



# Fertiliser Use on New Zealand Dairy Farms

## Acknowledgments

The results in this booklet are based on comprehensive soil fertility and fertiliser research.

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# FERTILISER USE ON NEW ZEALAND DAIRY FARMS

The principles and practice of soil fertility  
and fertiliser use on New Zealand dairy farms

This fourth edition is created by the Fertiliser Association of New Zealand

Edited by Ants Roberts and Jeff Morton



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# Foreword

In 1993 The Dairying Research Corporation, in conjunction with AgResearch, published a booklet on fertiliser use on dairy farms. This booklet proved to be extremely popular and many thousands have been supplied to dairy farmers and technical experts.

However, time has moved on and the accumulation of additional research information has enabled refinements to be made to recommendations. The range of fertiliser products available to farmers has also increased.

The most significant development, however, is the classification of fertiliser applied to agricultural land as a contaminant under the current Resource Management legislation.

The Fertiliser Association of New Zealand Inc (formerly NZ Fertiliser Manufacturer's Research Association Inc.), in conjunction with farming organisations, has developed a Code of Practice, which if followed, should help in meeting the requirements of the legislation.

These changes together with on-going demand for sound advice on fertiliser use have required a revision of the original booklet.

Fertiliser policy is a critical part of farm management. On high performing dairy farms annual expenditure on fertiliser is a significant proportion of the cost of producing one kilogram of milk solids and successful management of nutrients is essential for long term viability of the farming business.

The Fertiliser Association of New Zealand acknowledges the past and valuable contributions made to this booklet from both AgResearch and the Dairying Research Corporation (now Dairy NZ).

**John Henderson**

Chairman

Fertiliser Association of New Zealand Inc

# Introduction

On the average dairy farm, fertiliser makes up about 20% of farm working expenses. Expenditure on fertiliser has nearly doubled in the last ten years. Greater fertiliser use has been associated with increased farm profitability on some but not all dairy farms. Therefore it is important that dairy farmers understand the principles of soil fertility and fertiliser use.

This booklet presents dairy farmers with a simple and concise summary of the role of soil fertility and fertilisers in dairy production. The information presented has been synthesised from a large volume of historical soil fertility research on dairy farms.

There have been relatively few animal grazing trials in which the effect of fertiliser use on animal production has been directly measured. However, those that have been carried out show that, where nutrient additions increase pasture production, there is also an increase in animal production. On this basis, the relationship between pasture production and soil nutrient levels presented in this booklet can be used to predict likely animal production increases. This assumes that any increase in pasture production resulting from fertiliser use will be efficiently utilised.

Introductory sections provide brief descriptions of the major soil groups on dairy farms, the major and minor elements required by plants and animals, and the basic principles of fertiliser use in pastoral agriculture. These principles should be fully understood before continuing on to other sections.

Basically, the booklet is concerned with target soil fertility levels, how to find out where levels are now, and how to alter them if necessary. There are sections on monitoring soil fertility to 'fine-tune' a fertiliser programme and when to apply fertilisers. The use of nitrogen is also discussed.

The research information represents the average over a range of conditions. However, every farm is an individual situation and putting the results of research into practice will require some modification. If in doubt you should seek guidance from a professionally trained agricultural advisor or consultant.

# Soils

From a practical agricultural point of view, there are four groups of soils on dairy farms. These are:

**Ash soils** such as *Allophanic* soils (Waikato, Taranaki), *Granular soils* (Northland, Waikato), and the poorly drained (*Gley*) soils formed from volcanic ash (Waikato, Taranaki).

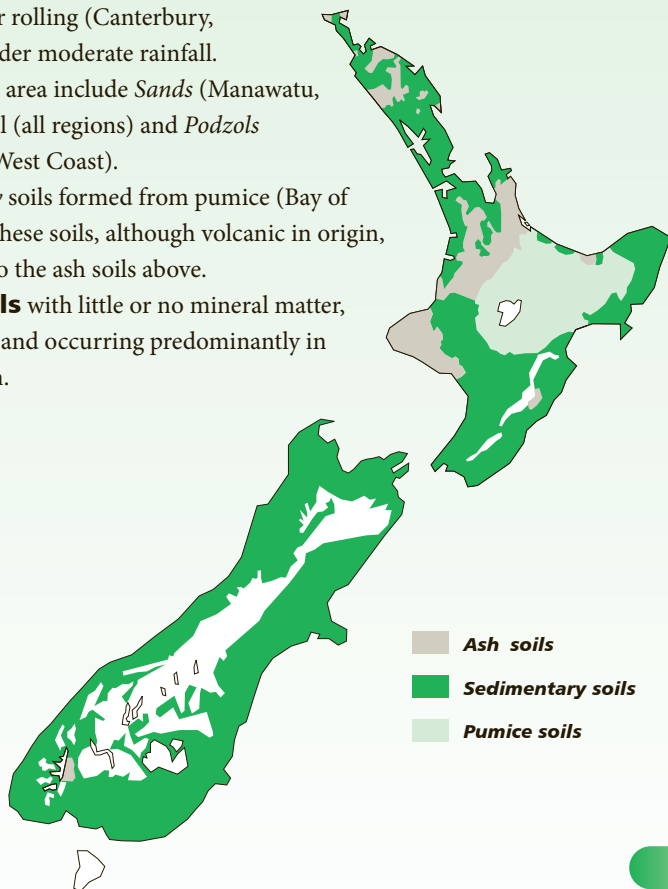
**Sedimentary soils** have been mainly formed from sedimentary rocks such as greywacke, sandstone and mudstone and include:

- **Brown** – terrace soils with reasonable drainage under moderate (Southland) to high rainfall (West Coast) or free draining stony plains soils under low rainfall (Canterbury/North Otago); moderately to highly leached soils under moderate rainfall (Northland).
- **Pallic** – poorly drained (Manawatu) or rolling (Canterbury, South Otago) soils terrace (Manawatu) or rolling (Canterbury, South Otago) soils under moderate rainfall.

Other soil groups of lesser area include *Sands* (Manawatu, Northland), *Recent alluvial* (all regions) and *Podzols* (Northland, Golden Bay, West Coast).

**Pumice soils** and *Gley* soils formed from pumice (Bay of Plenty, Central Plateau). These soils, although volcanic in origin, have different properties to the ash soils above.

**Peat or Organic soils** with little or no mineral matter, made up of plant residues and occurring predominantly in the greater Waikato region.



# Essential elements in plants and animals

Plant and animal tissue consists of carbon (C), hydrogen (H), oxygen (O) and 16 essential mineral elements. The first three (C, H, O), together with nitrogen (N), phosphorus (P) and sulphur (S), make up much of the tissue in plants and animals, while high levels of calcium (Ca) and P occur in animal skeletons. The remaining elements are generally required by the various enzyme systems of plants and animals, or for nerve activity in animals.

**The major and minor elements are as follows**

<b>Major elements</b>		<b>Minor elements</b>	
Nitrogen	(N)	Boron	(B)
Phosphorus	(P)	Iron	(Fe)
Potassium	(K)	Manganese	(Mn)
Sulphur	(S)	Copper	(Cu)
Calcium	(Ca)	Zinc	(Zn)
Magnesium	(Mg)	Molybdenum	(Mo)
Sodium	(Na)	Chlorine	(Cl)
		Cobalt	(Co)
		Selenium	(Se)

There is no known function for sodium (Na), cobalt (Co) or selenium (Se) in plants, although Co is required by the N-fixing rhizobia in clover nodules. There is no known function for boron (B) in animals.



# Balancing productivity, sustainability and environmental impacts on New Zealand pastoral farms

We can no longer hold to the tenet that for the economic well being of the country a pastoral farmer's goal should be to "grow two blades of grass where one grew before" without considering the effects of doing this on the wider environment. The fertiliser industry, in association with research providers have developed a number of procedures and tools to assist farmers to increase or maintain productivity while minimising the unwanted impacts of this activity. This section explains some of the processes and tools.

## Nutrient Management Plans (NMPs)

New Zealand farmers face challenges to demonstrate that practices are environmentally responsible. Pressures are not solely from environmental lobbyists or regulators. Market signals are increasing in clarity, particularly for exported food products. Horticultural enterprises first experienced these pressures through traceability and assurance schemes such as GLOBALGAP. Pastoral industries, including hill country, have seen such externally imposed schemes introduced over the last five years.

A more regulatory mindset is emerging. National water quality standards are being proposed which will affect land use options. Concurrently new environmental and market demands have been placed on farming. The economic drivers to enhance land productivity are exacerbated by rising farmland values. This leads to a drive to intensify per hectare production.

As a major input, fertiliser use (particularly nitrogen and phosphorus) is under intense scrutiny. Seldom does N or P fertiliser directly cause water quality effects, but rather the resultant land use intensification may. Intensive cattle operations are particularly prone to the leaching of nitrate-nitrogen from urine to groundwater. Phosphorus losses are principally but not exclusively from movement of fine soil particles into receiving water.

Farm Environmental Management Plans (FEMPs) include nutrient management plans together with riparian management, stream habitat and stock exclusion from streams plans. NMPs combine all the tools that science has produced to allow the fertiliser industry's trained nutrient advisors to develop fertiliser recommendations which maximise the productivity of individual farms or enterprises within farms, with respect to nutrient inputs, while minimising or mitigating the environmental impacts of N and P loss to surface and ground water. NMPs start by capturing the physical details of individual farms, the goals of the land managers and any regulatory conditions that need to be complied with by the managers. Soil, plant and animal tissue testing, with particular reference to longer term trends from regular monitoring programmes are used in conjunction with nutrient requirement and cycling models such as econometric

modelling and nutrient budgeting.

All of this information is used to formulate the fertiliser and lime recommendations for the farm, taking into account nutrients supplied from non-fertiliser sources such as farm dairy effluent and/or bought in supplementary feed. Fertiliser application and proof of placement maps along with the NMP form part of a full FEMP.

The benefits of having a NMP for your farm:

1. Ensure that the money spent on fertiliser nutrients maximises pasture production and quality for your individual farm situation.
2. Save money on fertiliser nutrients where these can be substituted by nutrients recycled through farm dairy effluent or brought in with supplements purchased off farm.
3. Match fertiliser nutrient expenditure to what is affordable given input costs and product prices to allow you to continue farming.
4. Record any initiatives you have in place on farm to decrease N leaching and P runoff in sensitive catchments.
5. Estimate the off-farm impacts of N and P on water quality and provide suggested mitigation strategies losses e.g., by changing form, rate or timing of N or P application or other mitigations.
6. Provide a permanent record of the information and process followed to develop the nutrient management actions for your farm.
7. Provide proof to any outside organisation that you have instigated best management practice with respect to nutrients on your farm.

It is recommended an experienced and certified nutrient management adviser or certified consultant with a good understanding of nutrient management tools and farming systems, is engaged to help formulate a nutrient management plan for the farm.

Certification of nutrient management advisers is overseen by a Nutrient Management Adviser Certification Programme (NMACP). Certified advisers are required to complete courses on nutrient management, pass tests on nutrient management knowledge and have written NMPs. Ongoing annual certification requires 15 hours of continuing professional development through attendance at appropriate conferences and workshops and completing on-line modules plus providing more NMPs.

## Nutrient budgets

### What do they do ?

A nutrient budget provides an estimate of all the nutrient inputs and outputs (N, P, K, S, Mg, Ca, Na) sourced from fertiliser, dairy effluent and feed supplements for a block of land, so that a nutrient balance can be derived. This is best carried out using OVERSEER® ( See the next section), a software programme designed to calculate nutrient budgets. From the outputs of N and P, OVERSEER can also predict the amount of N leached below the rooting zone and the P runoff loss risk, which can be used to assess the potential for impacts on receiving waters. The current version of OVERSEER contains a nutrient budget for acidification and maintenance fertiliser and lime requirements, greenhouse gas emission and energy use inventory reports and recommendations for the application of effluent to land.

### Why are they needed?

Nutrient budgets are required to ensure that nutrients leaving the farm are replaced and that excessive amounts of N and P are not being lost to potentially enrich ground and surface water. They should be carried out at the time when soil is tested and fertiliser recommendations are made by your fertiliser adviser. Alternatively you can acquire a copy of the OVERSEER software programme, free of charge from [www.overseer.org.nz](http://www.overseer.org.nz)

### Interpretation of nutrient balances and losses

As for all decision support tools, the interpretation of the model prediction is the critical factor. Some guidelines for maintenance of current soil fertility, for all soils are shown below.

<b>Nutrient</b>	<b>Target range of nutrient balance (change in inorganic pool) for production (kg/ha)</b>	<b>Environmental consideration</b>
N		> 11mg nitrate-N/L in drainage water
P	-5 to +5	+5 kgP/ha* (see losses of P from land to water)
K	-10 to +10	
S	-5 to +5	
Mg	-5 and above	
Ca	-10 and above	
Na	-5 and above	
Acidification	-2.5 to +2.5 meq	

\* only if Olsen P levels are at or above the target range for production

When interpreting the results from nutrient budgets, keep in mind:

- Balances for P, K, S, Mg and Ca should be checked against trends in soil test levels over time. For example if P is in deficit, soil Olsen P levels should be declining.
- A nutrient budget can be used to help determine fertiliser requirements as long as it takes into account where the soil test levels for the farm are in relation to economically optimum soil test ranges.
- Nitrate-N and P losses are more critical if they are contributing to a sensitive ground water domestic water supply or land is farmed close to a water body where weed and algal growth is N or P limited.

## Development of the OVERSEER® Nutrient Budget Model

OVERSEER® is a computerised nutrient budget model which supports decision making on farms and is jointly owned by the Fertiliser Association, AgResearch and Ministry for Primary Industries, but now independently managed by OVERSEER Ltd. It has been developed using detailed research on farming systems under New Zealand conditions and is a valuable tool for producing nutrient budgets and developing nutrient management plans.

OVERSEER uses readily available farm system information to estimate nutrient budgets based on long term annual averages. A nutrient budget is a summary of all nutrient inputs and outputs from a farm or block within a farm. Within the programme there are five separate models; pastoral, cut and carry, crop, fodder crop and fruit tree.

The use of the model means farmers are provided with the best management advice when planning their nutrient use. Notifications of possible fertiliser issues such as excessive leaching or excessive nutrient accumulation are provided, and users are alerted to their likely impacts and are offered more sustainable alternatives.

OVERSEER provides a means to examine the impact of nutrient use and nutrient cycling within a farm (as fertiliser, effluent, supplements or transfer by animals) on nutrient use efficiency and possible environmental effects.

The model is regularly upgraded as new science on nutrient cycling becomes available.

OVERSEER will benefit certified farm consultants and certified nutrient management advisers in their role of evaluating nutrient management practices on farms. It also has been adopted for use by policy bodies in assessing the potential for environmental effects and sustainability of agricultural management.

Nutrient budgets are recognised as an important tool for estimating nutrient cycling in farming systems and for supporting improved nutrient management for sustainable agriculture. While OVERSEER has been specifically designed to use parameters that the farmer knows or can readily obtain, often the best use would be via a certified consultant such as your fertiliser co-operative representative who has a good understanding of the model and is trained to fully interpret the programme output, and the factors which affect it.

*For more information refer to: <http://www.overseer.org.nz>*



## Spreadmark and Fertmark

Placement of fertiliser should conform to the Spreadmark Code of Practice for both aerial and ground spread fertiliser application. Companies registered under the Spreadmark and Fertmark schemes are independently audited and monitored.

**Fertmark** provides assurance that you are receiving the fertiliser product as described.

Fertmark is an independently assessed fertiliser and lime quality assurance programme run by the Fertiliser Quality Council. It provides quality assurance on the claimed nutrient content of each Fertmark registered fertiliser product. Independent audits are made on product quality and the quality systems of the participating fertiliser or lime companies.

Fertmark registered manufacturers, importers and suppliers also have an advertising code of conduct. This requires that any claims they make about the products they sell can be verified. The bright green Fertmark tick can only be used on Fertmark registered products.

**Spreadmark** accreditation means that spreading operators have been trained, their equipment independently assessed and systems audited. The Spreadmark Code of Practice for the Placement of Fertiliser in New Zealand enables farmers and land managers to get the best value for their fertiliser dollar through a fertiliser placement quality assurance programme. Like Fertmark, it is also administered by the Fertiliser Quality Council. There are two sections to the Spreadmark programme. One applies to ground spreading and another to aerial topdressing.

### **Spreadmark: Ground spreading**

The Spreadmark programme was established by the NZ Ground Spread Fertilisers' Association in 1994. It was subsequently expanded to a group with representatives from Federated Farmers, the NZGFA, fertiliser companies and the Fertiliser Association, and came under the Fertiliser Quality Council in 2002. It has as its objective the placement of fertilisers in locations where they can be of the most agricultural benefit and the least environmental harm. The scheme registers spreading companies provided they have certified spreading machinery that can operate with accuracy within defined bout widths, trained operators and an appropriate quality management system which ensures that farmer/land manager requirements are met and environmental sustainability is protected. Certification of spreading machinery is specific to each of the main fertiliser products, due to their different spreading characteristics. Overall systems are subject to an independent audit.

## **Spreadmark: Aerial Application**

In June 2006 the Fertiliser Quality Council introduced a programme for aerial applicators (fixed wing and rotary) of fertiliser. This was developed with the NZ Agricultural Aviation Association. The Spreadmark module can be completed as part of the NZAAA Accreditation Programme. Like the ground spreaders, aerial companies must have an active quality management programme, have spreading test patterns for their equipment, and certified, competent operators. The programme assists in the management of risks, and provides evidence of traceability and proof of placement.

### **Proof of placement:**

GPS (Global Positioning System) and GIS (Geographic Information System) mapping is provided by some operators and in combination with Spreadmark certification provides documented security and assurance that fertiliser has been applied where it is required and at the correct rates.

*For more information refer to: Code of Practice for Nutrient Management - Fact sheet 4 [www.fertiliser.org.nz/code-of-practice/fact-sheets](http://www.fertiliser.org.nz/code-of-practice/fact-sheets) or*

*Fertiliser Quality Council [www.fertqual.co.nz](http://www.fertqual.co.nz)*

*Ask for Fertmark registered fertilisers spread by Spreadmark certified operators.*

## **Fertiliser contaminants**

### **Cadmium (Cd)**

Cd has accumulated in our soils through the application of P fertilisers and can be detected to varying amounts in animal by-products and grains and vegetables. Plant uptake and animal exposure through plant ingestion can be reduced by improving soil organic matter, correction of soil pH, controlling weeds, grazing only older stock on high soil Cd areas and banding P fertiliser on crops. The Tiered Fertiliser Management System (TFMS) has been designed to manage the accumulation of soil Cd from P fertilisers. There are five tiers, ranging from no limitations on P fertiliser choice or rate (Tier 0 - < 0.6 ppm) to requiring no further Cd accumulation unless there is a detailed site specific investigation to identify risks and pathways for potential harm (Tier 4 - > 1.8 ppm). In conjunction with the TFMS values there are recommended field management practices to minimise the uptake of Cd by plants in agricultural soils. For further reading go to [www.fertiliser.org.nz/Site/resource\\_center/Tech\\_Papers.aspx](http://www.fertiliser.org.nz/Site/resource_center/Tech_Papers.aspx)

### **Fluoride (F)**

Fluoride is also present in superphosphate but is not taken up in significant amounts by agricultural plants. Digestion of high quantities of soil F can cause health problems in livestock but occurrence of this in New Zealand are extremely rare and related to grazing management.

# Environmental impacts of fertiliser use

Injudicious use of fertiliser may result in adverse environmental effects such as increasing nitrate concentrations in ground water, or N and/or P enrichment of surface water.

To assist farmers to meet their Resource Management Act obligations to avoid, remedy or mitigate any adverse effects of fertiliser application, the Fertiliser Association has produced in conjunction with farming organisations and regional councils a Code of Practice for Nutrient Management. If farmers follow this code, then it should help them to meet their RMA obligations where fertiliser use is a permitted activity, although it is advisable to check and fully comply with the rules and regulations of your Regional Council or unitary authority.

The code does not contain prescriptive practices for fertiliser use. Instead, the code sets out key indicators and symptoms of adverse effects of fertiliser use and provides practical options for avoiding, remedying or mitigating them. Examples of good practices for remedial action are outlined.

## **Nitrate leaching to groundwater**

- match nitrogen application to uptake by pasture
- split application, so less is applied more often
- avoid application if heavy rain is forecast or if the ground is saturated

*Code references:* Appendix 3, Fertiliser activities and environmental concerns p49.

## **Open water contamination through run-off**

- split application, applying smaller amounts more often
- avoid application if heavy rain is forecast or if the ground is saturated
- set realistic growth targets and match application to requirements
- be fastidious about accurate application (e.g using proof of placement technology)
- on steep slopes (say >15%) or where natural drainage runs towards open water, consider riparian strips and extend buffer zone between water and application site
- ensure pasture is 25 mm high (or 1000 kg DM/ha) at time of application.

*Code references:* Appendix 3, Fertiliser activities and environmental concerns p50.

### **Contamination of open water from direct application**

- when windy (anything greater than 5 kph) apply fertiliser when it is blowing away from open water
- be fastidious about accurate application, and containing fertiliser to application zone (e.g using proof of placement technology)
- use fertiliser with larger particle sizes (particles of less than 1 mm have poor ballistic properties)
- establish a riparian strip or allow for a realistic buffer zone

*Code references:* Appendix 3, Fertiliser activities and environmental concerns p51

### **Third party effects**

- consider noise implications and choose appropriate time
- consider sensitive times and places (for example schools, neighbour practising organic farming) and choose appropriate time and application techniques
- winds above 5 kph can create wind drift – so consider particle size and application method
- be fastidious about accurate application
- be neighbourly and tell others in advance – and of changes of plans

*Code references:* Appendix 3, Fertiliser activities and environmental concerns p52.

This should not be used as a substitute for the Code of Practice for Nutrient Management. It highlights some key considerations, and farmers are advised to refer to the code for more detailed information.

## Losses of ammonia (volatilisation)

Volatilisation losses of ammonia to the atmosphere straight after application are about twice as high from urea than di-ammonium phosphate and ten times higher than from ammonium sulphate. Losses are greater at high rates of N ( $> 50$  kg/ha in one application) or where there is insufficient rainfall or irrigation (less than 5 - 10 mm within eight hours of application) to move dissolved urea deeper into the soil profile where it is less susceptible to loss as ammonia gas. This rainfall occurrence is only recorded on 10 - 15% of days. Coating the urea granule with a urease inhibitor (Sustain or N Protect) can reduce ammonia losses (averaging 5 - 20% of the applied N) by approximately 50%.

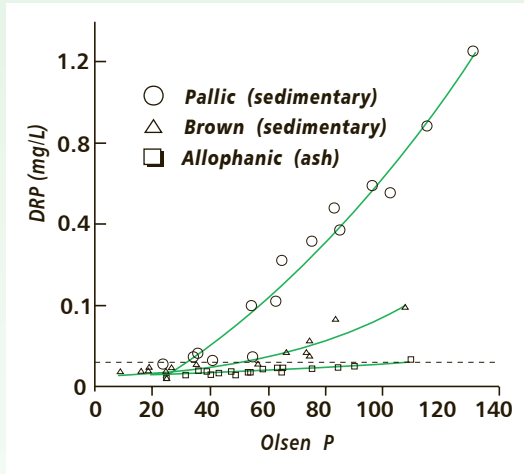


# Loss of P from land to water

## Lowland soils

The key points relating to P losses from flat and rolling land are:

- P losses are generally small (less than 100 g/ha/yr) in well structured, well drained soils.
- Greater P losses (up to 2 kg/ha/yr) occur from heavy textured soils because there is potentially more runoff from the compacted surface and mole pipe drainage allows greater transfer of dissolved, sediment and dung-P to surface waters.
- Most of the soil-derived P lost from a catchment is from within 5-10 m of streams or from mole pipe drained soils.
- Application of reactive phosphate rock (RPR) can reduce direct fertiliser losses where P fertiliser is applied in high risk situations.
- P concentrations in overland flow increase as soil Olsen P levels increase, especially in soils with anion storage capacity (ASC) less than 20%, where less P is bound to clay particles. This is shown in the graph below:



On the low ASC (15%) pallic soil the concentration of DRP (Dissolved Reactive Phosphorus) was greater than the guideline of 0.03 mg/L for surface water quality where soil fertility exceeded Olsen P 30, the upper end of the target range for sedimentary soils (see p 26). For the higher ASC brown (49%) and allophanic (ash - 83%) soil, DRP concentrations above the guidelines were achieved at much higher Olsen P levels (50 and 110 respectively).

Good Management Practices to minimise the transfer of P from land to water (as recommended in the Code of Practice) include:

- maintain Olsen P levels in the target ranges
- minimise pugging especially in areas near streams and drains
- allow a margin of greater than 10 metres between the fertilised area and open water
- fence off waterbodies from stock to exclude dung P and prevent stream bank erosion
- not applying P to saturated soils or before heavy rainfall or to pugged or compacted soils
- fencing off a riparian strip on each side of all swamps, drains, streams, rivers and lakes

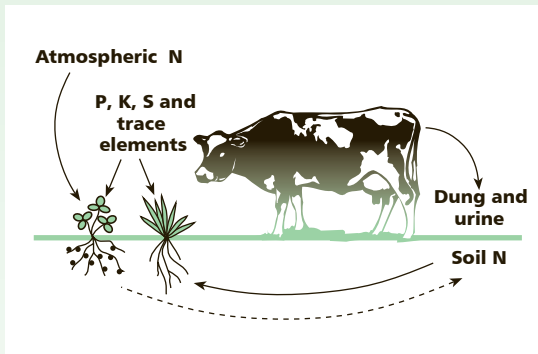
# Soil fertility practice on dairy farms basic principles

## The nitrogen cycle

The legume, principally white clover, is the most important component in the New Zealand pastoral system. It supplies nitrogen (N) that drives pasture production and provides high quality forage for milk production.

Grazing animals eat the clover and return a high proportion of the fixed N to the soil in dung and urine. Nitrogen also returns through death and decay of plant material. The N returned to the soil in this way adds to the soil N pool, and becomes available to the grass in the pasture through the action of micro-organisms in the soil.

phosphorus (P), potassium (K), sulphur (S), trace elements and lime are essential for good legume growth and N fixation. There are, however, periods of the year when N fertilisers, used tactically, will increase pasture production and profitability.

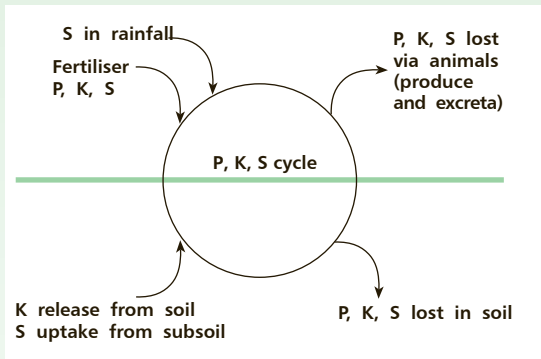


*Fertiliser nutrients are applied to encourage clover growth and N fixation. This N becomes plant available through dung and urine returned to the soil through plant death and decay.*

## Building soil fertility

Most New Zealand soils are inherently deficient in P, S, to a lesser extent K, and sometimes trace elements. Large capital inputs of fertiliser (and often lime), together with the passage of time and recycling of nutrients through the grazing animal, are required to build up soil nutrient reserves and organic matter. Pasture production and quality increases as the soil nutrient status increases through what is called the development phase. This development process may take many years, especially if initial inputs of fertiliser are not large.

Eventually, further increases in soil nutrient status will result in only relatively small increases in production. A soil nutrient status will be reached at which near maximum pasture production occurs. Fertiliser is then required simply to replace the losses of nutrients from milk and livestock leaving the farm, dung and urine deposited in gateways, races and farm dairies, and the inevitable losses of nutrients that occur in soils. At this stage maintenance fertiliser application is required.



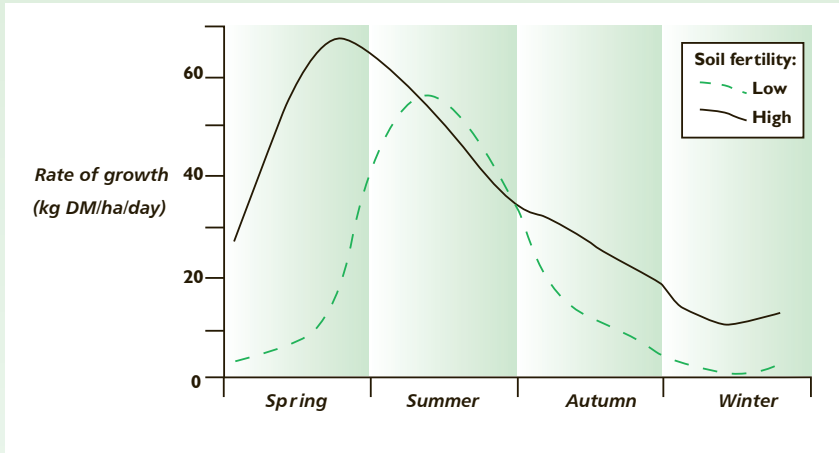
**N fixation by clover and its subsequent transfer through clovers and grazing to grasses is an important factor determining pasture production in New Zealand.**

**Fertiliser is applied to encourage this N fixation and transfer, to maximise pasture production.**

**The essential distinction between the development and maintenance phases are that, in the former, nutrient levels are still building up in the soil, where as in the latter, nutrient levels are being maintained at a steady level. For this reason the amounts of fertiliser required to develop soils are much greater than amounts required to maintain soil nutrient status, once the appropriate status is reached.**

## The importance of soil fertility to pastoral farm systems

The use of fertiliser nutrient and lime inputs to develop soils to increase pasture production and quality affects the sort of livestock production systems you are able to run. Fertiliser and lime addition, as required, is one of the key factors in moving the annual pasture production curve from a low fertility requiring grass dominant system to a high fertility requiring ryegrass/legume based annual pasture production curve.



*Typical pasture growth characteristics during the year, under high and low soil fertility.*

In the diagram above, the two pasture production curves are from farms in the same environment with the same soil characteristics. The principal difference is that the Olsen P level at the low fertility site (green dotted line) ranges from 5 to 10 while the high fertility site (dark solid line) had an Olsen P level ranging from 25-30 (i.e. within the target range for this soil). All other nutrients and pH were adequate and similar between sites. The consequent increase in pasture production and quality between the low and high fertility production curves means that in the latter case more capital stock can be carried through winter, more stock can be carried throughout, the onset of calving can be earlier and drying-off of dairy cows can be later.

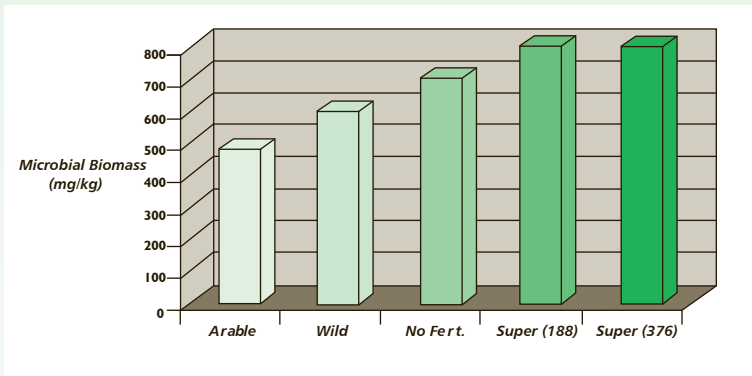


## Effect of fertiliser inputs on soil biology

Contrary to popular belief, the use of conventional ‘mineral’ fertilisers does not harm soil biology (the life in the soil). A long term field trial at DSIR Grasslands in Palmerston North during the 1950s and 60s showed that superphosphate application coupled with grazing the pasture with livestock led to an increase in both pasture production and earthworm numbers (see table).

Treatment	Earthworm numbers (million/ha)
No fertiliser	1.9
Superphosphate	5.1
Superphosphate + grazing animals (dung and urine return)	6.5

Similarly, at the Winchmore Research Station (AgResearch) superphosphate fertiliser has been applied to sheep-grazed farmlets since 1954 at 3 rates i.e., 0, 188 and 376 kg superphosphate/ha/yr. There has been no decrease in microbial biomass after 45 years of continual annual fertiliser addition. In fact, the opposite is true, whereby the application of fertiliser has increased microbial biomass, especially compared to ungrazed, unimproved areas and arable land.



The reason for the increases in both earthworm numbers and microbial biomass is simple. Just as applying fertiliser nutrients increases pasture productivity and feed supply to the farm’s grazing animals, so too is the food supply for everything that lives in the soil increased. This increase comes from the greater return of dung and urine, dead / uneaten herbage and from the turnover of the root systems of the pasture plants.

# Assessing soil nutrient status

Capital fertiliser inputs can be many times greater than maintenance inputs, especially if a rapid increase in soil nutrient status is required. Because of this, it is important to measure the existing soil nutrient status to assess whether a farm is in the development or maintenance phase. Soil testing, and taking into account fertiliser history, is the only way to do this. The following soil tests are available from most commercial laboratories:

- pH, Olsen P, K, Mg, Ca, sulphate-S, organic-S, anion and cation storage capacity.

These soil tests are used for the following purposes:

- **pH** – a measure of soil acidity and hence a test for lime requirement
- **Olsen P** – a measure of plant available P.
- **Quick Test K (QTK)** – a measure of plant available K.
- **Quick Test Mg (QTMg)** – a measure of plant available Mg.
- **Quick Test Ca (QTCa)** – a measure of plant available Ca.
- **Sulphate-S (SO<sub>4</sub>-S)** – a measure of the immediately plant available S.
- **Organic-S (Org-S) or Total S** – a measure of the long-term supply of S.
- **Tetraphenyl boron K (TBK)** - a measure of K reserves in the soil
- **Anion Storage Capacity (ASC)** – a measure of the capacity of a soil to store nutrients such as P and S (previously referred to as phosphate retention).
- **Cation storage capacity (CSC)** – a measure of the capacity of a soil to store nutrients such as Ca, Mg, K and Na (also referred to as cation exchange capacity).

## Soil Sampling

Annual soil sampling is required to monitor an increase in soil nutrient levels from capital applications or to assist in determining maintenance requirements. Once maintenance rates have been established, soil sampling should be undertaken at least once every 2 to 3 years. Taking samples 6 to 8 weeks prior to fertiliser application will allow the results of laboratory testing to be used to decide what and how much fertiliser should be purchased. The best benefit from soil test information is achieved by regular testing over a number of years.

The advent of inexpensive, hand held GPS (Global Positioning System) units has meant that permanently recording the sampling lines (transects) is made easy. This allows soil samples in future years to be collected from the same sampling lines which helps reduce spatial variability of soil test information.

A later section (page 42) discusses a soil fertility monitoring programme for farms.

## Calibrating soil tests

Soil tests are only useful if they are calibrated against pasture growth. This involves relating pasture growth to soil nutrient levels, as measured by soil tests. Relative pasture production is used in these relationships, i.e. production expressed as a percentage of the maximum. This allows data to be aggregated from different trials. The calibration curves have similar shapes, described by the term “diminishing returns” whereby increases in production become smaller with increasing soil test levels. Results from trials on a range of sites and years on a given soil type have given the “average” calibration curve for the nutrients P, K, S and for pH. These curves and an indication of variability are shown in the next section (pages 26-33).

**The percentage relative pasture production figures can be converted to estimates of actual pasture dry matter production from the following information in each region**

<i>Annual pasture production</i>	<i>t DM/ha</i>	
<i>Region</i>	<i>Average</i>	<i>Range</i>
Northland	12	8-17
Waikato/Bay of Plenty/Taranaki	14	11-17
Manawatu/Wairarapa/Hawkes Bay	11	9-15
Golden Bay/West Coast	11	8-16
Canterbury/North Otago (irrigated)	12	9-17
Otago/Southland	12	8-17

## Target soil tests

Dairy farmers will want to get high levels of pasture production to provide the cheapest feed for the herd. The calibration curves allow soil test values to be selected that will ensure high pasture productivity. However, because of the variability in the calibration curves and in soil tests, there is no precise soil nutrient level that will guarantee, in all situations (paddocks, farms, locations, years etc.), a particular pasture production. On these calibration curves the soil test value that gives 97% of maximum production across all relevant trials is indicated. In addition, to take account of variability, a target range is given as a guideline for soil tests that should be aimed for, to ensure sustainably high production. The target ranges given in the following sections of this booklet are a guide. They assume that factors such as drainage, pasture species and management are not limiting.

Target ranges for the different nutrients encompass the biological optimum soil test levels determined from the research which has been described later in this booklet. Raising soil fertility levels significantly above these target ranges will result in only very small increases in annual pasture production.

The economically optimum soil fertility levels may be different from the biologically optimum levels indicated by the target ranges. Economically optimum soil fertility levels are determined primarily by the relationship between the cost of fertiliser nutrients applied and the returns from milk produced.

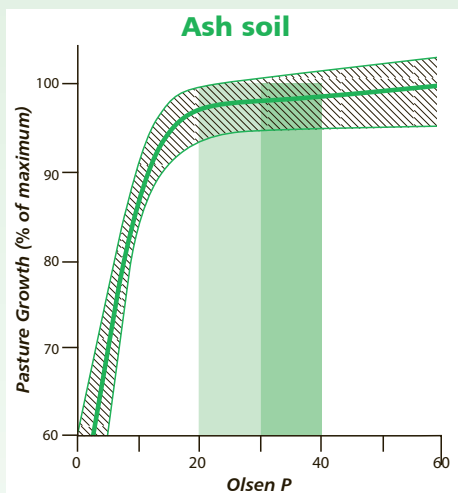
**Soil tests indicate general soil fertility, provided they are calibrated against pasture growth. Soil tests do not give a measure of the amounts of nutrients required for maximum pasture growth. Target ranges for soil tests indicate levels needed for high levels of pasture production.**

# Target soil test ranges

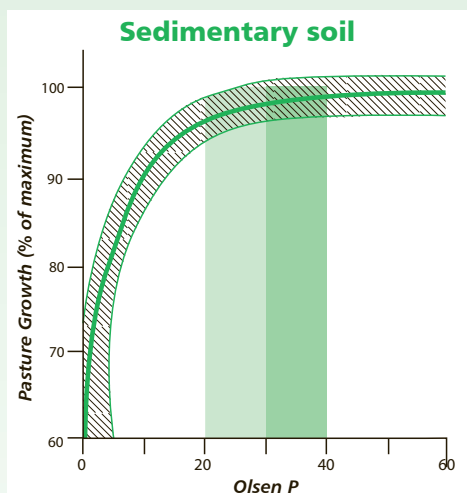
Average calibration curves (bold centre line) are presented for each major soil group. The thinner curves beside the solid curve indicate that there is a 95% probability that the average relationship lies within this band. This also applies to all the other calibration curves. Target soil test levels are presented as a range for each major soil group. If achieved, they will ensure high levels of pasture production which can be converted to milk solids with good grazing management

## Soil Olsen P

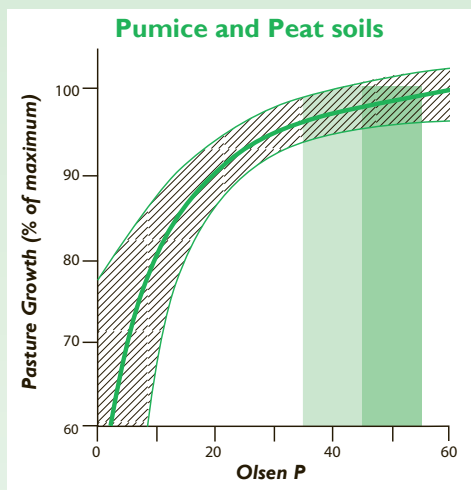
The relationships between Olsen P and pasture production are different for the major groups of volcanic ash, sedimentary, pumice and peat soils.



*The relationship between relative pasture production and Olsen P for ash soils. The shaded boxes represent target ranges for soil Olsen P for standard (light green) and high (dark green) milk solid production. High milk solid production is defined as where current milk solid production/ha is in the top 25% of the supply area or it is intended to increase to this level.*



*The relationship between relative pasture production and Olsen P for sedimentary soils. The shaded boxes represent target ranges for soil Olsen P for standard (light green) and high (dark green) milk solid production. High milk solid production is defined as where current milk solid production/ha is in the top 25% of the supply area or it is intended to increase to this level.*



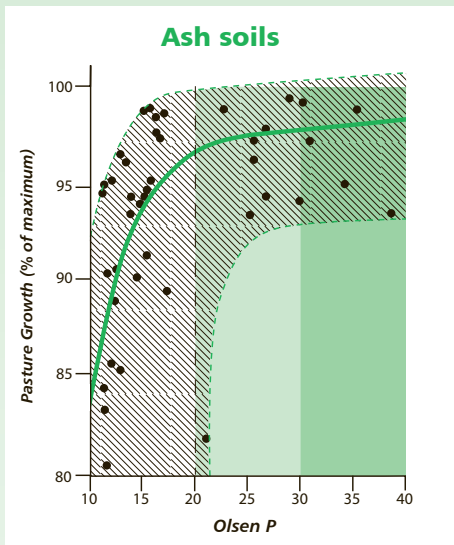
*The relationship between relative pasture production and Olsen P for pumice and peat soils. The shaded box represents target ranges for soil Olsen P for standard (light green) and high (dark green) milksolid production levels. High milksolid production is defined as where current milksolid production/ha is in the top 25% of the supply area or it is intended to increase to this level.*

The Olsen P target ranges which will sustain near-maximum pasture production are

<b>Soil</b>	<b>Target Olsen P</b>
Ash	20-30
Sedimentary	20-30
Pumice	35-45
Peat	35-45

### Soil Olsen P for high milksolids production per hectare

Although on average, near maximum pasture production is achieved at Olsen P 20-30 for ash and sedimentary soils and 35-45 for pumice and peat soils, at some trial sites further small increases in pasture production were gained at Olsen P greater than these target ranges. This is shown in the figure below which is a magnified version of the upper end of the earlier graph for ash soils. Because of variability in the measurement of pasture production and Olsen P between trial sites, at any Olsen P level there is a range of relative pasture production that could be achieved. This range is shown by the dashed lines about the solid bold centre line on the graph. At Olsen P 22, 97% of maximum pasture production is grown (on average) on ash soils. However there is still a probability (as indicated by the dashed lines) that at the lower end of the range, only 88% of maximum pasture production could be achieved. In this situation there is still a potential 12% of maximum pasture production that could be grown at higher Olsen P levels. Conversely at other sites about the upper range, Olsen P levels lower than 22 could result in near maximum pasture production.



*The relationship between relative pasture production (80-99%) and Olsen P (10-40) for ash soils. The shaded boxes represent target ranges for soil Olsen P for standard (light green) and high (dark green) milk-solid production (see the highlighted text below).*

This small increase in pasture production (1-2 t DM/ha/yr) has to be utilised by the herd before a profitable return on the investment of applying capital fertiliser to increase Olsen P (>30 on ash and sedimentary soils, >45 on pumice and peat soils) can be achieved. The management system required for this includes high stocking rates and/or per cow production to utilise 80-90% of the pasture grown. Spring pasture surpluses need to be identified early, conserved as high quality silage and fed in late lactation to maximise lactation length.

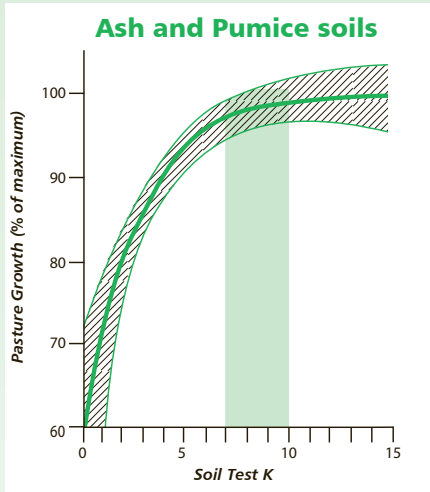
Where high rates of N fertiliser are used, i.e. in excess of 200 kg N/ha annually, there is no scientific evidence to suggest that the target Olsen P ranges discussed in this section should be altered.

#### **Recommendations for optimising Olsen P on dairy farms are:**

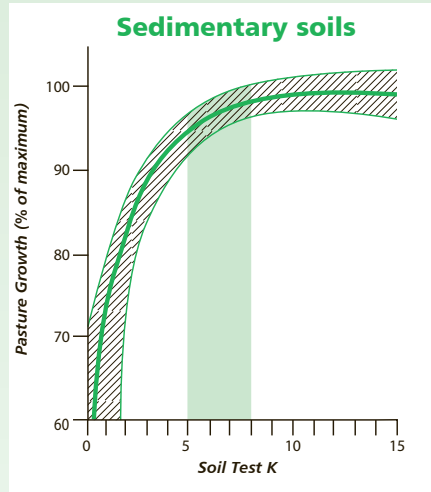
- **Where current milk solids production/ha is near the average for the supply area, maintenance of soil Olsen P levels in the target range for near maximum pasture production (20-30 for ash and sedimentary soils, 35-45 for pumice and peat soils) will allow best economic return.**
- **If current milk solids production/ha is in the top 25% for the supply area, or it is intended to increase to this level, increasing soil Olsen P above the target range (to 30-40 for ash and sedimentary soils and 45-55 for pumice and peat soils) may be justified if a response in pasture production is obtained and the appropriate management system is used to convert the extra pasture to milk solids.**

## Soil test K

Potassium (K), unlike P, is a nutrient which moves through the soil, and soil group differences are less important. Almost the same relationship between pasture production and soil test K applies across all groups.



*The relationship between relative pasture production and soil test K for ash, and pumice soils. The shaded box represents the target range.*



*The relationship between relative pasture production and soil test K for sedimentary soils. The shaded box represents the target range.*

**The soil test K levels which will sustain near maximum pasture production are**

<b>Soil</b>	<b>Target soil test K</b>
Ash	7-10
Pumice	7-10
Sedimentary	5-8
Peat	5-7



A tentative relationship has been determined between pasture growth and soil test K for peat soils. It is difficult to raise the K status of these soils above soil test K of about 4. This may also be the case for coarse-textured ash and pumice soils and Podzol soils under high rainfall. In these situations, pasture K levels, in conjunction with soil tests, should be used as an indication of soil K status.

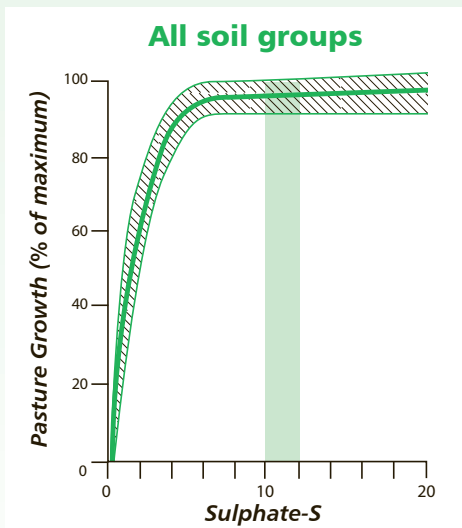
Some sedimentary soils, particularly recent soils and some Pallic soils, supply considerable amounts of K for pasture growth. This K is provided by continual weathering of clay minerals and is not measured by QTK.

A measure of this reserve K is given by the tetraphenyl boron (TBK) test. The TBK range that will sustain near maximum pasture production for the lower North Island and South Island are:

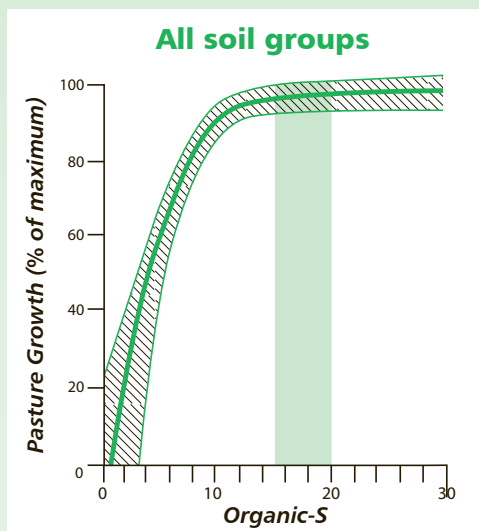
<b>Soil</b>	<b>Target TBK</b>
<b>Sedimentary</b>	<b>0.8 - 1.2</b>

### Soil test S

Like K, sulphur (S) is a nutrient which moves through most soils, and soil group differences are of lesser importance. Furthermore, there are two types of soil tests for S, one which measures immediately available S (sulphate-S) and the others which measures the slowly available S (organic-S and total S). Analysis of trial data shows that a single relationship between pasture growth and soil test S applies to all soil groups.



*The relationship between relative pasture production and soil sulphate-S for all soil groups. The shaded box represents the target range.*



*The relationship between relative pasture production and organic-S for all soil groups. The shaded box represents the target range.*

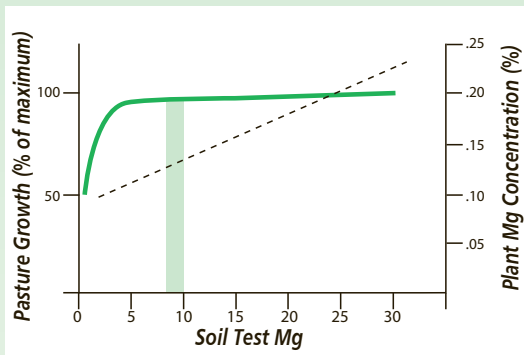
The soil test S levels that will sustain near maximum pasture production are:

<b>Soil</b>	<b>Target Ranges</b>		
	<b>Sulphate-S</b>	<b>Organic-S</b>	<b>Total-S</b>
<b>Sedimentary</b>	10-12	15-20	900-1000
<b>Ash</b>	10-12	15-20	900-1000
<b>Pumice</b>	10-12	15-20	900-1000
<b>Peat</b>	10-12	15-20	900-1000

Low levels of organic-S indicate that there are low reserves of plant available S in the soil and that an effective S fertiliser programme is required to supply adequate S to the pasture. High levels of organic-S and sulphate-S indicate that maintenance S fertiliser is required to maintain soil S levels. On some soils with low ASC (anion storage capacity), for example, podzols and peats, it is not possible to increase sulphate-S into the target ranges shown above. In these situations, rates of S to overcome a deficiency should be applied (see p34).

## Soil test Mg

Pasture production responses to magnesium (Mg) fertiliser are rare. The exception is on some pumice soils, especially if soil test Mg is less than 5. However, further increases in soil Mg levels result in higher pasture Mg concentrations. Ideal levels for animal health are considered to be 25-30 because, in general, herbage Mg levels are maintained at 0.22% or better. However, even then Mg supplementation of dairy cows in the spring may be necessary if pasture feeding levels are inadequate.



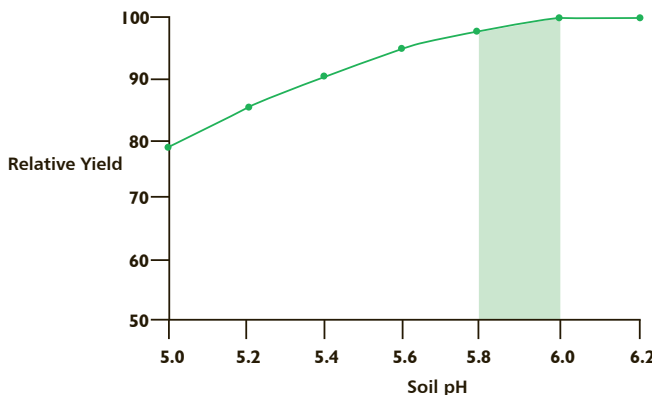
The relationship between soil test Mg, pasture production (—) and plant Mg concentration (---). The shaded box represents the target range for pasture production.

Soil test Mg levels which are appropriate for dairy farms are

Soil	Target soil test Mg (pasture)	Ideal soil test Mg (animal)
Ash	8-10	25-30
Sedimentary	8-10	25-30
Pumice	8-10	25-30
Peat	8-10	25-30

### Soil pH

Lime is applied to increase soil pH. As the soil pH increases, the size of the response to lime decreases. At pH 5.0 increases in pasture production of between 8-12% occur, depending on the rate of application. At pH levels of between 5.8-6.0, lime responses are small, indicating the target range has been reached. There is no benefit, in terms of pasture production, from liming soils with a pH greater than 6.0. Pasture growth responses to lime on undeveloped peat soils are large if the soil pH is less than the target range. It is important that the pH at the 75-150 mm soil depth also reaches the target range. This will require deep incorporation of lime.



The relationship between the response(%) in annual pasture production as a result of liming and soil pH for all soils except peats. The shaded box represents the target range. This does not apply to peat soils.

Target soil pH levels for dairy farms are:

<b>Soil</b>	<b>Depth (mm)</b>	<b>Target soil pH</b>
Ash	0-75	5.8-6.0
Sedimentary	0-75	5.8-6.0
Pumice	0-75	5.8-6.0
Peat (undeveloped)	0-75 (75-150)	5.0-5.5 (4.5-5.0)

**Target soil test ranges:**

<b>Soil Test</b>	<b>Ash</b>	<b>Sedimentary</b>	<b>Pumice</b>	<b>Peat</b>
<b>Olsen P</b>	20-30	20-30	35-45	35-45
<b>Soil test K</b>	7-10	5-8	7-10	5-7
<b>Sulphate-S</b>	10-12	10-12	10-12	10-12
<b>Organic-S</b>	15-20	15-20	15-20	15-20
<b>Soil test Mg</b>	pasture 8-10 animal 25-30	pasture 8-10 animal 25-30	pasture 8-10 animal 25-30	pasture 8-10 animal 25-30
<b>pH</b>	5.8-6.0	5.8-6.0	5.8-6.0	5.0-5.5 (0-75 mm) 4.5-5.0 (75-150 mm)

# Raising soil fertility status

If the decision is made to raise soil test levels, how is this done?

## Increasing Olsen P

Field trials indicate that the following rates of P, over and above those required to replace the annual losses from the farm, are required to raise Olsen P by 1 unit:

### Amount of P (kg/ha) to raise Olsen P by 1 unit

<i>Soil</i>	<i>Average</i>	<i>Range</i>
Ash	11 (122)*	7-18
Pumice	7 (78)	4-15
Sedimentary	5 (57)	4-7
Peat	**	6-9

\* superphosphate equivalent \*\* depends on ASC

It should be noted that there may be a delay before Olsen P levels increase from capital P applications.

## Increasing soil test K

Research data indicate that the following applications of potassium (K) are required to increase the K soil test by 1 unit:

### Amount of K (kg/ha) to raise the soil test K by 1 unit

<i>Soil</i>	<i>Average</i>	<i>Range</i>
Ash	60 (120)*	45-80
Pumice	45 (90)	35-60
Pallic soils	125 (250)	100-250
Brown soils	50 (100)	
Peat	45(90)	35-60

\* potassium chloride equivalent

Pallic soils are unlikely to require capital application of K. The high requirement to increase soil test K is due to the ability of clay minerals to retain K. Check K reserves using the TBK test. Recent alluvial soils are likely to be similar to Pallic soils. There were inadequate data available for Brown soils.

## Correcting soil S deficiency

There are no data available on the rates of sulphur (S) required to raise soil S test levels. However, trial results show that S deficiencies can be overcome with moderate inputs, even in situations where the deficiency is severe. Thus, where soil S levels are below optimum, maximum production can be obtained providing inputs of S are applied as follows:

**Amount of S (kg S/ha) to overcome deficiency**

<i>Soil</i>	<i>Average</i>	<i>Range</i>
Ash	25 (235)*	20-30
All Sedimentary	35 (330)	30-40
Pumice	45 (425)	40-50
Peat	30 (285)	20-40

\*superphosphate equivalent

Peat soils probably behave similarly to pumice soils with respect to sulphate-S. It is worthwhile noting that on ash soils, if P is applied in the form of superphosphate, S requirements are usually also met or exceeded.

**Correcting soil Mg deficiency**

Soils which are initially low in magnesium (Mg) will require around 25 kg Mg/ha (45 kg magnesium oxide/ha) to eliminate pasture Mg deficiency. On average 7 kg Mg/ha will raise QTMg by 1 unit. Satisfying animal Mg requirements will require higher inputs (100 kg Mg/ha) initially followed by maintenance applications of 20-30 kg Mg/ha/yr.

**Increasing soil pH**

Lime is essential for good pasture establishment and maintenance. On ash, pumice and sedimentary soils the following guide applies:

**1 tonne/ha of good quality limestone will raise soil pH by 0.1 unit.**

Good quality limestone contains greater than 80% calcium carbonate and has been ground to the required fineness (50% with particle diameter < 0.5 mm and all less than 2mm). If local limestones have lower calcium carbonate contents than 80%, then proportionately higher rates of lime will need to be applied to raise soil pH. Peat soils should be limed according to the following:

**Amount of lime (t/ha) to raise the soil pH by 1 unit on developed peats and peaty loams**

<i>Method of application</i>	<i>Soil Depth (mm)</i>	<i>Rate of Lime (t/ha)</i>
Surface applied	0-75	9
	75-150	–
Half surface applied and half incorporated	0-75	16
	75-150	34

Surface applied lime does not move down into peat soil. If the pH (75-150 mm) is less than 4.5 it will be necessary to incorporate lime into the subsoil during cultivation.

**Amounts of nutrients required to raise the soil test by 1 unit**

<i>Soils</i>	<i>Ash</i>	<i>Pumice</i>	<i>Sedimentary</i>	<i>Peat</i>
<b>Phosphate (P) (kg/ha)</b>	11	7	5	6-9
<b>Potassium (K) (kg/ha)</b>	60	45	125**	30
<b>Sulphur (S) (kg/ha)*</b>	25	45	35	30
<b>Lime (t/ha)</b>	10	10	10	***

\* To overcome deficiency \*\* Pallic soils \*\*\* Depends on depth

## Maintaining soil fertility status

Once target soil test levels have been achieved, how much fertiliser is required to maintain soil fertility status? More precise maintenance rates can be calculated from establish ing trends in soil test levels over time through the use of annual soil testing (see p42). The amounts of P, K and S required to maintain soil fertility status at different stocking rates, across all soils, are:

### Maintenance nutrient requirements (kg/ha) in relation to stocking rate

<b>Stocking rate (cows/ha)*</b>	<b>Maintenance rate</b>		
	<b>P</b>	<b>K</b>	<b>S</b>
2	20-28	20-50	10-23
2.5	27-36	25-58	13-30
3	34-45	40-70	16-35
3.5	43-55	50-82	19-40
4	54-65	60-95	22-45

\* 1 cow at 460 kg liveweight producing 330 kg milksolids.

### Examples of maintenance requirements

Using the *OVERSEER* programme, maintenance requirements for P, K and S have been calculated for a dairy farm on ash and sedimentary soils with average milksolids production/ha. Input data and predicted requirements are shown in the table below:

<b>Parameter</b>	<b>Ash soil</b>	<b>Sedimentary soil</b>
Slope	Flat	Flat
Olsen P	30	30
Soil organic-S	10	6
S applied in last 2 yrs (kg/ha)	50	50
Quick test K	7	7
Reserve K	Very low	Low
K leaching	High	High
Rainfall (mm)	1000-1500	1000-1500 (includes irrigation)
Kg MS/ha	800	750
Stocking rate (cows/ha)	2.7	2.6

<i>Parameter</i>	<i>Ash soil</i>	<i>Sedimentary soil</i>
<b><i>Maintenance requirements (kg/ha)</i></b>		
<b>P</b>	<b>38</b>	<b>30</b>
<b>S</b>	<b>25</b>	<b>30</b>
<b>K</b>	<b>61</b>	<b>25</b>

Because these rates of nutrients maintained near maximum pasture production, there was no financial advantage to increasing soil PKS values by applying higher rates of fertiliser nutrients. A general rule-of-thumb can be stated as:

### **Ash and pumice soils**

**Apply 0.6 to 0.8 kg/ha 20% potassic superphosphate or equivalent for every 1 kg/ha milksolids produced.**

### **Sedimentary soils**

**Apply 0.5 to 0.7 kg/ha 15% potassic superphosphate or equivalent for every 1 kg/ha milk solids produced.**

**Whichever 'recipe' is followed, farmers should monitor their soil fertility levels and make adjustments to their fertiliser programme accordingly. Once target soil test levels have been reached, maintenance fertiliser applications are appropriate. Maintenance fertiliser rates can be calculated from nutrient losses, which are largely determined by milksolids production per ha.**

### **Irrigated soils**

Trial work on irrigated and dry land systems indicates that maintenance P, S, and K requirements of pasture on sedimentary soils are similarly dependent on stocking rate and production per hectare. Since irrigated pastures are higher producing than dry land pastures, animal production and hence nutrient losses are also greater. These greater losses of nutrients mean that higher maintenance rates of nutrients are required to replace them. With high irrigation rates on stony free draining soils, a more slowly available form of S may need to be applied and this is covered on p40.



# Withholding fertiliser

Historical information suggests that as fertiliser is a major expense in most dairy farm budgets, it is one of the few items that is often reduced during downturns in the farming economy. However, serious consideration should be given to the following when re-examining the fertiliser budget:

1. Completely withholding P fertiliser is an option if you are at or above the economic optimum soil fertility levels for your farm and will avoid any possible effect to the long term financial viability of your business. Remember that the application of other nutrients such as sulphur (S) and potassium (K) if required should remain unchanged unless they too are above the optimum for your situation.
2. If you are at or below the economic optimum soil fertility levels, wherever possible, apply enough of the required nutrients to maintain your current levels of soil fertility.
3. If you are not in a position to apply full maintenance nutrient requirements due to financial constraints, then sub-maintenance rates will be much better than applying none. Remember that this mostly applies to P, not to the mobile nutrients such as S and K.
4. A further option is to differentially apply fertiliser. You could extensively test all blocks or paddocks to determine areas of high and low soil fertility and redistribute your fertiliser applications to bring all areas together at the economic optimum soil fertility levels.

# Timing of fertiliser application

The factors which determine the timing of nutrient application, and the need for single or split dressings, are:

- the rate at which the particular nutrient moves through the soil
- the ability of the soil to 'hold' the nutrient
- the amount of rainfall
- the texture of the soil

## Phosphorus

Soil phosphorus (P) moves slowly through soils, a consequence of its incorporation into organic matter and binding onto soil minerals (often referred to as phosphate retention). There are very few leaching losses of P. It does not matter when P fertilisers are applied, but if the soil test levels are low and an immediate increase in production is required, the sooner it is applied the sooner there will be benefits. Application rates of greater than 100 kg P/ha (1100 kg superphosphate/ha) in a single application are not recommended. If capital inputs higher than this rate are required, then the dressing should be split. In the maintenance situation, P can be applied at any time of the year. However, from an environmental point of view, applying soluble P fertilisers outside the high risk months of April to October will reduce the risk of P runoff.

Peat soils have low anion storage capacity because they have little mineral matter. There may be some advantages in splitting P dressings on these soils, especially at high application rates, but there is no experimental evidence to prove this.

To minimise the effect of fluoride poisoning, animals should not graze pastures where phosphate fertiliser has been applied until at least 25mm of rain has fallen. This is especially true where capital rates of P have been applied.

## Potassium

In contrast to P, potassium (K) moves quickly through the soil and leaching can occur. However, timing of application is only important where rainfall is high.

### **Ash and pumice soils with rainfall above 1500 mm and peat soils**

Trial results show greater annual pasture production where K is applied in spring rather than autumn. However, for all situations, when capital amounts are required (greater than 50 kg K/ha), it is advisable to split the application. The plant will take up less K and there will be fewer losses in urine through the animal, reducing the opportunity for K leaching.

## **Ash and pumice soils with rainfall below 1500 mm**

Under these circumstances, where normal K inputs are required (50-100 kg K/ha), spring or autumn applications are equally effective.

### **Sedimentary soils**

Trial results, for a single application show greater annual pasture production where K is applied in spring rather than autumn. There is no evidence to suggest that split applications are superior at typical rates of application (30-60 kg K/ha).

### **For all soils**

Avoid applying K before and during calving as it can worsen cow metabolic problems. Apply K after calving when clover growth is increasing. Ryegrasses which make up most of the pasture in early spring are very efficient at extracting K from the soil and can usually grow to their potential without K fertiliser over that period.

## **Sulphur**

Sulphate-S, the form present in superphosphate, is readily available to the plant and moves rapidly through soils, whereas elemental-S must first be oxidised by soil micro organisms to sulphate-S before it is plant available. Elemental-S should be more effective than sulphate-S on soils with high rainfall and low anion storage capacity (ASC).

### **Pumice and peat soils**

The form of S to be used will depend on when the normal fertiliser application is made. Trial results on coarse textured pumice soils showed larger responses from fine elemental S, than from sulphate-S when applied in the autumn, but there was no difference when applied in spring.

### **Ash soils: free draining (ASC above 90)**

Trials on these soils show that neither form of S nor the time of application, have any effect on pasture production. Either form of S can be used, irrespective of when the fertiliser is applied.

### **Ash soils: poorly drained (ASC below 90)**

For these soils there is no difference, in terms of long-term pasture production, between sulphate-S and fine elemental-S. However, there is evidence that elemental-S will maintain more even pasture S concentrations.

### **Sedimentary soils (rainfall & irrigation >1500 mm)**

A mix of sulphate-S (superphosphate, ammonium sulphate) and fine elemental-S (particle diameter < 500µm) should be applied in spring, especially on stony free-draining soils. Alternatively, split applications of sulphate-S can be made in August/September and February.

### **Sedimentary soils (rainfall and irrigation <1500 mm)**

For these soils there is no difference, in terms of long-term pasture production, between sulphate-S and fine elemental-S. However, there is evidence that elemental-S will maintain more even pasture S concentrations.

- **Timing of P fertiliser application is unimportant, but no more than 100 kg P/ha (1100 kg/ha superphosphate) should be applied in a single dressing.**
- **Split applications of K fertiliser are only important on coarse textured soils when rainfall is high (above 1500mm) or on all soils when greater than 50 kg K/ha (100 kg/ha muriate of potash) is required. Avoid the application of K before and during calving.**
- **Timing of S fertiliser application is unimportant on ash soils but more important on sedimentary, peat and pumice soils. Using a mixture of sulphate-S and elemental-S on these soils reduces the requirement for split applications. On sedimentary soils S fertiliser application should be carried out in spring. Elemental S should be used on Podzol soils, and where rainfall and/or irrigation is greater than 1500mm on free draining soils.**

## Monitoring the soil fertility status of the farm

As fertiliser is treated as one of the major items of discretionary expenditure on the dairy farm, the investment in soil fertility should be monitored regularly.

However, soil tests, like all biological measurements, are variable and therefore a single soil test taken at one time is of limited value.

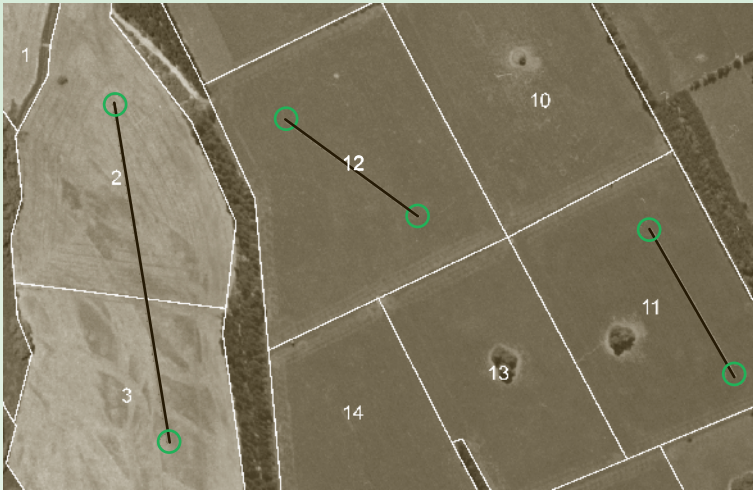
Maximum advantage from soil analysis will be achieved by repeated testing over a number of years. In this way, a picture of trends in soil fertility status of the farm is built up. The use of inexpensive handheld GPS units will assist in permanently identifying where soil samples are collected from, which will allow repeated testing from the same areas each time.

A farm soil fertility monitoring programme can be set up as follows:

- For farms which vary in soil type and slope, divide the farm into areas of similar soils, slope and grazing management history.
- Set up sampling lines within each area avoiding gateways, fences, trees, hedges and water troughs. Ideally three sampling lines should be set up for each area.
- Collect a soil sample (15 or more cores, 75mm deep) along each sampling line every year until a trend is established.
- Sample in the same month each time, usually a few weeks prior to applying fertiliser. Avoid sampling in very dry or wet soil conditions.
- Graph the average soil test results (and the lowest and highest value) for each area.
- Follow the trends and adjust fertiliser inputs accordingly.

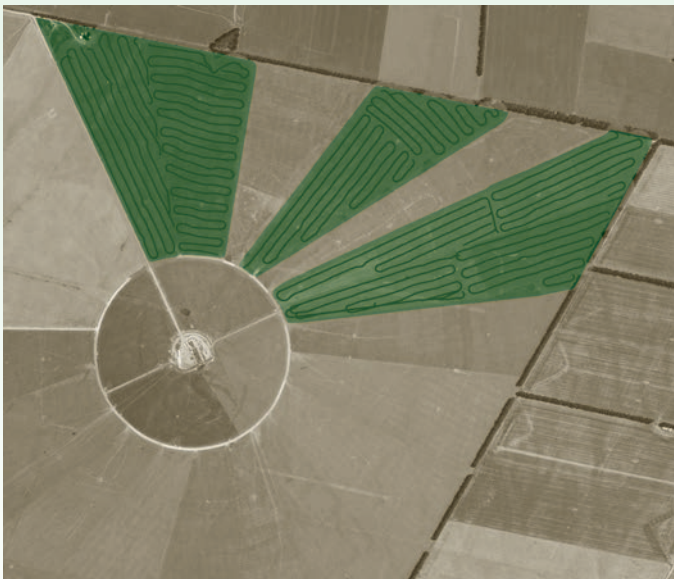
Alternatively, if the farm is uniform in slope and soil type, identify 4-6 monitor paddocks and set up one sampling line across each.

Pasture samples can be collected from the same sampling lines.



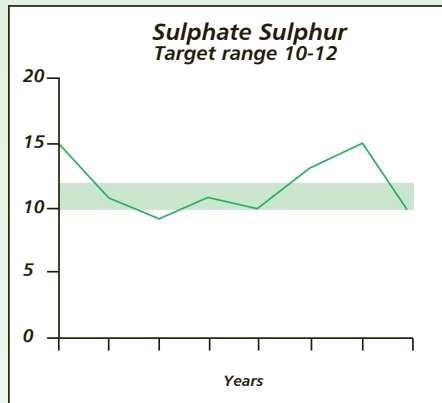
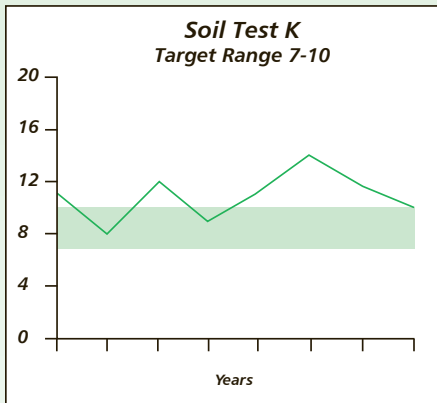
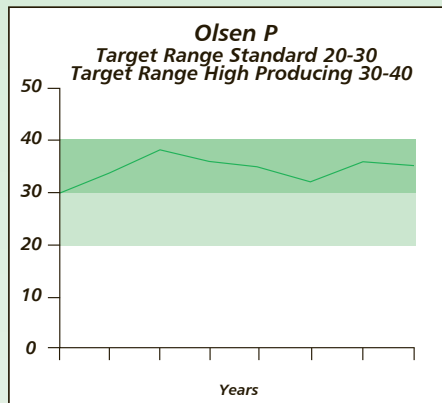
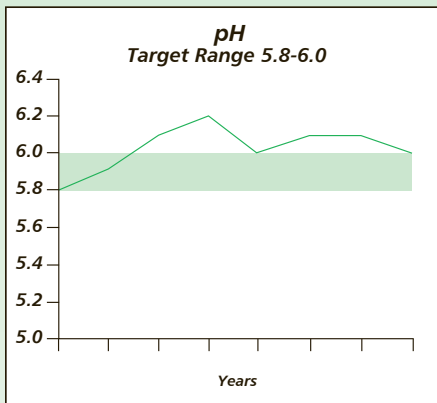
### Sampling lines for monitoring soil fertility

Sampling lines should be selected to cover different soils, slopes and management with samples taken from these lines every year until a trend is established. Sampling lines can be permanently identified by painting fence post tops or placing pegs under fence, or by recording co-ordinates using a hand held GPS unit as shown in this figure.



### Proof of placement

Electronic records of fertiliser applications provide proof of placement and are a valuable record when assessing environmental and production outcomes.



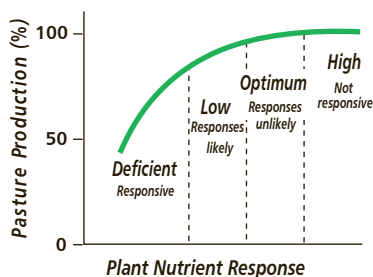
An example of the results of a soil fertility monitoring programme are shown here. The shaded areas represent the target ranges for pasture production. For Olsen P the dark shaded area represents the target range for high production levels. Annual average soil test trends for this Waikato farm on an ash soil are shown relative to the target range for above average production. For several years this farm has maintained the Olsen P level within the 30-40 optimum range and a maintenance P fertiliser is appropriate to continue. The K levels are climbing above the target range and maintenance K fertiliser inputs adjusted downwards accordingly. A nutrient budget for this farm would assist in this decision. As with P, soil test S is being maintained in the appropriate target range. Soil pH has bounced around at the top end of the target range for some years and so either no lime is required on this farm or a maintenance rate at 200- 400kg/ha annually could be applied to maintain soil pH at current levels.

# Pasture analysis

Pasture plant nutrient analysis is a useful back-up to soil testing. While soil testing determines available soil nutrient status, pasture analysis should be used to assess how much nutrient has been taken up from a fertiliser application. It is also useful to check on trace element status. Pasture samples should be taken from 2-3 paddocks in late spring, when climate is not limiting pasture growth rate and analysed for the major nutrients. If pasture concentrations are low then more nutrient can be applied to correct this. Soil tests do not accurately measure the amounts of trace elements available to pastures and animals, but can indicate the build up of a trace element in the soil after it is applied in fertiliser. Trace elements are present in small quantities in the soil making the relationship between soil content and plant and animal requirements hard to define.

Pasture nutrient concentrations have been calibrated against pasture production, in the same manner as soil test levels. By relating pasture nutrient concentrations to yield, levels can be defined as either deficient (production responses will occur), low (responses may occur), optimum (responses unlikely) or high (responses will not occur).

Extreme care is needed when interpreting pasture analysis results, because nutrient levels in pasture are more variable than in soils. They are affected by pasture composition, time of year, stage of growth and soil moisture conditions. Professional advice should be sought before collecting samples and interpreting results. In general, for dairying, ash soils may be low in Co and Se. Pumice soils are typically deficient in Co and Se and low in Na. Boron (B) may also be deficient for plant growth, particularly lucerne or brassicas. Peat soils are typically deficient in Cu, Se and molybdenum (Mo), although some peats are very high in Mo, and can be low in Na.



See table:  
*Guidelines for interpreting mixed pasture chemical analysis for pasture growth*



## Guidelines for interpreting mixed pasture chemical analysis for pasture growth

### Concentrations

<b>Nutrient</b>	<b>Deficient</b>	<b>Low</b>	<b>Optimum</b>	<b>High</b>
<b>(% of DM)</b>				
N	<4.0	4.0-4.7	4.7-5.5	>5.5
P	<0.30	0.30-0.34	0.35-0.40	>0.40
K	<2.0	2.0-2.4	2.5-3.0	>3.0
S	<0.25	0.25-0.27	0.28-0.35	>0.35
Mg	<0.15	0.15-0.17	0.18-0.22	>0.22
Ca	<0.25	0.25-0.29	0.30-0.50	>0.50
<b>ppm</b>				
Fe	<45	45-49	50-65	>65
Mn	<20	20-24	25-30	>30
Zn	<12	12-15	16-19	>19
Cu	<5	5	6-7	>7
B <sup>1</sup>	<13	13-14	15-16	>16
Mo <sup>1</sup>	<0.10	0.10-0.14	0.15-0.20	>0.20

<sup>1</sup>Clover only, NOT mixed pasture samples. For a Mo deficiency, clover N must also be below 4.5%.

Mixed pasture containing the optimum mineral contents given above will generally also supply animal requirements, provided the grazing animals are fully fed. However, for sodium (Na), copper (Cu), cobalt (Co), selenium (Se) and iodine (I), the pasture concentrations required to meet the animal's nutritional needs are greater than for the plant alone. The pasture concentrations given for these below are to meet animal requirements, not pasture requirements:

### Guidelines for critical mineral concentrations (where levels should be above) in pasture for adequate nutrition of a lactating cow

<b>Nutrient</b>	<b>Pasture Concentration</b>
Na	0.11%
Cu <sup>1</sup>	10 ppm
Co	0.06 ppm
Se	0.03 ppm
I <sup>2</sup>	0.25 ppm

<sup>1</sup> Depends on Mo and Fe concentrations

<sup>2</sup> 2 ppm I recommended if feed contains goitrogens (e.g. forage kales, other brassicas).  
(Source: The Mineral Requirements of Grazing Ruminants, 1983)

# Correction of trace element deficiencies

When trace-element deficiencies have been identified by herbage and/or animal liver tissue (or body fluid) analyses, they may be corrected by the addition of the required mineral(s) to the fertiliser to be applied. Alternatively, some trace elements can be directly administered to animals. This may be the only option to ensure animals receive sufficient available copper (Cu) in situations where high molybdenum (Mo) and/or iron (Fe) levels occur in pasture. A response in pasture production to Mo will only occur if both clover Mo and N are deficient (< 0.1 ppm Mo, < 4.5% N). Responses to B application will generally only occur in brassica, lucerne and clover seed crops.

## Trace element applications sufficient to overcome clinical deficiencies

<b>Element</b>	<b>Additive</b>	<b>Application rate</b>	<b>Frequency of additive</b>
Co <sup>1</sup>	Cobalt sulphate (21% Co)	(capital)	350 g/ha (Late Spring) Annually for 5-10 years
		(capital)	240 g/ha (Summer) Annually for 5-10 years
		(maintenance)	60-100 g/ha (Spring) Annually
Cu <sup>2</sup>	Copper sulphate (25% Cu)	(capital)	5-10 kg/ha (Autumn) Initially, then
		(maintenance)	5 kg/ha (Autumn) Every 4-5 years
Mo <sup>3</sup>	Sodium molybdate (40% Mo)	50-100 g/ha (Spring)	Every 4-5 years after testing clover
Se <sup>4</sup>	Selcote Ultra prills (1% Se)	0.5-1.0 kg/ha (Spring or Autumn)	Annually
	Selprill Double (2% Se)	0.5 kg/ha (Spring or Autumn)	Annually
B	Sodium borate (15% B)	5-10 kg/ha (Spring)	initially after testing clover, then
		5 kg/ha (Spring)	Every 4-5 years

<sup>1</sup> Where Granular Co (10% Co) is used, apply twice the rate

<sup>2</sup> Effective where pasture Mo levels are less than 1ppm

<sup>3</sup> Where granular Mo (10% Mo) is used, apply four times the rate

<sup>4</sup> Application rates should not exceed 10g/ha of selenium (as sodium selenate).

# Nitrogen fertiliser for pasture

Pasture legumes fix atmospheric nitrogen (N) which, when converted to soil N drives pasture production. Maximising legume production and function requires a high soil fertility status in terms of phosphate (P), potassium (K), sulphur (S), lime and trace elements. Once this high fertility status has been achieved, there is a place for the strategic use of N fertiliser. N fertiliser is a management tool because it is a way of producing extra feed at times when animal requirements exceed pasture growth – in effect, N fertiliser is a form of ‘supplementary feed’.

**The key to profitable, strategic N use is to identify feed deficits early and apply N to fill those periods.**

## Seasonal responses

If pasture growth is being restricted by cold temperatures (i.e., below 5°C), waterlogged soils or dry conditions, then N responses will be limited. In general, pasture responses are largest and most reliable when the growth rate of pasture is greatest i.e., in mid-late spring in most regions. Autumn responses are generally smaller and less reliable than those in spring, while winter responses are lowest and the risk of direct loss of fertiliser N by leaching is greatest. Mid-to-late summer applications of N fertiliser are not recommended where low soil moisture limits growth. However good responses can occur on irrigated farms or regions which have reliable summer rainfall.

## Guidelines for maximising pasture response from N fertiliser

To maximise response from N fertiliser:

- Use appropriate application rates:
  - grazed pasture 25-50 kg N/ha (50- 100 kg urea/ha)
  - silage and hay 50-75 kg N/ha (100- 150 kg urea/ha)
- Apply to pastures with some regrowth e.g. 1600-1800 kg DM/ha (50 mm) or better
- Graze within 4 to 5 weeks of application or cut silage or hay within 5 to 6 weeks.
- Apply in advance of feed deficits

## Strategic N use on dairy farms

Calving dates on many dairy farms are before the onset of spring growth. When the milkers are rotating through the pastures for the second time after calving, there is often a feed deficit as pasture growth rates are exceeded by herd requirements. Late winter/ early spring applications of 30-50 kg N/ha to winter grazed pastures, as they reach a herbage mass of 1600-2000 kg DM/ha, will ensure good responses and can increase the potential for milk production.

Spring applications of 40-60 kg N/ha to rapidly growing pastures allows full feeding of lactating cows, lifting cow condition and increasing milk production. Alternatively, spring applications can be used to increase the amount of supplement conserved, especially silage. The extra supplement above the winter requirement, may then be fed back in dry summers, although good silage quality is essential. Autumn applications of 20-40 kg N/ha can be used to extend milking and lengthen the lactation as drying off approaches. This allows a feed wedge to be created for winter grazing.

## N and the environment

Good N management creates a win:win situation – it is profitable and minimises direct environmental impacts from N fertiliser use.

### Nitrate leaching

- Nitrate leaching is minimised when there is rapid nitrogen uptake by actively growing pasture. This is obtained by not exceeding recommended application rates and applying N at the suggested times
- Direct leaching from nitrogen fertiliser is greatest in winter

### Soil factors

- Nitrogen fertilisers slowly acidify soil over time. Monitor soil pH regularly and lime as necessary
- Nitrogen fertiliser use may increase Ca leaching losses in soil. Monitor levels of Ca and other nutrients by soil and/or herbage testing annually

#### **Summary of good management practices for nitrogen fertilisers**

- **Use N fertiliser as a strategic tool to complement clovers.**
- **Time N fertiliser applications to meet a specific feed shortage.**
- **Graze N boosted grass at the same height as non-N fertilised pasture.**
- **With N fertiliser, silage can be grown more quickly, so paddocks are returned to grazing sooner.**
- **By regular soil testing, ensure that soil pH and levels of other nutrients are adequate for high pasture growth rates.**
- **Leave an unfertilised strip next to creeks and drains to avoid spreading N fertiliser directly into them. This will minimise adverse environmental effects on surface water.**
- **Operate your fertiliser spreading machinery to obtain an even spread at the required rate.**

**Do not exceed the recommended N fertiliser application rates. Higher rates may give short term benefits at the expense of long term environmental damage. Total N fertiliser applications of 200 kg N/ha/year or more should only be implemented after referring to the Code of Practice for Nutrient Management (Fertiliser Association of New Zealand, 2013) and obtaining the advice of a certified consultant.**

# Applying farm dairy effluent to land

## Benefits

Farm dairy effluent mainly comprises dung, urine, udder washwater, milking plant washwater and milk spillages.

- It contains valuable nutrients N, P, K, S and trace elements.
- It adds organic matter to the soil and increases earthworm activity.
- It can be applied directly from the farm dairy, or after storage in ponds or barrier ditches.

## Nutrient content

The nutrient value of effluent varies greatly between farms, and even within a farm over the season. To get the best value from it, a number of samples throughout the season, particularly in spring, should be analysed to decide the most appropriate application rate.

## Land application

Most but not all Regional Councils allow land application of effluent as a permitted activity under the Resource Management Act, provided very specific conditions are met. e.g., annual loading rates do not exceed certain levels such as, 150 kg N/ha or 200 kg N/ha depending on the Regional Council.

Make sure you are familiar with all the requirements for land application of effluent- whether it is a permitted activity or requires a consent, and ensure you abide by all conditions set by the Regional Council.

**For more information contact:** Fertiliser Association of New Zealand Inc  
PO Box 11519  
Manners Street Central  
Wellington, New Zealand  
Ph. (04) 473 6552  
Fax (04) 473 6551  
Email: [info@fertiliser.org.nz](mailto:info@fertiliser.org.nz)  
Website: [www.fertiliser.org.nz](http://www.fertiliser.org.nz)

# Forms and types of fertiliser

Over recent years, the range of fertiliser products has greatly increased. When choosing the appropriate fertiliser the following factors should be considered;

- current soil fertility
- past fertiliser history
- farmer objectives
- which product is going to provide the required mix of nutrients at the best price

A brief description of the broad categories of fertilisers available is given. A fertiliser company technical representative can provide more specific production information. Figures in brackets after each fertiliser are the typical N-P-K-S ratings.

## P fertilisers

### Fully acidulated P fertilisers

#### Superphosphate (0-9-0-11)

- a soluble (readily plant available) P and S fertiliser
- contains appreciable quantities of Ca
- often mixed with K, N and Mg

#### Triple Superphosphate (0-21-0-2)

- as above, except contains more P than single superphosphate and insignificant S

### Unacidulated P fertiliser (RPR)

#### Reactive Phosphate Rock (0-13-0-1)

- slow release, requires soil processes to release P
- rate of P release greater as soil pH decreases from pH 6 to pH 5
- contains little or no S
- not suitable for rapidly increasing soil P status

## K fertilisers

### Potassium Chloride (0-0-50-0)

- also called muriate of potash
- soluble and readily plant available
- often mixed with all of the above P fertilisers
- coarser potassium chloride (chip potash) is also available for mixing with well-granulated fertiliser (eg. DAP, urea)

### Potassium Sulphate (0-0-40-17)

- soluble and readily plant available
- contains both K and S
- usually more expensive than KCl

## S fertilisers

### Calcium Sulphate (0-0-0-20)

- the form of S in superphosphate
- soluble

### Elemental S (0-0-0-100)

- slow release form of S
- particle size controls the rate of S release
- often mixed with RPR
- also used to increase the S content of superphosphate for specific farm conditions

## N fertilisers

### Urea (46-0-0-0)

- soluble

### Ammonium Sulphate (21-0-0-24)

- soluble
- contains both N and S

## Mg fertilisers

### Magnesium Oxide (MgO)

- contains 55% Mg
- slow release
- often mixed with superphosphate

## Compound fertilisers

eg. DAP (18-20-0-2), MAP (11-22-0-1)

- soluble
- contain varying amounts of N, P, K and S depending on formulation

## Liquid fertilisers

- a varied range of products made from seaweed extracts, fish waste and blood and bone etc.
- variable nutrient contents
- N-P-K-S ratings may be similar to 10-4-5-0
- these products are generally diluted substantially before application.  
Nutrients applied will therefore be proportionately less than label N-P-K-S ratings





