will show deficiency symptoms before symptoms appear in plants.

Magnesium levels in plant tissue below 0.2% could indicate a deficiency.

MANAGEMENT

A soil test level >1.6 me/100g exchangeable magnesium is adequate for virtually all pastures and forage crops.

Many pastures with lower soil test levels may not respond to additional magnesium inputs, unless the soil test level falls below 0.3 me/100g. The risk of animal health problems increases at these low levels.

A decline in magnesium status may occur on intensively farmed properties with high product removal. Nutrient budgets with a net loss of magnesium indicate a need for fertiliser application.

INTERACTIONS

The most important interaction for pasture production is with potassium. Increased levels of potassium decrease the uptake of magnesium by plants, especially in spring.

Excess magnesium in relation to calcium can cause clay dispersion in heavy soils. Clay soils with magnesium percentage of exchangeable cations greater than 20% may be cloddy and difficult to work.

Paddocks that have a long history of irrigation with effluent or spread with cattle manures will have an excess of potassium. Magnesium fertilisers may be useful to reduce the effects on animals of low magnesium uptake by plants.

AVOIDING HEALTH PROBLEMS

The most important animal health issue is grass tetany (hypomagnesaemia). This is associated with low magnesium levels in the pasture, combined with high potassium and protein levels. Cold weather in late winter or early spring increases the risk.

In ruminants, high levels of nitrogen from protein in pastures can interfere with the absorption of magnesium in the rumen.

Magnesium can be added to the diet in several ways. An effective treatment is to add magnesium oxide as Causmag® to hay.

ENVIRONMENTAL CONSIDERATIONS

Magnesium is abundant in nature and there are no environmental issues associated with its use.

Ground water often contains large amounts of magnesium.

MOST COMMONLY USED MAGNESIUM FERTILISERS

Dolomite, a combination of magnesium and calcium carbonate, is the most commonly used magnesium fertiliser. It is slow to react with the soil. However, the more finely ground the dolomite, the faster it becomes available to plants.

Magnesium oxide is the most concentrated of the magnesium fertilisers but it is also slow to react. Like dolomite, it can take several months to show a response.

Potassium magnesium sulfate is a more soluble magnesium fertiliser. It can be used at planting if cropping or when sowing a new pasture.

Magnesium sulfate (Epsom salts) readily dissolves in water and is best used as a foliar spray or where fertiliser can be applied by irrigation.

MAKING A FERTILISER DECISION

Soil magnesium deficiencies are not common. Most problems occur due to a nutrient imbalance or on sandy acid soils.

Dolomite alone or mixtures of dolomite and lime could be used on acid soils to increase pH and amend magnesium deficiency.

Magnesium fertilisers are generally slow to react with the soil so need to be applied in autumn to be effective for spring pasture growth.

Annual application rates of 20 kg magnesium/ha are typical, but larger applications can be made every 3–4 years.

Magnesium can be applied to hay to reduce the risk of animal health problems.

FERTILISER	kg FERTILISER TO APPLY 20 kg MAGNESIUM/ha	kg OTHER NUTRIENTS APPLIED
dolomite	160–240*	34 calcium
magnesium oxide	38	
magnesium sulfate (Epsom salts)	208	28 sulfur
potassium magnesium sulfate	190	34 potassium 42 sulfur
poultry litter (average analysis)	4000 (10.0 m^3)	104 nitrogen 72 phosphorus 24 sulfur 100 calcium 40 potassium

Common magnesium fertilisers, the amount needed to provide 20 kg of magnesium and other nutrients supplied

* depending on grade of dolomite

Cation Exchange Capacity

OVERVIEW

The cation exchange capacity (CEC) of the soil is a measure of its ability to exchange and retain positively charged particles called cations. Many of the nutrients used by plants are in the form of cations.

The five most abundant cations are calcium, magnesium, potassium, sodium and aluminium. Their concentrations are measured as centimoles of positive charge per kilogram of soil, which is equivalent numerically to milliequivalents per 100 gram (me/100g). Both units are used in soil test reports.

The total of the concentrations of these five cations approximates the cation exchange capacity. This total is also known as the effective CEC, and is used to calculate the relative percentages, that is, 'the balance' of each cation.

The size of the CEC is determined by the amount of clay and organic matter in the soil. The more clay and organic matter, the higher the CEC.

The CEC is a major factor affecting soil structure, nutrient availability and soil pH. It also affects the soil's response to fertiliser.

RATING	CATION EXCHANGE CAPACITY me/100g
low	<3
medium	3–6
high	>6

Soils with a low CEC have insufficient nutrients to sustain vigorous plant growth

CATION	% OF CEC DESIRABLE FOR PLANT GROWTH
calcium	65–80
magnesium	10–15
potassium	1–5
sodium	0–1
aluminium	<5

The balance of cations that make up the effective CEC is important to plant growth

PRINCIPLES FOR MANAGEMENT

Sandy soils and acid soils with a high aluminium percentage are more likely to respond to management than other soils.

INDICATORS OF RESPONSIVE SOILS

Soils with the following features may respond to treatment:

- sandy and acid
- low CEC
- high exchangeable aluminium percentage
- structureless and erodible as a result of a high exchangeable sodium percentage (ESP) or a low calcium to magnesium ratio

Pastures grown on these soils are dominated by acid tolerant species.

MANAGEMENT

Increasing soil organic matter levels with large amounts of organic fertilisers will raise the CEC. The increase will be more noticeable in light sandy soils, especially in the long term. It is not recommended to add clay in order to raise the CEC.

Soil organic matter can be maintained or increased by good pasture management. The CEC will gradually increase as plant residues and animal manure accumulate in the soil.

INTERACTIONS

In very acidic soil the CEC will be inflated by high exchangeable aluminium levels.

In soils very low in organic matter (<1%), there is a risk of clay dispersion when the ratio of available calcium to magnesium is less than 2.

MOST COMMONLY USED FERTILISERS

Poultry litter, recycled organic matter and green manure crops can be useful to increase the CEC of a soil.

AVOIDING HEALTH PROBLEMS

Animal health risks are associated with the use of poultry litter, animal manure and other recycled materials. Stock must not have access to stockpiles of recycled materials.

MAKING A FERTILISER DECISION

Most fertiliser applications will not affect the CEC of a soil.

A single application of 15 m^3/ha of poultry litter can raise the CEC of a sandy soil by 40%.

Trace minerals

OVERVIEW

The trace minerals necessary for plant growth are copper, zinc, manganese, boron, molybdenum, cobalt and iron. Selenium is also important for animal production. These essential minerals are required in only tiny quantities.

Chemical interactions can occur with trace minerals that reduce their availability and cause deficiencies, even when there is sufficient nutrient in the soil.

Heavy metals in some fertilisers and organic materials can affect livestock health. Residues can affect market access.

PRINCIPLES FOR MANAGEMENT

Soil tests are usually not reliable to determine the status of available trace minerals in the soil.

Visual symptoms can be used as a guide to trace mineral deficiencies. Plant tissue and animal sample tests are useful to confirm most trace mineral deficiencies.

Moderate amounts of organic matter help sandy soils retain trace minerals that would otherwise leach down past the root zone.

INDICATORS OF RESPONSIVE PASTURES

Poor growth and typical symptoms of nutrient disorder, eg yellowing between the leaf veins, may be observed in apparently fertile soils with a regular fertiliser programme.

Refer to page 23 for typical symptoms of trace mineral deficiencies and the fertiliser rate to correct them.

INTERACTIONS

The most important trace mineral interaction is the reduced availability of copper due to a reaction with molybdenum and sulfur. The overuse of molybdenum, recent liming and high levels of sulfur can induce a copper deficiency in livestock.

Liming alters the availability of trace minerals. It increases the availability of molybdenum and reduces that of cadmium and manganese, usually producing an overall benefit to pasture production. Lime can also reduce copper, boron and zinc availability, which may not be desirable in some circumstances.

MANAGEMENT

As well as nutrients and organic matter, animal manures contain a wide range of trace minerals that may be useful in correcting pasture deficiencies.

MOST COMMONLY USED FERTILISERS

Some fertilisers and blends have trace minerals added to them. Selcote® contains selenium and Mo superphosphate contains molybdenum.

Borax corrects low boron levels, copper sulfate corrects low soil copper and zinc sulfate corrects low zinc levels.

TRACE MINERAL EXCESSES

Some trace minerals can lead to plant and animal health problems if present in soil in excessive quantities.

Excess **molybdenum** can cause copper deficiency in grazing animals. Mo superphosphate is best used every 4–5 years, not annually. (see animal health section)

Copper toxicity in stock is rare and more commonly seen in sheep than cattle. It is usually associated with an oversupply of copper in the ration during hand feeding. Pastures that contain *Heliotropium*, *Echium* (eg Paterson's Curse) or *Senecio* (eg ragwort) have been associated with chronic copper poisoning.

Cobalt, **zinc** and **selenium** toxicities are rare and usually associated with an oversupply in hand prepared feeds. Do not give selenium intra-ruminal pellets to young animals.

Boron is only required in small amounts by plants and the range between deficiency and toxicity for this trace mineral is narrow.

Exceeding the recommended application rate or applying boron too frequently can result in toxic concentrations of boron in soils and plants.

High concentrations of **manganese** that restrict plant growth can occur in acid soils. Liming will reduce the incidence of manganese toxicity.

Cadmium, **lead**, **mercury** and **fluorine** are present in some fertilisers and organic materials. Ingestion can lead to toxicity symptoms in livestock. Once in contact with the soil, plant uptake is generally poor.

Adequate nutrient levels and nutrient deficiency symptoms in pasture plants

Nutrient deficiency can be identified in plant tissue by laboratory analysis. Fertiliser may be needed if the level of one or more minerals falls below adequate.

If visual symptoms are evident in the plant, soil nutrient levels have already been depleted and pasture yield reduced. A soil test will help guide the type and amount of fertiliser needed to correct deficiencies.

ELEMENT	ADEQUATE TEST RESULT OF VEGETATIVE GROWTH				LEAVES SHOWING SYMPTOMS FIRST	VISUAL SYMPTOM (IF UNSURE, SEEK EXPERT ADVICE)
	RYEGRASS	KIKUYU	LUCERNE	WHITE CLOVER		
nitrogen %	4.5–5.0	3–4.5	4.5–5.0	4.8–5.5	oldest	pasture yellowing, obvious urine patches
phosphorus %	0.35–0.4	0.24–0.35	0.26–0.7	0.35–0.40	oldest	dark green leaves, leaf tips brown and die, leaves curl and become stunted
potassium %	2.0–2.5	2.33–3.86	2.5–3.8	2.0–2.4	oldest	scorched margins and localised mottling, increased clover growth in urine patches
sulfur %	0.27–0.32	>0.12	0.26–0.5	0.27–0.32	youngest	similar to nitrogen and molybdenum but appears on young leaves
calcium %	0.25–0.3	0.4–0.7	0.51–3.0	0.4–0.5	youngest	tips dry then become brittle and die, leaves distorted and blackened
magnesium %	0.16–0.2	0.3–0.58	0.31–1.0	0.18–0.22	oldest	pale areas between leaf veins, yellow or reddish purple leaf margins, mid rib remains green
manganese mg/kg	50–300	70–90	25–30	25–30	oldest or youngest	yellowing between leaf veins, veins pale green
copper mg/kg	6–7	6–9	>5	6–7	youngest	pale areas on leaf, brown discolouration, stunted growth, delayed maturity, lodging
iron mg/kg	50–60	50–70	45–60	50–65	youngest	pale areas between leaf veins, veins dark green, young leaves almost white
boron mg/kg	5–15	10	25–35	25–30	youngest	yellowish tints (lucerne), reddish colouration (clover), distorted thickened leaves, umbrella-shaped growth (lucerne); lack of legume persistence in pastures due to poor seed set
cobalt mg/kg	unknown				oldest	legumes appear nitrogen deficient
molybdenum mg/kg	0.3–0.4		0.15–3.0	0.15–0.2	oldest	legumes appear nitrogen deficient, cupping of leaves and distortion of stems
zinc mg/kg	14–20	30	15–40	16–19	middle	pale areas between leaf veins, striping effect, in severe deficiency leaves turn grey-white and die

A guide to nutrient deficiency in cattle

Livestock may show symptoms of mineral disorders. Veterinary attention will normally be required to immediately correct deficiencies in the animal.

MINERAL	VISUAL SYMPTOM IN CATTLE	MORE LIKELY TO OCCUR IN SOILS THAT ARE	APPLICATION AND RATE OF FERTILISER FOR CORRECTION
nitrogen	poor growth rate, poor feed intake	sandy, low in organic matter or have long cropping history	see specific section
phosphorus	depraved appetite, reduced reproductive performance, joint stiffness, dull coat	low in organic matter, highly weathered iron rich acid, alkaline, lost topsoil or a long cropping history	
potassium	depressed milk yield, depraved appetite, tetany	low in organic matter, sandy, eroded or a history of hay removal	
sulfur	reduced feed intake, reduced milk production	low in organic matter, eroded or sandy	
calcium	milk fever, grass tetany, muscle twitching and weakness	sandy, sodic or high in aluminium	
magnesium	grass tetany	sandy and acid, strongly acid peat and muck or heavily fertilised with calcium or potassium	
manganese	reduced reproductive performance, bone deformities in calves	alkaline, poorly drained peat, or sandy and strongly acid	1 kg manganese/ha as a foliar spray
copper	hair abnormalities – 'spectacles', rough coat, anaemia	alkaline sand, stongly leached acid or peat and muck with high organic matter	1–2 kg copper/ha to soil
iron	anaemia	alkaline, waterlogged, sandy, peat, muck or acid, strongly leached	supply mineral lick containing iron
boron	not essential to cattle	sandy, low in organic matter or alkaline	10–15 kg borax/ha to soil
cobalt	wasting disease – decreased growth rates, diarrhoea and bleached hair	some sandy coastal or peat soils	0.3–2 kg copper sulfate/ha to soil or, 0.14 kg copper sulfate/ha foliar spray
molybdenum	no symptoms shown by cattle	acid, heavy sulfur application	apply Mo superphosphate or lime if pH_{Ca} is below 4.8
zinc	reduced feed intake, excessive salivation, hair loss on face	alkaline, leached sand, shallow topsoil or frequent heavy applications of phosphorus	1–10 kg zinc/ha in a single application to soil
selenium	white muscle disease, ill thrift, retained placenta, infertility. Low levels of blood glutathione peroxidase	low in organic matter , eroded or sandy	apply selenium coated fertiliser or treat adult animals

Organic materials as fertiliser

OVERVIEW

Organic materials used as fertilisers include poultry litter, dairy effluent, animal manures, sewage treatment waste (biosolids and waste water) and wastes from food processing.

Solid materials supply valuable organic matter which improves soil structure and helps it to hold on to nutrients and moisture. They can improve soil and plant health by increasing the activity of beneficial microbes and encouraging the build-up of soil organisms such as earthworms.

Organic materials contain a range of beneficial nutrients and usually can be supplied at a relatively low cost. However, they are often bulky, can be difficult to handle and require planning to avoid nutrient imbalances, animal health problems and possible environmental damage.

Recycled organic materials require specialised equipment to ensure even spreading.

PRINCIPLES FOR MANAGEMENT

The nutrient quality of these products is often highly variable due to differences in inputs, processing, waste treatment and moisture content.

An analysis of the material is highly desirable to guide its long term use.

Salt levels can be high, especially in dairy effluent and recycled waste water. It may be necessary to monitor salt levels and shandy effluent with other water sources when irrigating.

Solids and sludges such as poultry and dairy manure, biosolids and grease-trap wastes can be difficult to handle. Uneven spreading can produce uneven growth of pasture.

Unless highly treated, most wastes require a quarantine period of at least three weeks after application before grazing occurs. Animals must not have access to organic waste stockpiles.

Nutrients are not as immediately available as in conventional fertilisers, but tend to be released slowly as the material decomposes.

INDICATORS OF RESPONSIVE SOILS

It is cost effective to use organic materials on soils:

- that are deficient in a range of nutrients
- have low CEC and organic matter
- that have a history of hay or silage removal
- are on recently cleared land intended for improved pasture production
- that are light, sandy and low in organic matter

MANAGEMENT

Solids can be spread on existing pastures on level to gently sloping paddocks. On more sloping country it is best to leave an unfertilised buffer at the bottom of the slope. Harrowing will spread manure solids around more evenly.

Material can be incorporated prior to sowing improved pastures or fodder crops. On existing pastures and crops, material should simply be left on the surface to break down naturally.

Injection of liquid or semi solid food processing wastes is advisable to minimise health risks and prevent contamination of surface water.

Dairy and treated sewage effluent is best applied to rapidly growing pastures. Do not apply more than 25 mm of effluent in one application. Dairies and feedlots should aim to distribute effluent over as much of the farming area as practical. Rotate applications through the area.

To avoid a build-up and imbalance of nutrients, spread dairy effluent over at least 10% of the farming area.

TIMING

Apply after grazing to rapidly growing pasture.

Avoid using these materials on waterlogged soils.

The survival of intestinal worm eggs is favoured by warm, moist weather conditions (late spring, autumn). Avoid harrowing to spread manure at these times.

INTERACTIONS

Potassium levels can be high in areas used to spread manure and effluent.

Soil salt levels can rise after repeated applications of dairy and treated sewage effluent and some food processing wastes. This can lead to soil structural problems (refer to sodicity section).

Scald patches can appear in pastures following heavy use of greasy materials. These materials are rich in carbon and often require additional nitrogen fertiliser for rapid decomposition.

Weed seeds can be present in cattle and horse manure, especially if the animals have been fed imported hay or grain contaminated with weeds.

AVOIDING HEALTH PROBLEMS

Dairy effluent and manures are rich in potassium which may increase the incidence of health problems in cows in late pregnancy and early lactation. They also may contain parasites and bacteria (Bovine Johne's Disease, salmonella and leptospirosis) which can affect younger cattle. Avoid grazing these classes of livestock on pastures spread with dairy waste.

Well composted manure contains fewer pathogens than fresh material.

To reduce the risk of botulism, salmonella and bovine spongiform encephalitis (BSE), dead birds and meat products must not be fed to livestock.

Faecal egg counts are recommended if horses graze land spread with horse manure. Parasite control measures should be undertaken regularly.

Effluent must not be used on crops intended for human consumption.

WARNING

Poultry litter and manure may contain discarded or spilled feed containing meatmeal. It is illegal to feed meatmeal to ruminants, or allow them access to it, in order to prevent the possible spread of exotic animal diseases such as BSE. Therefore stock must not be fed on, or have access to, bulk litter.

MAKING A FERTILISER DECISION

The amount of product applied will depend on the nutrient content. The table below gives a guide to the rates typically applied. An analysis of the material is advisable to determine the application rate and guide long term use.

Choose paddocks carefully when considering the use of these materials. Areas remote from the centre of operations, hay cutting paddocks and those likely to pose minimal environmental risk are recommended.

Additional fertilisers (eg magnesium with dairy effluent and nitrogen with greasy food wastes) may need to be applied at the same time.

Paddocks that have received repeated applications of poultry litter will be high in phosphorus and may benefit from follow up applications of nitrogen fertiliser.

Organic materials can be relatively cheap. Transport and spreading costs can be much higher than for conventional fertilisers and should be considered when calculating economic value.

Compost, shredded green waste and vermicast are required in very large quantities, making their use on large areas of pasture impractical.

WASTE	RATE APPLIED	NITROGEN	PHOSPHORUS	POTASSIUM	SULFUR	CALCIUM	MAGNESIUM
		KG/HA TYPICAL ANALYSIS					
poultry litter	15 m³ (6t)	180	126	80	40	175	35
dairy manure	1 t dm	40	7	25	4	15	6
horse manure	1 t dm	30	5	20	4	30	6
biosolids	10 t dm	400	250	20		150	30
dairy effluent	25 mm (0.25 ML/ha)	25	7	50	5	*	6
sewage effluent	25 mm (0.25 ML/ha)	5	1	3.5	*	*	*

* depends on water quality dm = dry matter

Some organic fertilisers, typical rate applied and nutrients applied

Animal health disorders & fertiliser use

Fertilisers can sometimes affect animal health, either by inducing the disorder or by assisting in alleviating the condition.

HYPOMAGNESAEMIA (GRASS TETANY)

Grass tetany is a condition where cows and occasionally sheep have low levels of serum magnesium, commonly seen in late pregnancy and early lactation. The usual cause is an excess of potassium in relation to magnesium and calcium in the diet.

Pastures are able to absorb more potassium from the soil than is required for plant growth, especially if receiving dairy effluent and manures or recently fertilised with potassium.This reduces magnesium uptake by the plant, causing an imbalance of potassium and magnesium. It is most commonly seen in green cereal pastures, autumn kikuyu and short, grass dominant pastures in late winter/ early spring.

The risk of grass tetany increases when animals in late pregnancy and early lactation graze pastures with a potassium to magnesium imbalance, especially in late winter and early spring. Nitrogen fertiliser applied in spring can also increase this risk.

The diet of cattle at risk of developing this disorder can be tested for minerals.The potassium balance of the diet can then be calculated as

$$\frac{\%\ \text{potassium} \times 256}{(\%\ \text{calcium} \times 499 + \%\ \text{magnesium} \times 823)}$$

If this exceeds 2.2, then precautions against grass tetany are necessary.

Increasing the magnesium content of the diet is recommended to reduce this risk. There are several ways to increase the amount of magnesium in the diet, including

- feeding supplements containing magnesium
- providing feeds low in potassium eg mature hays
- adding magnesium to hay as Causmag®
- providing mineral blocks containing magnesium
- dusting pastures with magnesium oxide

HYPOCALCAEMIA (MILK FEVER)

Milk fever is caused by low levels of calcium in the blood of cows. An imbalance of certain minerals (eg potassium and sodium to sulphates and phosphates) in the diet can reduce the animal's ability to draw on calcium stored in body tissue.

High milk producing, older cows, immediately post calving are most likely to succumb. The risk of milk fever increases when they graze pastures with a high potassium content.

Cows close to calving should be maintained on pastures and hays of lower quality. Pellets containing anionic salts can be fed. Do not feed additional calcium as this reduces even further the ability of the animal to draw from its own stored reserves.

COPPER DEFICIENCY & COPPER DEFICIENCY INDUCED BY MOLYBDENUM AND SULFUR

Copper deficiencies in animals can be direct, caused by insufficient copper in the diet, or induced, due to an interaction with other elements. A direct copper deficiency is most likely to occur in animals grazing pastures on sandy soils in high rainfall areas.

Induced copper deficiencies can be caused by excessive use of molybdenum enriched fertilisers (eg Mo super). Excess sulfur can also induce a copper deficiency.

To determine whether a copper deficiency is direct or induced, pasture samples need to be analysed. If the concentration of copper in the pasture is low (<7 mg/kg), there is a direct copper deficiency in the soil. If the pasture copper levels are normal (>9 mg/kg), there may be an induced copper deficiency arising from excess use of molybdenum, lime or sulfur fertilisers.

Supplements or injections containing copper may be necessary to overcome immediate deficiency symptoms; however care needs to be taken to avoid copper poisoning. The use of copper fertilisers should be considered.

Animals must not have access to manure stockpiles.

AMMONIA TOXICITY AND BLOAT

Ammonia-induced bloat can occur following ingestion of nitrogen-rich pastures, often following the use of nitrogen fertilisers. Young, lush pastures with a high legume content can also induce bloat.

Do not allow hungry stock onto these pastures. Providing access to low quality hay and the use of bloat oils and capsules will also help reduce this risk.

NITRATE TOXICITY

Some pasture and weed species are known to accumulate nitrogen as nitrate. There is a risk of nitrate poisoning in ruminants if plants containing nitrate are consumed as the major feed source.

High rates of nitrogen fertiliser can increase the risk of nitrate toxicity in the plant, especially 7–14 days after nitrogen application.

Other factors that can increase the amount of nitrate in plant tissues are low sulfur concentration, rain following moisture stress, prolonged periods of cloudy weather and pastures grown in soils after a long fallow.

Plant tissue tests can be performed on pastures suspected to have toxic levels of nitrate. These are available through NSW DPI staff or your vet.

SELENIUM DEFICIENCY

Cattle can suffer from selenium deficiency, but not plants. A blood test will determine the selenium status of cattle.

Selenium applied as fertiliser or a selenium bullet placed in the rumen of adult cattle is recommended in districts known to have a low soil selenium level, if there are deficiency symptoms (white muscle disease, retained placenta), or as indicated by blood tests.

Retained foetal membranes can indicate selenium deficiency in cattle.

PHOSPHORUS DEFICIENCY

Phosphorus deficiency symptoms include low production and impaired reproduction performance. Cattle will have abnormal cravings (pica) and chew bones and sticks. The biggest disease risk to phosphorus deficient animals is botulism from chewing bones.

The use of phosphorus fertilisers and dietary mineral supplements is recommended for deficient animals. Vaccination for botulism should be considered.

USING FERTILISERS AS FEED SUPPLEMENTS

Urea can be fed as a form of protein to ruminants. Best results are obtained from feeding urea with low protein roughages such as dry hays and pastures and maize silage.

The most common methods of supplying urea are as a feed premix, a block or as a lick. Recommended feeding level is 60 g/hd/day and must not exceed 100 g/hd/day as excess urea is toxic. In a total ration, a urea level of 1% on a dry matter basis (ie 10 kg urea/ tonne dry matter) is recommended.

Superphosphate has been used as a mineral supplement however it contains small amounts of potentially toxic cadmium and fluorine. Alternative phosphorus supplements, such as dicalcium phosphate, are recommended. Avoid applying superphosphate to damp pastures immediately prior to grazing as the dust can adhere to the pasture and be ingested.

Poultry litter must not be fed to ruminants. It can cause salmonella infections and botulism. There is a risk of meat meal contaminating the litter and causing bovine spongiform encephalitis (BSE). Litter stockpiles must be fenced off and paddocks quarantined for at least three weeks after application.

Pastures treated with **dairy effluent** and **manures** can pose a health risk to young animals and cows close to calving. Bovine Johnes disease (BJD) and parasites can be transmitted to young cattle. These classes of livestock should be excluded from pastures treated with effluent and manures.

Nutrient budgets

A nutrient budget calculates the balance between inputs and outputs of nutrients over a chosen area. This area may be one paddock, a sub-catchment or a complete farm. A budget will aid management decisions eg which paddock is best suited to hay cutting in order to reduce excess nutrient?

Nutrient inputs to a farm are mainly in the form of feed and fertiliser, while the outputs are product removal, (sale of livestock, milk and wool) and environmental losses (from runoff, leaching, sorption by the soil and loss of nitrogen to the atmosphere).

A simple nutrient budget accounts for fertiliser input and product removal in hay and silage paddocks. These areas are often rapidly depleted of nutrients, especially if used frequently.

Nutrient budgets become more complex when stock movements within the farm are included.

Manure is deposited and nutrients concentrated in stock camps and areas close to the centre of operations eg stock holding yards, dairy night paddocks and feedpads, transferring nutrients from the grazing area.

On horse properties, nutrients are relocated within a paddock with the formation of 'lawns and roughs'. This is caused by manure avoidance and preferential grazing of clean pasture. Nutrients are also removed (as manure), especially if horses are confined to stables and yards for long periods.

Compared to other outputs, environmental losses from grazed pasture are generally small. They can be influenced by many factors including rainfall (intensity, season and time after fertiliser application), soil type, slope, soil moisture, ground cover, pasture height, and type of fertiliser applied.

Nutrients are lost from the grazing area and moved to less productive areas of the farm, such as stock camps.

STEPS TO CALCULATE A NUTRIENT BUDGET

1. Measure areas of each paddock (hectares)
2. Keep records of inputs of feed and fertiliser
3. Calculate amount of nutrient imported as fertiliser from the bag's label or the table on page 31

Nutrient imported as fertiliser kg = tonnes fertiliser x nutrient content (%) x 10

4. Calculate amount of nutrient in each feed from its analysis or the table on page 32

Nutrient imported as feed kg = tonnes ingredient x nutrient content (kg/t)

5. Add results from step 3 and 4
6. Calculate amount of nutrient lost as product from the table on page 32 or other reference material

Nutrient exported = tonnes product x nutrient content (kg/t)

7. Subtract exported nutrient (step 6) from imports (step 5) to estimate balance
8. Divide by area (hectares) of the farming operation

The following nutrient budgets show how particular farming practices affect nutrient balances (expressed as kg/ha). A separate budget for each type of land use history is useful when deciding fertiliser needs.

SCENARIO 1

Maize silage paddock, fertilised with 15 m^3 /ha (6 tonne) poultry litter, producing 18 tonne/ha maize silage dry matter.

NUTRIENT	INPUTS (POULTRY MANURE)	OUTPUTS (MAIZE SILAGE)	BALANCE (kg/ha)
nitrogen	156	259	-103
phosphorus	108	49	59
potassium	60	166	-106
sulfur	36	22	14
calcium	150	47	103
magnesium	30	52	-22

This paddock will require additional inputs of nitrogen, potassium and magnesium in subsequent years to prevent rundown of nutrients stored in the soil. On the other hand, these amounts could be applied as bagged fertiliser prior to sowing to ensure that sufficient quantities are available for the crop.

SCENARIO 2

Heifer rearing or steer fattening paddocks, running 1 beast/ha, turned off at 500 kg, fed lucerne hay June to September (120 days) at 8 kg dry matter/hd/day with remainder of feed obtained from grazing a grass dominant pasture. Fertilised with 125 kg superphosphate/ha/year.

NUTRIENT	FERT. INPUTS	FEED INPUTS	OUTPUTS	BALANCE (kg/ha)
nitrogen		34	11	+23
phosphorus	11	2	4	+9
potassium		17	1	+16
sulfur	14	2	1	+15
calcium	24	13	7	+30
magnesium		1	1	0

Strategic use of nitrogen fertiliser can be used to extend the pasture growing season and reduce the amount of imported feed required. To promote legume growth, molybdenum and potassium status need to be investigated. Clover seed treated with molybdenum may need to be broadcast. Soil testing is recommended to monitor the depletion of phosphorus, potassium and sulfur if hand feeding is reduced.

Stocking rate could be increased following additional fertiliser use.

A nutrient budget for this maize crop can be calculated prior to sowing to estimate fertiliser needs and ensure sufficient nutrients are supplied during the growing period.

SCENARIO 3

Five horses (500 kg liveweight) on 10 hectares, each fed 4 kg lucerne hay, 2 kg copra meal daily, grazing paddocks from 8 am to 4 pm, stabled at night, manure removed from the stables and used in the garden.

Remainder of feed coming from pasture to provide a total of 12 kg dry matter intake/day (equivalent to 2.4% bodyweight).

NUTRIENT	INPUTS (AS FEED)	OUTPUTS (AS MANURE)	BALANCE (kg/ha)
nitrogen	13.5	21.9	-8.4
phosphorus	1.4	2.2	-0.8
potassium	6.8	14.6	-7.8
sulfur	0.9	2.2	-1.3
calcium	3.5	2.9	0.6
magnesium	0.8	0.8	0

More nutrients are lost from the paddock as pasture in manure than are gained to the paddock from feed.

This property is slowly declining in most nutrients as a large proportion of the nutrients in the manure are not deposited in the paddock.

Changes in management, including returning manure to the paddock or reducing the amount of time horses are stabled, may reduce the amount of nutrient rundown on this property. Some fertiliser application would be of benefit.

NUTRIENT CONTENT (%) OF COMMONLY USED FERTILISERS

FERTILISER	%NITROGEN	%PHOSPHORUS	%POTASSIUM	%SULFUR	%CALCIUM	%MAGNESIUM
urea	46					
anhydrous ammonia	82					
aqua ammonia	20					
monoammonium phosphate (MAP)	11	22		1–2		
diammonium phosphate (DAP)	18	20		1–3		
ammonium nitrate	34					
ammonium sulfate	20			24		
single superphosphate		9		11	19	
triple superphosphate		18		1–4	15.5	
sulfur fortified superphosphate		5–8		25–45	12–17	
sulfur coated MAP	9	19		12	1.7	
sulfur coated DAP	16	18		12	0.6	
powdered sulfur				100		
calcium nitrate	15				19	
potassium nitrate	13		37.5			
potassium chloride (muriate of potash)			48–51			
potassium sulfate			40–42	16		
ground phosphate rock range		11–16			30–37	
lime					35–40	
gypsum				10–18	12–20	
dolomite					16–21	8–13
sewage ash (average)		8	0.3	1	30	0.5
blood and bone range	4–7	3–9			8–15	
poultry litter range (average)	1.4–8.4 (2.6)	1.2–2.8 (1.8)	0.9–2.0 (1.0)	0.5–0.8 (0.6)	1.7–3.7 (2.5)	0.4–0.8 (0.5)

Blends of two or more of these products are sold under various tradenames. Consult your supplier for details of their nutrient content.

TYPICAL ANALYSIS OF FEEDS AND PRODUCTS

This table gives an estimate of the nutrient content of various feeds and products. It can be used to calculate the nutrient gains and loss in a nutrient budget. These results are typical of the product, but for more accurate calculations, a feed test can be performed on your own samples. To convert kg/tonne to %, divide value by 10.

FEED	NITROGEN	PHOSPHORUS	POTASSIUM	SULFUR	CALCIUM	MAGNESIUM
	kg/tonne dry feed					
oats	17.0	3.2	4.1	2.3	1.0	1.4
wheat	22.0	3.8	4.7	2.2	0.4	1.6
barley	18.0	3.8	4.8	1.7	0.6	1.5
corn	15.0	2.8	3.6	1.2	0.2	1.6
sorghum	21.0	3.2	3.9	1.8	0.4	1.4
lucerne hay	35.0	2.3	17.4	2.0	13.3	1.3
clover hay	30.0	2.2	12	2.7	11.4	2.0
oaten hay	25.0	2.3	20.0	2.0	2.9	2.0
wheaten hay	25	1.8	10.0	2.0	2.5	1.5
ryegrass hay	30	3.0	20.0	3.0	4.0	3.0
maize silage	14.4	2.7	9.2	1.2	2.6	2.9
canola meal	59.8	12	12.5	6.2	8.0	4.6
copra meal	41.1	6.7	12	3.7	2.1	3.9
cottonseed meal	67.8	14.1	16.5	4.7	2.3	6.4
sunflower meal	75.2	10.3	10.6	3.3	4.3	7.5
linseed seeds	40	5.5	8.4	2.5	2.3	4.3
lupin	51.5	3.0	8.1	2.3	2.2	1.6
field pea	36.8	3.4	9.1	1.8	0.7	1.2
faba bean	38.8	4.1	9.6	1.3	1.2	1.0
wheat bran	27.5	13.8	13.7	2.4	1.5	6.5
wheat straw	5.9	0.8	6.7	1.8	1.6	1.2
molasses	9.4	1.1	40.2	4.6	10.5	4.7
brewer's grain	38.4	6.0	1.0	2.4	1.0	2.6
PRODUCT (AS IS)	NITROGEN	PHOSPHORUS	POTASSIUM	SULFUR	CALCIUM	MAGNESIUM
500 kg livestock	11	3.5	1	1	7	
1000 litres milk	5	0.9	1.4	0.3	1.2	0.1
100 kg fleece	14	<0.1	1.8	2.8		

Fertiliser calculations

From Agnote DPI 496, Rose 2004.

CALCULATING THE AMOUNT OF FERTILISER REQUIRED ▶

The following simple calculations will allow you to accurately determine how much fertiliser to apply. **The cost of fertiliser will vary, up to date prices need to be obtained for accurate calculations.**

This information can be used to calculate the amount of a fertiliser needed for a given amount of nutrient:

Calculation A

Amount of fertiliser kg/ha
= kg/ha nutrient ÷ % nutrient in fertiliser x100

Example: You need 20 kg/ha of phosphorus and you plan to use superphosphate with 8.8% P.

Apply calculation A

Amount of superphosphate required (kg/ha)
= 20 kg/ha ÷ 8.8 (% P) x 100
= 227 kg superphosphate/ha

CALCULATING THE AMOUNT OF NUTRIENT REQUIRED ▶

You can reverse this calculation to work out how much of a nutrient you are applying.

Calculation B

Amount of nutrient kg/ha
= Amount of fertiliser kg/ha x % nutrient in fertiliser ÷ 100

Example: You plan to apply 125 kg/ha of single superphosphate

Apply calculation B

Amount of phosphorus applied (kg/ha)
= 125 kg/ha x 8.8 (% P) ÷ 100
= 11 kg P/ha

CALCULATING THE COST PER SINGLE NUTRIENT ▶

Select fertilisers for the nutrients they supply, what your soil lacks and what your plants require. If only one nutrient is deficient, compare fertilisers on the cost of that nutrient. Use the following calculation to compare the cost of that nutrient

Calculation C

Price per kg nutrient
= price per tonne ÷ 10 ÷ % nutrient

Example: urea @ $410/tonne or DAP @ $580/tonne

Apply calculation C

Urea
= $410/t ÷ 10 ÷ 46 (% N)
= $0.89/kg nitrogen

DAP
= $580/t ÷ 10 ÷ 18 (% N)
= $3.22 per kg nitrogen

Note the spreading cost may need to be added to compare fertilisers with different spreading cost.

CALCULATING THE COST OF MORE THAN ONE NUTRIENT ▶

You can use a range of fertilisers including blends, to apply the same amount of nutrients. For the fertilisers you are considering, work out the rate you would have to apply to get the nutrients required (calculation A), then use calculation D to work out the cost per hectare. When a fertiliser has two or more of the desirable nutrients, use the nutrient least supplied in the fertiliser to calculate the rate.

Calculation D

Cost per ha
= cost / tonne x rate (kg/ha) ÷ 1000

In the paddock you need 40 kg/ha nitrogen and 20 kg/ha phosphorus

Option 1: Urea and superphosphate

Apply calculation A

Rate urea
= 40 kg nitrogen ÷ 46 (% N) x 100
= 87 kg urea /ha

Rate single superphosphate
= 20 kg phosphorus ÷ 8.8 (% P) x 100
= 227 kg superphosphate / ha

Apply calculation D

Cost per ha urea
= urea @ $410/t x 87 kg/ha ÷ 1000
= $35.67

Cost per ha superphosphate
= superphosphate@ $262/t x 227 kg/ha ÷1000
= $59.47

Total cost per ha $95.14

Option 2: DAP plus urea

Apply calculation A

Rate DAP
= 20 kg P ÷ 20 (% P) x 100
= 100 kg DAP

Apply calculation B

Amount of nitrogen in 100 kg DAP
= 100 kg/ha × 18 (% N) ÷ 100
= 18 kg N/ha
An additional 22 kg of nitrogen is required as urea

Apply calculation A

Rate urea
= 22 kg N ÷ 46 (% N) x 100
= 48 kg urea

Apply calculation D

Cost per ha
DAP @ $580/t x 100 kg ÷ 1000
= $58.00
urea @ $410/t x 48 kg ÷ 1000
= $19.68

Total cost per ha $77.68

In this example, it is cheaper to apply nitrogen and phosphorus as DAP and urea.

Further reading

NSW Department of Primary Industries Publications

PROGRAZE manual

LANDSCAN™ manual

Managing Native Pastures for Agriculture and Conservation (2004)

Best Management Practices for Graziers in the Tablelands of NSW (2004)

NSW Department of Primary Industries website
www.dpi.nsw.gov.au

Mineral Content of Common Ruminant Feedstuffs, Agnote DAI 290 (Blackwood 2003)

Fertiliser Calculations, Agnote DPI 496 (Rose 2004)

Soil health and fertility

- Acidity
- Salinity
- Sodic soils
- Fertilisers and soil improvement
- Soil management guides
- Soil types, structure and condition

Field crops and pastures

Animal health, diseases and pests

Australian Soil Fertility Manual 1999
Edited by: JS Glendinning
Publisher: CSIRO PUBLISHING

Incitec Pivot

DAIRY AUSTRALIA

Canpotex

Australian Government
Land & Water Australia

Natural Heritage Trust
Helping Communities Helping Australia
A Commonwealth Government Initiative

CMA CATCHMENT MANAGEMENT AUTHORITY

ORTA RECENS QUAM PURA NITES

NSW DEPARTMENT OF
PRIMARY INDUSTRIES

ORTA RECENS QUAM PURA NITES

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PRIMARY INDUSTRIES