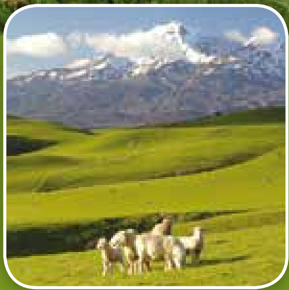

Fertiliser Use on New Zealand Sheep and Beef Farms

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FERTILISER USE ON NEW ZEALAND SHEEP AND BEEF FARMS

The principles and practice of soil fertility and fertiliser use on New Zealand sheep and beef farms.

This fifth edition is created by
Fertiliser Association of New Zealand

Edited by Jeff Morton and Ants Roberts

Contents

Foreword

The fertiliser manufacturing industry in New Zealand plays a vital role in the well being of land users and the environment. We continue to monitor information trends and develop research programmes to meet current and future trends. Since 1993 the accumulation of additional research information has enabled refinements to be made to valuable recommendations contained within this booklet.

Use of fertiliser is vital, not only to individuals farming our land, but also to the well being of New Zealand as a whole. Under use means landowners are not making the best uses of the resources available, while overuse can be expensive and lead to undesirable environmental effects and be damaging economically to users. Efficient and effective use of fertiliser is a cornerstone to long term sustainable management. Our Code of Practice for Nutrient Management uses this as its core objective.

We commend this booklet to you to help in understanding more effective and efficient use of fertilisers.

John Henderson
Chairman
Fertiliser Association of New Zealand Inc

Introduction

Farm profitability is directly linked to fertiliser use. Inappropriate or inadequate fertiliser nutrient application can result in unsustainable farming systems, both economically and environmentally.

This booklet presents farmers with a simple and concise summary of the role of soil fertility and fertilisers in sheep and beef production. Where possible, research results are shown which support the information presented. This information has been extracted from a computer database containing the records of past fertiliser field trials which have measured the effects of fertiliser applications on pasture production.

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 in New Zealand, as well as the major and minor elements required by plants and animals. Given the increased interest from the public in general about the sustainability and environmental impact of farming systems, considerable care must be taken by farmers with respect to nutrient management. The fertiliser industry has developed a number of tools to assist farmers in this endeavour. These are presented in the early sections of this booklet.

The basic principles of fertiliser use in pastoral agriculture, are presented and these should be fully understood before continuing on to other sections.

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 fertiliser company nutrient management advisor, or consultant.

Soils

From a practical agricultural point of view, there are two major groups of soils on which sheep and beef farming is carried out. These are:

Sedimentary soils: These soils have been derived from sedimentary material (greywacke, sandstone, mudstone) and include:

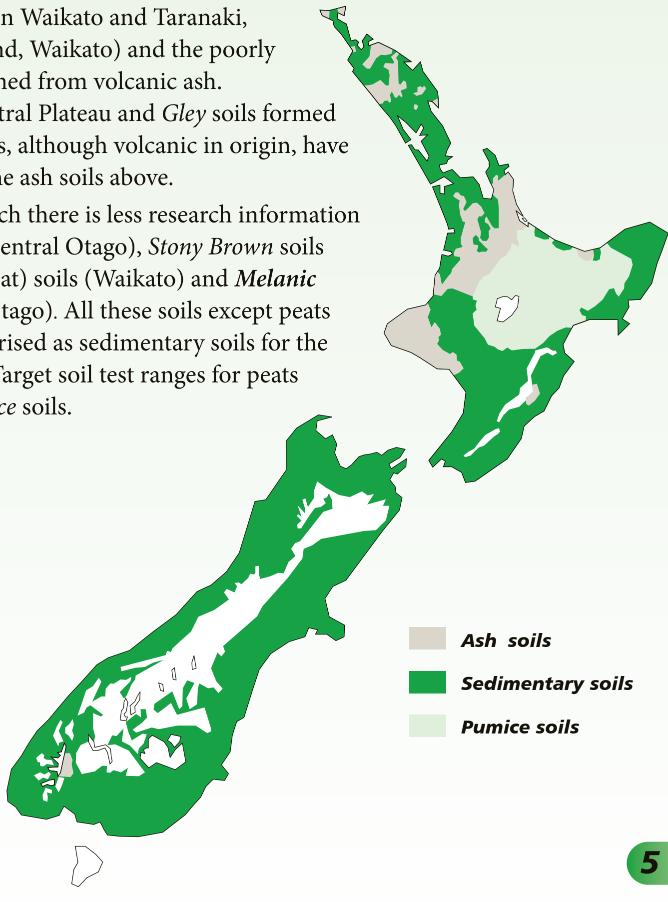
- ***Brown*** soils on terraces (Southland) and hill country (both North and South Island). Generally these are well drained soils under moderate rainfall.
- ***Pallic*** soils are either poorly drained soils on terrace or rolling lands under moderate rainfall (Manawatu, South Otago) or free draining soils on terraces or rolling lands under low rainfall (Hawkes Bay, Wairarapa, Marlborough, Canterbury).

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

Volcanic soils:

- ***Ash or Allophanic*** soils in Waikato and Taranaki, *Granular* soils (Northland, Waikato) and the poorly drained (*Gley*) soils formed from volcanic ash.
- ***Pumice soils*** on the Central Plateau and *Gley* soils formed from pumice. These soils, although volcanic in origin, have different properties to the ash soils above.

Other soil groups for which there is less research information include: *Semi-arid* soils (Central Otago), *Stony Brown* soils (Canterbury), ***Organic*** (peat) soils (Waikato) and ***Melanic*** (limestone) soils (North Otago). All these soils except peats and Podzols can be categorised as sedimentary soils for the purposes of this booklet. Target soil test ranges for peats tend to be similar to *Pumice* soils.



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

Major elements		***Minor elements***	
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 have been established which will affect land use options. Concurrently new environmental and market demands are being 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 from movement of fine soil particles into receiving water.

Farm Environment Management Plans (FEMPs) include nutrient management plans together with riparian management, stream habitat and stock exclusion from stream plans. NMPs combine all the tools that science has produced to allow the fertiliser industry's trained nutrient advisers 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 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 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 to reduce losses e.g., by changing form, rate or timing of N or P application.
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, tested 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 completion of on-line modules plus completing 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 and feed supplements for a block of land, so that a nutrient balance can be derived. This is best carried out using OverseerFM software (see the next section) which is designed to helps farmers and their advisers to understand nutrient movements within a farm, including the production of nutrient budgets for the farm. From the outputs of N and P, the Overseer model 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. OverseerFM contains reports including whole farm or farm management block nutrient budgets, block maintenance fertiliser and lime requirements, whole farm greenhouse gas emissions.

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. The software can be accessed by visiting *https://fm.overseer.org.nz* and following the registration/login instructions.

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 all soils are shown below.

Nutrient	Target range of nutrient balance (change in consideration inorganic pool) for production (kg/ha)	Environmental consideration
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 should 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 Fertiliser Association, AgResearch and Ministry for Primary Industries.

The Overseer model 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. (A full development history can be found on the *www.overseer.org.nz* website). Following significant investment and development the model is now available through the OverseerFM software platform.

OverseerFM 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 nutrient management issues such as excessive leaching or excessive nutrient accumulation are provided. Users are alerted and can seek more sustainable alternatives.

OverseerFM provides a means to examine the impact of nutrient use and nutrient cycling within a farm (as fertiliser, supplements or transfer by animals) on nutrient use efficiency and nutrient loss.

The model is regularly upgraded as new science on nutrient cycling becomes available. OverseerFM 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 OverseerFM 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 many spreading 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,** *www.fertiliser.org.nz* or **Fertiliser Quality Council** *www.fertqual.co.nz*

Ask for Fertmark registered fertilisers spread by Spreadmark certified operators.

Contaminants in fertiliser

Cadmium (Cd)

Cd has accumulated in our soils from application of P fertilisers and can be detected to varying amounts in animal by-products and grain and vegetables. Plant uptake and animal exposure through plant ingestion can be reduced by improving soil organic matter content, 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 soil cadmium tiers, with fertiliser management ranging from no limitations on P fertiliser type and rate (Tier 0 < 0.6 ppm) to requiring no further soil 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 designed to minimise the uptake of Cd by plants in agricultural soils.

For further reading go to *www.fertiliser.org.nz*

Fluoride (F)

Fluoride is also present in superphosphate but is not taken up by agricultural plants in significant amounts. Ingestion of high quantities of soil F can cause health problems in livestock but occurrences 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 groundwater, or N and/or P enrichment of surface water. As defined under current Resource Management legislation, fertiliser, along with a large number of other substances, is included in the definition of a contaminant. As such a Resource Consent should be obtained each time fertiliser is applied unless it has been allowed by a Rule in a Plan (e.g. given permitted activity status). The Fertiliser Association of New Zealand (FANZ) has produced, in conjunction with farming organisations, 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 reducing them. Examples from the Code of Practice for Nutrient Management of good practices for remedial action are outlined below:

Nitrate leaching to groundwater (see Section on Fertiliser Activities and Environmental Concerns p49 of the Code)

- match N applications to plant growth
- split N applications so that smaller amounts (25-50 kg N/ha) are applied more frequently.
- avoid application if heavy rain is likely or when there are puddles on the pasture

Contamination of open water from fertiliser run-off

- on slopes greater than say 15 degrees or with natural drainage lines running down to open water apply smaller amounts of fertiliser more frequently, develop riparian strips and increase buffer distance between application and the open water.
- check weather forecast and avoid application if rain seems likely.
- ensure pasture cover is greater than 1000 kg DM/ha or 25 mm height.
- if soil permeability is low, improve drainage and reduce soil compaction.
- apply fertiliser when tile drains are not running

Avoid direct application of fertiliser to open water

- apply fertiliser when wind direction is away from open water
- have fertiliser storage sites more than 10m from open water

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 in well structured, well drained soils.
- Greater P losses 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 5-10m of streams or from mole pipe drained soils.
- 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.

Hill country soils

The key points relating to P losses from hill country are:

- Most P losses (up to 2 kg/ha/yr) occur from relatively small near-stream areas (within 5-10 m) and within-paddock channel flows during a few storm events each year when runoff occurs.
- The largest proportion of P loss is from P bound to soil particles from bank or slip erosion (high P concentration) or transport of soil particles in overland flow (low P concentration).
- P losses increase with increased Olsen P (as above for lowland soils).
- Application of reactive phosphate rock (RPR) and serpentine superphosphate can reduce short term direct fertiliser P losses up to 60 days after application where P fertiliser is applied in periods of high risk of heavy rainfall events. In the longer term, there is no difference in direct fertiliser P losses between the fertiliser types.

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

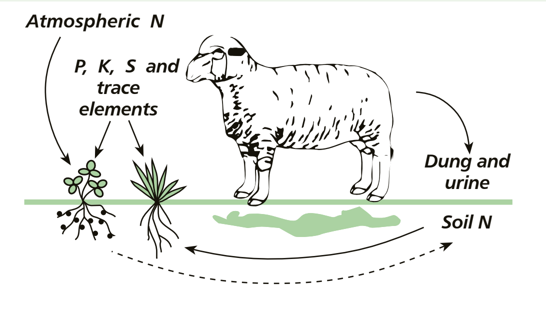
- maintain Olsen P levels in the target ranges.
- minimise pugging especially in areas near streams and drains.
- allow a margin of greater than 10 metres between the fertilised area and open water.
- fence off waterbodies from stock to exclude dung P and prevent streambank erosion.
- not applying P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

Soil Fertility Practice on Pastoral 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.

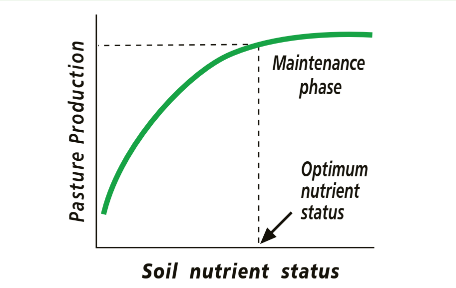


Fertiliser nutrients are applied to encourage white clover growth and N fixation. This N becomes plant available through dung and urine returned to the soil and through plant death and decay.

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.

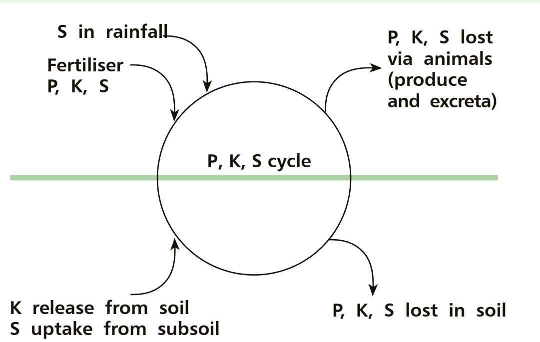
Building soil fertility

Most New Zealand soils are inherently deficient in P, S, to a lesser extent K, and some times 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.



Application of fertiliser builds up reserves of nutrients in both organic (i.e. as organic matter) and inorganic forms and hence total soil nutrient status increases. Initially pasture production increases rapidly as soil nutrient status increases during the development phase. When the maintenance phase is reached only small pasture growth increases result from large increases in soil nutrient status.

Land that has pasture recently established from its original state will still be in the development phase. Large inputs of nutrients will be needed to build soil fertility reserves. 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. Farms at this stage of development can be regarded as being in the maintenance phase. Fertiliser is then required simply to replace the loss of nutrients from produce and livestock leaving the farm, from being transferred to camping spots by dung and urine deposits and from the inevitable losses of nutrients that occur in soils. At this stage maintenance fertiliser application is required. The term maintenance refers specifically to the rate of fertiliser nutrient required to maintain the soil test at a constant level.

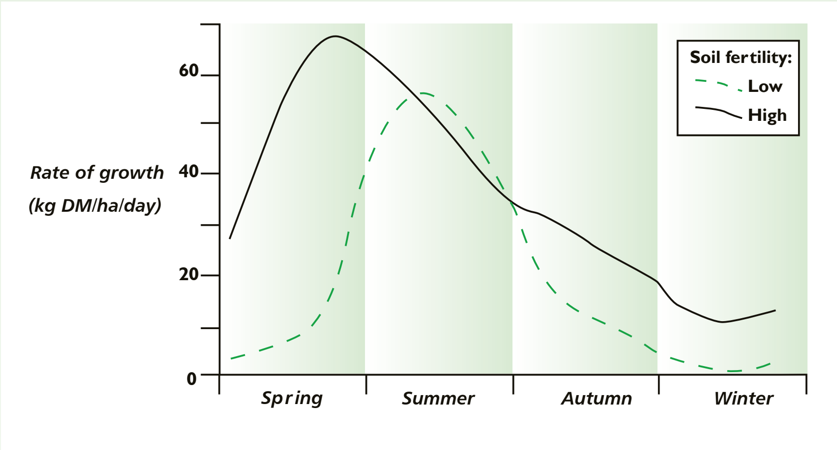


When a farm is in the maintenance phase,fertiliser nutrients are required simply to replace losses occurring due to natural soil processes and grazing with animals.

N fixation by clover and its subsequent transfer through clovers 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 is that, in the former, nutrient levels are still building up in the soil, whereas 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.

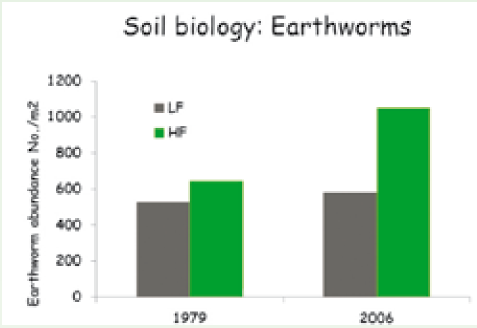


Typical pasture growth characteristics during the year, under high and low soil fertility.

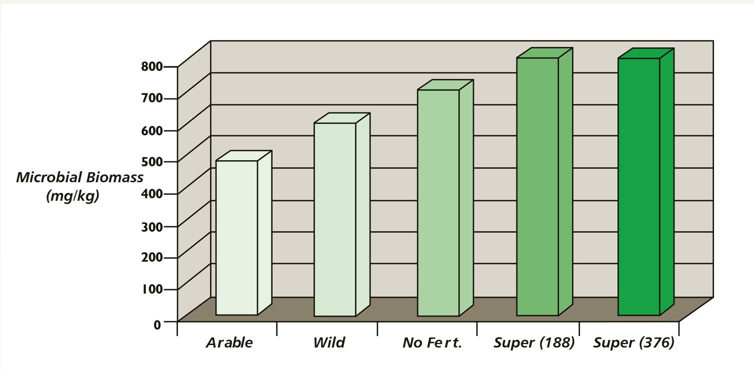
In the diagram above, the two pasture production curves are from farms in the same environment with the same soil characteristics. The principal difference is that the Olsen P level at the low fertility site (green dotted line) ranges from 5 to 10 while the high fertility site (dark solid line) had an 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 or finished during the rest of the year, the onset of calving/lambing can be earlier, and there is more opportunity to flush ewes for mating.

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 Ballantrae Research Station in Southern Hawkes Bay during the 1970s and 80s showed that superphosphate application coupled with grazing the pasture with livestock led to an increase in earthworm numbers (see figure).



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_4-S)** – a measure of the immediately plant available S.
- **Tetra-phenyl boron K (TBK)** – a measure of the long term supply of K.
- **Organic-S (Org-S) or Total S** – a measure of the long-term supply of S.
- **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 the increase in soil nutrient levels from capital fertiliser applications or to assist in determining the maintenance requirements. In the normal farm situation, 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 in this book (page 38) discusses a soil fertility monitoring programme for the farm.

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" - 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 each nutrient, P, K, S and for pH. These average curves and an indication of variability are shown in the next section (page 23).
The percentage figures can be converted to actual dry matter production from the maximum pasture production for any one location. For the regions covered in this booklet, the long-term average is 10 t DM/ha/yr, with a range of 5-17 t DM/ha/yr.

Target soil tests

The soil test calibration curves indicate the average likely response in pasture production to fertiliser nutrient application. However, because of the variability in the calibration curves and in soil tests, there is no precise soil nutrient level, in all situations (paddocks, farms, locations, years etc), that will guarantee a particular pasture production. This variability is greatest in the medium range of soil test values and least in the extreme low and high range.

In this booklet, the soil test which, on average, has given 97% of maximum production across all relevant trials indicates near maximum pasture production. 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 high production.

For a particular nutrient, soils below the optimum in the development phase will generally respond to fertiliser. Above the optimum in the maintenance phase, nutrient deficiency is not significantly limiting pasture growth and responses are less likely. For this situation, withholding fertiliser will "mine" soil nutrient reserves, which will fall as a result.

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.

Economics

The economically optimum soil fertility is not necessarily the same as the soil fertility providing near-maximum pasture production. Sheep and beef farms will be required to grow different amounts of pasture depending on stocking rate and animal production. Only the highly stocked, finishing farms (15 – 20 SU/ha) with favourable soils, climate and terrain will be required to achieve near-maximum pasture production (12 – 15 t DM/ha/yr) for which target soil test ranges are outlined as a benchmark in the next section. These target ranges include Olsen P levels of 20 – 30 for sedimentary and ash soils, and 35 – 45 for pumice and peat soils, QT K levels of 7 – 10 for pumice and ash soils, 5 – 8 for sedimentary soils and 5 – 7 for peat soils and soil sulphate-S levels of 10 – 12 for all soils.

Most sheep and beef farms are breeding operations with some finishing livestock. They have varying proportions of hill country and seasonally variable rainfall. These farms are typically stocked at 8 – 10 SU/ha and require less than near-maximum pasture production. The economically optimal soil test ranges for these farms will be lower, for example, Olsen P 12 (hills) to 20 (flats), QT K 4 – 5 and sulphate-S 6 – 8 ppm.

Farms stocked at 10 – 15 SU/ha will have target soil test ranges between these two extremes. The graphs that show the relationship between soil test level and pasture growth in the next section illustrate these points.

For an individual farm, econometric modelling for P, K, S and lime can be carried out to determine the economically optimal soil test ranges and the rates of fertiliser nutrients required to achieve or maintain them.

This economic optimum can be defined as the point at which the cost of an additional fertiliser nutrient is equal to the resulting financial return in production, over a timespan of several years.

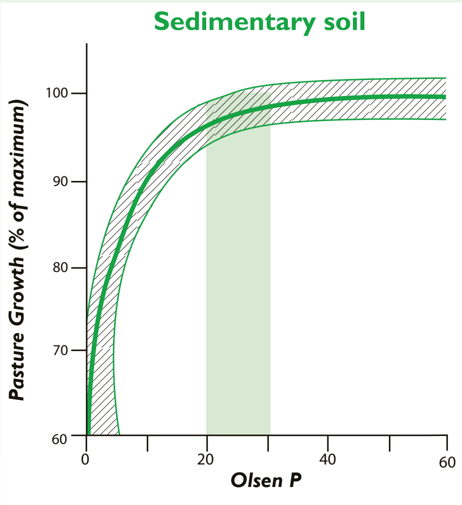
Although target soil test ranges for near-maximum pasture production are shown in the next section, only highly productive farms growing 12 – 15 t DM/ha/yr and running 15 – 20 SU/ha will be required to achieve them.

On most sheep and beef farms economically optimal soil fertility will necessarily achieve and maintain soil test results below the target soil test range for near-maximum pasture production.

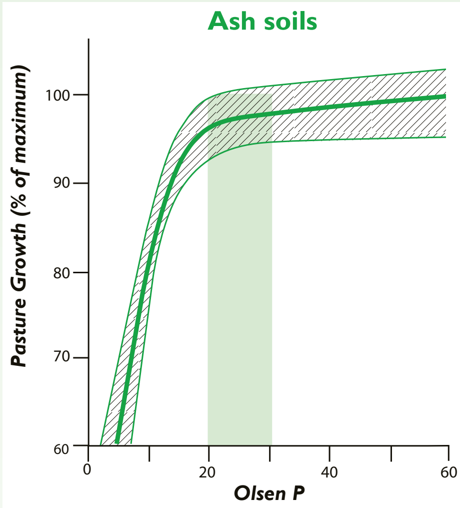
Target soil test ranges

Average calibration curves (bold centre line) are presented for each major soil group. The thinner line beside the solid average curve indicates that there is a 95% probability that the average relationship lies within this band. This applies to all the calibration curves. Target soil test levels are presented as a range for each major soil group.

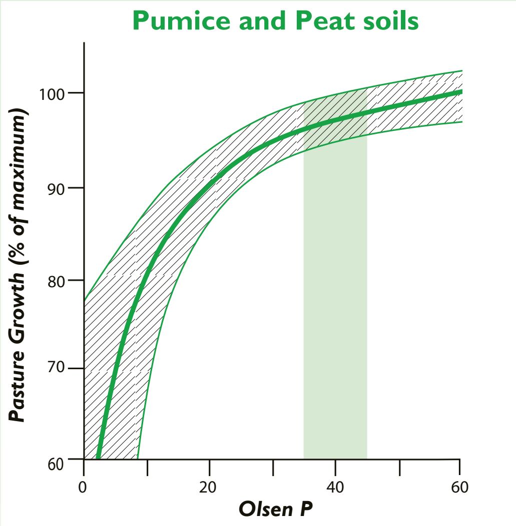
Soil Olsen P



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



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



The relationship between relative pasture production and Olsen P for* pumice and peat soils*. Near maximum pasture production is achieved at Olsen P 38. The shaded box represents the target range for soil Olsen P.

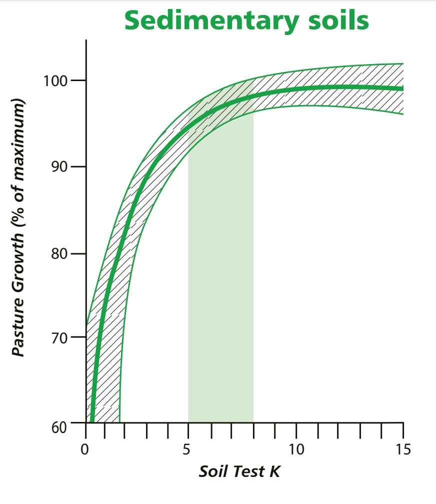
The Olsen P levels which will sustain near-maximum pasture production are

Soil	***Target Olsen P***
Ash	20-30
Sedimentary	20-30
Pumice	35-45
Peat	35-45

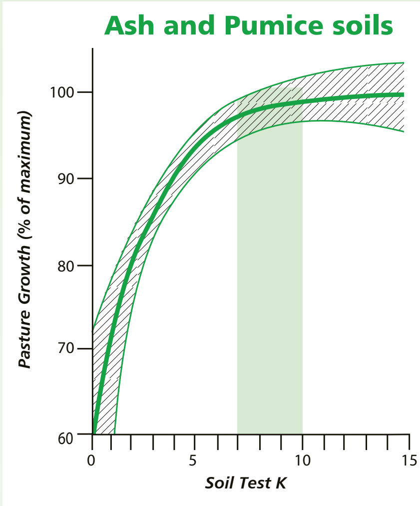
Podzol soils that have not been hump and hollowed or flipped have a range of Olsen P 12-15 for near maximum pasture production.

Soil test K

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



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



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

The soil test K levels that will sustain near maximum pasture production for New Zealand sheep and beef farms are:

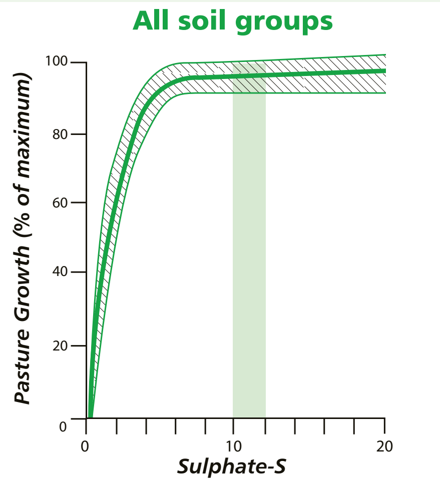
Soil	*Target soil test K*
Sedimentary	5-8
Ash	7-10
Pumice	7-10
Peat	5-7

No definite relationship has been determined between pasture growth and soil test K for peat and Podzol soils. It is difficult to raise the K status of these soils above soil test K of 4. This may also be the case for coarse-textured ash and pumice 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.

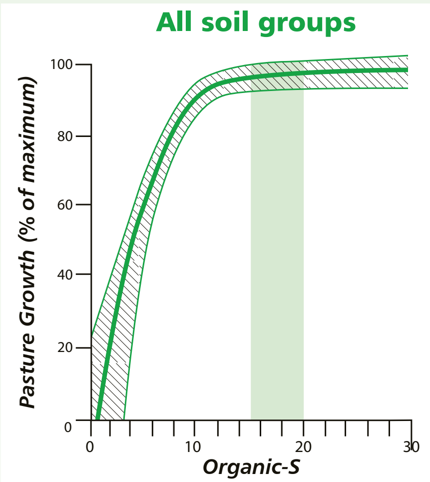
The soil TBK test should be used to measure reserve K in recent and yellow-grey earth soils. Limited calibration data indicates that a level of 1.0 me% will result in near maximum pasture production.

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 measure 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 for soil Sulphate -S.



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

The soil test S levels that will sustain near maximum pasture production for New Zealand sheep and beef farms are:

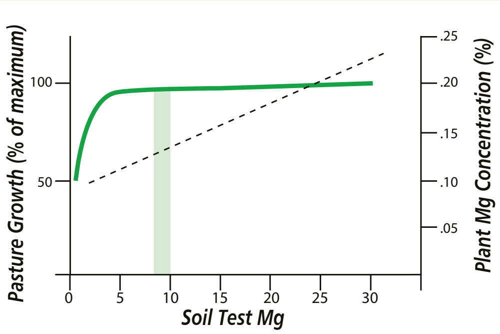
Soil	***Target Ranges***		
	Sulphate-S	***Organic-S***	***Total-S***
Sedimentary	10-12	15-20	900-1000
Ash	10-12	15-20	900-1000
Pumice	10-12	15-20	900-1000
Peat	10-12	15-20	900-1000

Low levels of organic-S or total 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 p30).

Soil test Mg

Pasture production responses to magnesium (Mg) fertiliser are rare, except on some pumice soils, especially if soil test Mg is less than 4-5. However, further increases in soil Mg levels result in higher pasture Mg concentrations. Ideal levels are considered to be 25-30, but even then Mg supplementation of ewes and beef cows in the spring will be necessary if they are underfed.



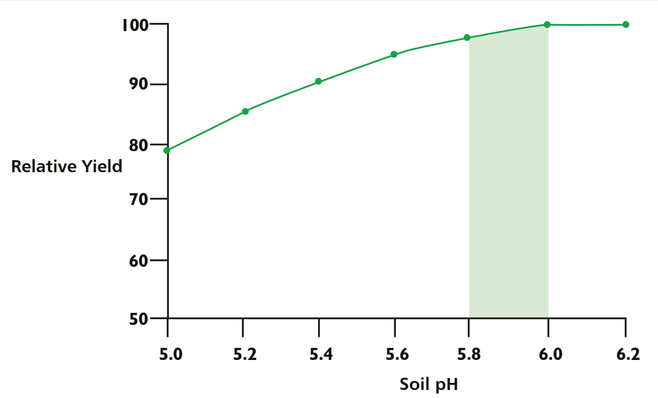
The relationship between soil test Mg(QTMg), pasture production(—) and plant Mg concentration(-----). The shaded box represents the target range for pasture production.

Soil test Mg levels that are appropriate for New Zealand sheep and beef 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 Increase (%) in annual pasture production as a result of liming, and soil pH. The shaded box represents the target range for soil pH. This does not apply to peat soils

Target soil pH levels for New Zealand sheep and beef farms are:

Soil	*Depth (mm)*	*Target soil pH*
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:

Soil Test	Ash	Sedimentary	Pumice	Peat
Olsen P	20-30	20-30	35-45	35-45
Soil test K	7-10	5-8	7-10	5-7
Sulphate-S	10-12	10-12	10-12	10-12
Organic-S	15-20	15-20	15-20	15-20
Soil test Mg	pasture 8-10 animal 25-30	pasture 8-10 animal 25-30	pasture 8-10 animal 25-30	pasture 8-10 animal 25-30
pH	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 and move up the pasture development/ maintenance curve, how is this done?

Increasing Olsen P

It is important to use large capital inputs of soluble P fertiliser to raise soil P status. It is more effective to apply a high rate of P over 1 or 2 years, than to apply the same amount of P over several years. Field trials indicate that on sites where there has been a previous history of P application, 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. Where pasture is established on previously undeveloped land, more capital P may be initially needed.

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

Soil	*Average*	*Range*
Sedimentary	5 (56)*	4-7
Ash	11 (122)*	7-18
Pumice	7 (78)*	4-15
Peat	**	6-9

* superphosphate equivalent ** depends on ASC

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

Soil	*Average*	*Range*
Sedimentary	125[1] (250)[2]	100-250
Ash	60 (120)[2]	45-80
Pumice	45 (90)[2]	35-60

[1] This requirement applies to Pallic soils only. These soils are unlikely to require capital application of K. The high requirement is because of the ability of clay minerals to retain K. Check K reserves using the TBK test, some recent soils are likely to be similar to Pallic soils. There was insufficient data available for Brown soils.

[2] muriate of potash equivalent

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

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

*superphosphate equivalent

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

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

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

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

In pasture growth trials, on soils above the target range, the amounts of phosphate (P), potassium (K) and sulphur (S) required to keep soil test levels constant over time, (i.e. generalised maintenance rates), have been determined.

There is a wide variation in annual maintenance requirements between soil types and farming systems e.g. 5-50 kg P/ha, 0-60 kg K/ha, 5-40 kg S/ha.

The amounts of P, K and S required to maintain soil fertility status for the appropriate soil test level at different stocking rates are:

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

Stocking rate (SU/ha)	***Maintenance rate***		
	P	***K****	***S***
7	6-18	0-21	6-19
10	10-22	0-28	8-25
13	15-28	0-35	10-29
16	21-34	0-41	13-33
19	28-41	0-48	15-37
22	34-44	0-54	17-41

* K can be supplied by clay minerals on some sedimentary soils (eg recent, Pallic soils) so there is no immediate requirement for K. In this situation, K reserves will become depleted and K fertiliser will be required in the future. Where hay and silage crops are removed an additional 15-20 kg K per tonne of dry matter should be applied on all soils.

Examples of maintenance requirements

In addition to stocking rate, maintenance nutrient requirements also vary according to other factors including soil type, topography and rainfall. Some examples of maintenance requirements for different farming regions are shown below:

Location	Farm	SU/ha	Soil	Topo-graphy	Rainfall mm/yr	P	K	S
						kg/ha/yr		
Waikato	Beef/heifer grazing	22	Ash	Flat	1000	36	30	30
Waikato	Sheep/beef	16	Ash	Easy	1000	30	25	26
CentralPlateau	Beef/heifer grazing	19	Pumice	Rolling	1200	34	26	30
Central Plateau	Sheep/beef	14	Pumice	Easy	1200	28	22	24
Hawkes Bay	Sheep/beef	13	Sedimentary	Rolling	1100	20	0	18
Wairarapa	Sheep/beef	10	Sedimentary	Steep	1100	18	0	17
North Canterbury	Sheep	8	Sedimentary	Steep	700	10	0	9
Mid Canterbury	Sheep*	16	Sedimentary	Flat	1200	23	0	20
Southland	Sheep	15	Sedimentary	Flat	800	21	20	17
Southland	Deer	15	Sedimentary	Flat	800	21	20	17

* border irrigated

Although nutrient rates have been calculated to maintain near maximum pasture production in the above table, requirements for lower pasture production have not been determined. The best procedure for farmers to determine the rate of nutrient required to maintain soil tests in the appropriate target range for their farm is to monitor soil test levels as shown on pages 38 to 40. If the soil test levels are constant over several years, the nutrient application rate over this period will be the required maintenance rate. An increasing trend over time without an increase in pasture production indicates that the rate of nutrient application has been too high. A declining trend suggests that insufficient nutrient is being applied to maintain existing production.

If these trends are not available, use the Maintenance Nutrient reporting within OverseerFM Nutrient Budgets to estimate maintenance nutrient requirements.

Because production per hectare is related to stocking rate, as an alternative, a general rule-of-thumb for P, K and S can be stated as:

Apply 15-20 kg/ha superphosphate or equivalent per SU wintered.

Where K or elemental S is required these should be added to the above e.g. 20-25 kg 15% potassic superphosphate or equivalent per SU wintered.

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 soil test level and stocking rate.

Withholding fertiliser

Historical information suggests that as fertiliser is a major expense in most sheep and beef 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.

Long term fertiliser trials

Over 7 years under high rainfall at Ballantrae Hill Country Research Station in Southern Hawkes Bay, pasture production declined by 22% when no superphosphate was applied compared to 250 kg of superphosphate/ha/yr.

At Winchmore Research Station in mid-Canterbury under irrigated sheep grazing, annual pasture production was 54% lower when no fertiliser was applied compared with 188 kg of superphosphate/ha/yr. These results confirmed that withholding fertiliser has a significant negative effect on productivity.

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 relatively slowly through most 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 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 (1 tonne superphosphate/ha) in a single application are not recommended. If capital inputs higher than this 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. However on dry hill country, there can be significant P loss in runoff from summer-applied fertiliser because of hydrophobic (water repellent) soil conditions reducing infiltration into the soil.

Peat, and Podzol 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 risk 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

Sedimentary, 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, there is no evidence to suggest that split applications are superior at typical rates of application (20-50 kg K/ha). However, 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 through the animal.

Sedimentary, ash and pumice soils with rainfall below 1500 mm

Under these circumstances, where normal K inputs are required (20-50 kg K/ha), spring or autumn applications are equally effective. For rates greater than 50 kg K/ha, a split application is recommended, applying equal amounts in autumn and spring.

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 (30-50 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 is fast moving through soils, whereas elemental-S must first be oxidised by soil microorganisms 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).

Sedimentary soils

The form and timing of S application depends mainly on annual rainfall plus soil drainage.

< 1000 mm	Apply sulphate-S in spring or autumn
1000 - 1500 mm	Free draining soils - apply elemental-S in spring or autumn Other soils - apply sulphate-S in spring or elemental-S in autumn
> 1500 mm	Apply elemental-S if only one S application per growth season

Ash soils: free draining (ASC above 90%)

Trials on these soils show that neither form of S, nor the time of application, has 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 higher and more even pasture S concentrations.

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.

- **Timing of P fertiliser application is unimportant, but no more than 100kg 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.**
- **Timing of S fertiliser application is unimportant on ash soils but more important on sedimentary, pumice and peat soils. Using a mixture of sulphate-S and elemental-S on these soils reduces the requirement for split applications.**

Monitoring the soil fertility status of the farm

Because fertiliser is the major item of discretionary expenditure on the farm, 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:

Flat and rolling land

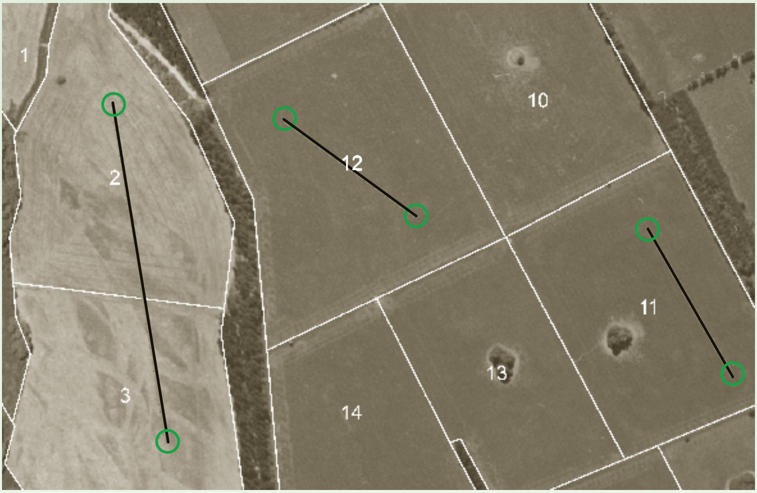
- For farms which vary in soil type and slope, divide the farm into areas of similar soils, slope and grazing management history.
- Set up sampling lines within each area avoiding gateways, fences, trees, hedges and water troughs. Ideally three sampling lines should be set up for each area.
- Collect a soil sample (15 or more cores 75mm deep) along each sampling line every two years.
- Sample in the same month each time usually a few weeks prior to applying fertiliser.
- 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 relatively 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.

Hill country

Since variability in soil test levels is greater in hill country than flat and rolling land, a more detailed sampling protocol is required. In hill country, select three representative paddocks in each block and on a typical mid slope site on the dominant aspect mark out one 100 m or two 50 m long transects with permanent markers at each end. Take one soil core every 10 m (within a 30 cm radius) and bulk all 27 cores from each block.

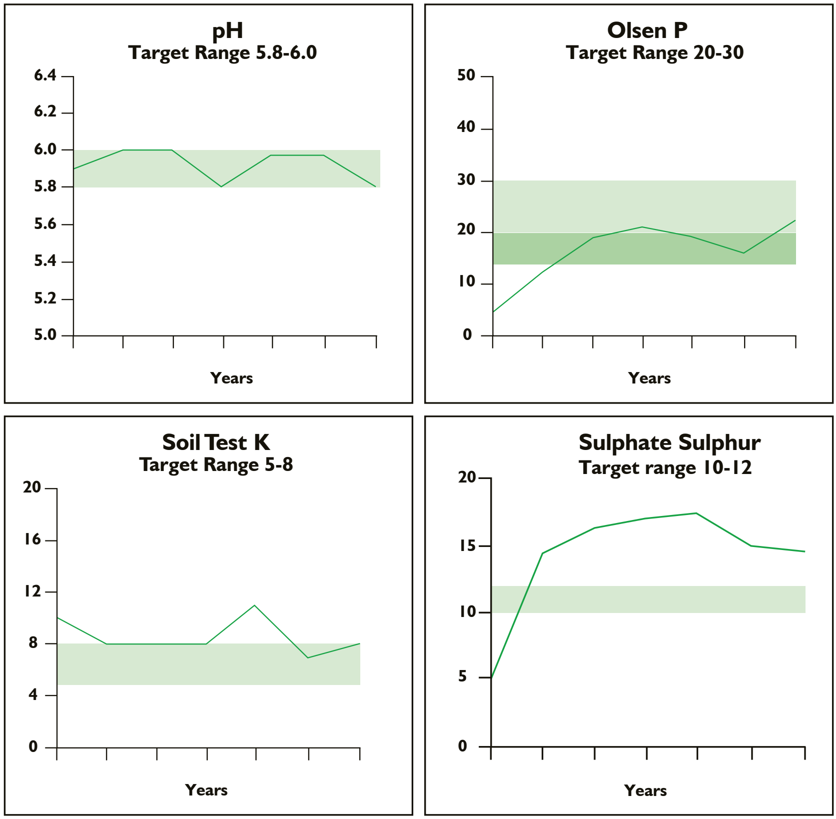


Sampling lines for monitoring soil fertility

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 a monitoring programme is shown here. The shaded areas represent the target ranges for pasture production. For Olsen P the dark shaded area represents the possible economic optimum range (see page 22). Soil test trends for this South Island beef farm on a sedimentary soil are shown relative to the target ranges for this farm. The graph plots the annual average soil test results. The Olsen P was initially very low and capital fertiliser rates were applied (at nearly twice maintenance) until the target range was approached. Olsen P levels then started to trend down, and further capital applications were required, to bring soil levels back into the target area before resuming maintenance rates. While maximum pasture growth maybe expected when Olsen P levels are within the target range, the economic optimum may be at slighter lower Olsen P range, depending on current market conditions. Soil sulphur tests have risen to above target levels due to the capital application of superphosphate, before settling closer to the target range when maintenance application rates replaced the earlier capital applications. K levels meet pasture requirements despite no K fertiliser having been applied. This indicates that the soil reserves are supplying adequate K. With periodic lime applications, soil pH has been maintained within the target range.

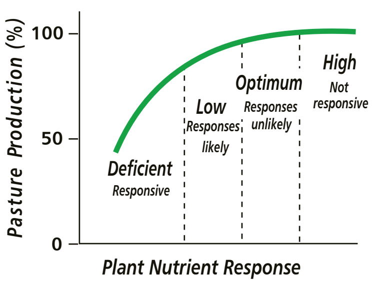
Pasture analysis

Pasture plant nutrient analysis is a very useful back-up to soil testing when determining soil nutrient status. Soil tests are unreliable for assessing trace element status because they are present in small quantities in the soil making the relationship between soil content and plant and animal requirements hard to define. Pasture analysis is essential to assess 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.

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, ash soils may be low in Co and Se, while 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

Nutrient	Deficient	Concentrations Low	Optimum	High
(% of DM)				
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
ppm				
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[1]	<13	13-14	15-16	>16
Mo[1]	<0.10	0.10-0.14	0.15-0.20	>0.20

[1] Clover only, NOT mixed pasture samples. For a Mo deficiency, clover N must also be low (<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 nutrient concentrations given for these nutrients are to meet animal requirements, not pasture requirements:

Guidelines for critical mineral concentrations in pasture for adequate nutrition of a young sheep

Nutrient	Pasture Concentration
Na	0.09%
Cu[1]	10 ppm
Co	0.10 ppm
Se	0.03 ppm
I[2]	0.25 ppm

[1] Depends on Mo concentrations
[2] 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 normal fertiliser application. Alternatively, some trace elements can be directly administered to animals. Apply fertiliser Mo only when both clover Mo and N is deficient (Mo < 0.1ppm, N < 4.5%). A response to fertiliser B will only be obtained from brassicas, lucerne and clover seed crops.

Trace element applications sufficient to overcome clinical deficiencies.

Element	***Additive***		***Application rate of additive***	***Frequency***
Co[1]	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[2]	Copper sulphate	(25% Cu)		
		(capital)	5-10 kg/ha (Autumn)	Initially, then
		(maintenance)	5 kg/ha (Autumn)	Every 4-5 years
Mo[3]	Sodium molybdate	(40% Mo)	50-100 g/ha (Spring)	Every 4-5 years after testing clover
Se[4]	Selcote Ultra prills	(1% Se)	0.5 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

1 Where Granular Cobalt (10% Co) is used, apply twice this rate.

2 Effective where pasture Mo levels are less than 1ppm

3 Where Granular Molybdenum (10% Mo) is used, apply four times this rate

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

Nitrogen fertiliser for pasture

Pasture legumes fix atmospheric nitrogen (N) which drives pasture production. Maximising legume production and function requires a high soil fertility status in terms of phosphorus (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 feed requirements exceed pasture growth - in effect, N fertiliser is a form of 'supplementary feed'. **The key to strategic N use is to identify feed deficits early and apply N to increase pasture production to fill those deficit periods.**

Timing of fertiliser N

Fertiliser N will not provide extra pasture production when climatic conditions such as cold (ie; soil temperature below 5 degrees C), or excessively dry or wet periods are preventing growth, nor will a response be obtained if soil N is already in adequate supply. Although the largest responses to N fertiliser will occur when growth rates are highest, 'out-of-season' N responses will still occur. Responses to N applied in March to May (autumn) in low rainfall areas are variable, but are more consistent in areas with reliable rainfall. Depending on the region, reliable N responses can be obtained between early June (Northern North Island) and September (Southern South Island) to provide extra pasture in early spring. However there is a greater risk of N leaching from winter applications.

Large responses to N may be obtained when shutting up silage or hay crops (spring/early summer). Using N on conservation crops is a way of:

- reducing the area required for conservation
- obtaining greater amounts of conserved feed and/or
- reducing the time pastures are out of the normal rotation.

Reliability of N response

The reliability of obtaining N responses can be expressed as the likelihood of achieving a response of 10 kg DM/kg N applied;

Likelihood (% probability) of achieving a 10:1 response to N.

Season		%
Autumn:	Low rainfall	20-40
	High rainfall	50-70
Late Winter/Early Spring		60-80
Spring/Early Summer		80-100

Guidelines for maximising pasture response from N fertiliser

To maximise response from N fertiliser:

- Use appropriate application rates:
  grazed pasture 20-40 kg N/ha (45-90 kg urea/ha)
  silage and hay 30-60 kg N/ha (65- 130 kg urea/ha)
- Apply to pastures with some regrowth e.g. 1600-1800 kg DM/ha (50 mm) or better
- The optimum time to graze is within 4 to 5 weeks of application or cut silage or hay within 5 to 6 weeks.
- Apply in advance of feed deficits

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

Useful N responses will be obtained in autumn (March/ May), late winter/early spring (June/August) and spring/ early summer (September/ October).

Appropriate rates of N range from 20-60 kg/ha and should be applied to pasture with some regrowth (1600-1800 kg DM/ha). Pastures should be spelled for 4 to 5 weeks to allow the N response to fully express itself.

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

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 when there is insufficient rainfall or irrigation (< 5 -10 mm within 8 hours after 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 that slows down the conversion of urea to ammonia gas (Sustain or N Protect) can reduce ammonia losses (averaging 5-20% of the applied N) by approximately 50%.

Summary of best 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 Inc) and obtaining the advice of an certified consultant.

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
- 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

Fertiliser Association

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