FERTILISER ASSOCIATION OF NEW ZEALAND

Fertiliser use on New Zealand Dairy Farms

Fertiliser Association

Shaping profitable and sustainable farming

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Editors: Ants Roberts and Jeff Morton

For more information:

PO Box 11519, Manners Street Central, Wellington, New Zealand 04 473 6552
info@fertiliser.org.nz

www.fertiliser.org.nz

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Introduction

All farm systems are dependent on an adequate supply of essential nutrients, whether it is for cropping and horticulture or pasture for livestock. The role of fertiliser, along with other sources of nutrients such as crop residues, nitrogen (N) fixation, soil reserves, compost and effluent is to help ensure adequate levels of essential nutrients are present for plant growth and animal health.

Our welfare and our nation's food and fibre production are intrinsically linked to our natural resources of soil and water. This booklet presents farmers with recommendations for fertiliser nutrient use in dairy production.

These recommendations are designed to sit alongside the Association's Code of Practice for Fertiliser Nutrient Management. The Code provides guidance on supplying the nutrients while avoiding and minimising the loss of those nutrients to the environment. The Code is available at www.fertiliser.org.nz

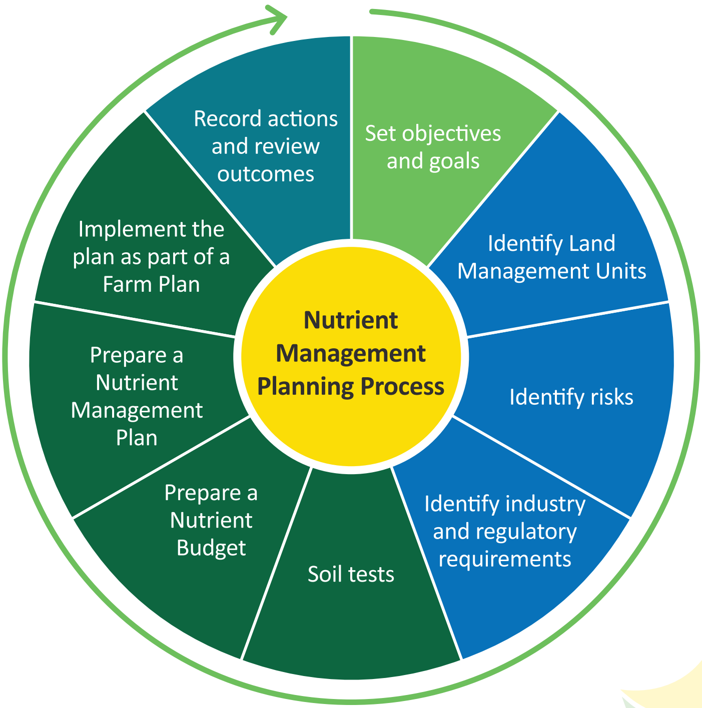
Efficient use of fertiliser requires that applications match plant needs as closely as possible, and that soil nutrient status is maintained by balancing nutrient input to nutrient removal.

The information presented in this booklet has been synthesised from a large volume of research on fertiliser nutrient requirements of dairy farms. The information represents the average over a range of conditions. However, every farm is different and so some modifications may be required for individual farm conditions.

Use of forage crops is increasingly common on dairy farms. Information on fertiliser use in forage crops is provided in the booklet "Fertiliser use on New Zealand forage crops" at www.fertiliser.org.nz/site/resources/booklets.

New Zealand's pasture-based livestock industry relies on a mix of pasture species which includes grasses, legumes and herbs. Legumes require a high soil nutrient status in terms of phosphorus (P), potassium (K), sulphur (S) and trace elements. Lime use to manage soil pH is also essential. This booklet primarily focuses on the P, K and S requirements for maximising legume production and function. Once the required soil nutrient status has been achieved, there is a place for the tactical use of N fertiliser to meet short-term feed gaps. This booklet describes N fertiliser as a management tool to produce extra feed at times when animal requirements exceed pasture growth - in effect, by promoting additional pasture growth, N fertiliser is a form of 'supplementary feed'.

We recommend that 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 nutrient advice, whether as part of a nutrient plan or as part of a freshwater farm plan.



Nutrient budget and fertiliser Nutrient Management Plans

Central to good fertiliser nutrient management is understanding the nutrient demands and nutrient cycles for your farm system.

Nutrient inputs and outputs should be documented in a nutrient budget. The actions and nutrient management requirements to achieve production goals and manage environmental risks should be clearly documented in a nutrient management plan which can be monitored and reviewed at the end of each production cycle.

Nutrient budget

This is a statement of the total nutrient inputs and outputs for a specific land area or management unit.

A nutrient budget indicates where soil nutrient status is in decline, constant (at maintenance) or increasing. This nutrient budget could be based on modelled information using tools such as OverseerFM or estimates of stock requirements or crop removals, and soil test data. The nutrient budget should be reassessed when there is a significant change to the farm system and/or production goals, and/or where there is new soil testing information. The nutrient budget should address regional council and national regulations.

The information in a nutrient budget estimates the size of nutrient pools in the farm system, the risk of nutrient loss and the nutrient requirements for production. It also helps to inform fertiliser recommendations and development of a nutrient management plan.

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 decline.
- A nutrient budget should inform where the current soil test levels for the farm are in relation to the appropriate target soil test ranges.
- N and P losses can impact on surface and groundwater quality and the Code of Practice should be carefully followed to minimise such risks. The Code is available at www.fertiliser.org.nz

Nutrient management plan

A nutrient management plan is a documented plan that describes how the major plant nutrients (N, P, K, S, and any others of importance) will be managed annually on a particular land management unit or farm. The purpose is to ensure farmers and growers get the best return from their spend on fertiliser and minimise nutrient losses so adverse effects on the environment are mitigated.

It is anticipated that the nutrient management plan will be incorporated as part of the freshwater farm plan, which addresses the wider farm system.

Soils

From a practical agricultural point of view, there are two major orders of soils on which 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 in hill country (Wairarapa/ Wanganui/King Country). 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 under low rainfall (Hawkes Bay, Marlborough, Canterbury).

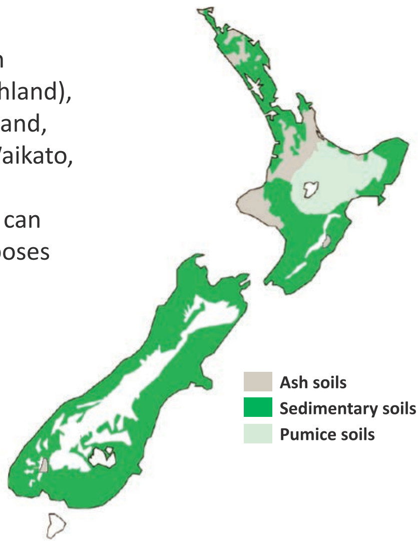
Volcanic soils:

- ***Ash (allophanic) soils*** in Waikato and Taranaki and granular soils in Northland.

- ***Pumice soils*** on the Central Plateau and in Hawkes Bay and Poverty Bay. These soils, although volcanic in origin, have different properties to the allophanic soils above.

Other soil orders for which there is less research information include sands (Manawatu and Northland), recent alluvial soils (all regions), podzols (Northland, West Coast, Golden Bay), organic (peat) soils (Waikato, Southland) and melanic (limestone) soils (North Otago). All these soils, except peat and podzols, can be categorised as sedimentary soils for the purposes of this booklet.

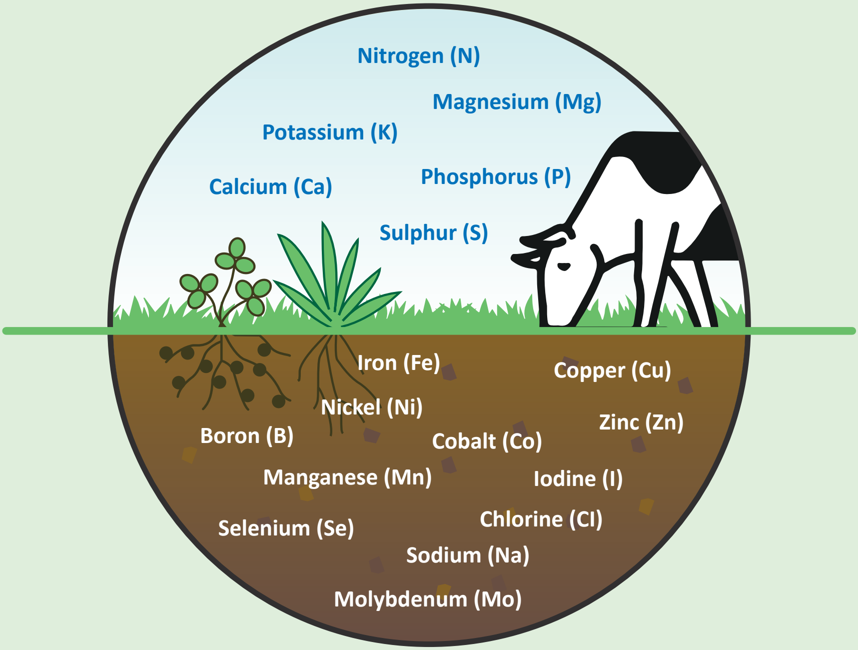
Detailed soil information is available from Manaaki Whenua at smap.landcareresearch.co.nz



Essential elements in plants and animals

Major and minor elements are the fundamental nutrients which make up the building blocks of all plant and animal tissue. An adequate supply is necessary for growth and survival. There are 18 essential elements for plant and animal health.

Major and minor elements for plants and animals



There is no known function for sodium (Na), cobalt (Co) or selenium (Se) in plants, however Co plays an important role for N-fixing rhizobia in clover nodules.

Sodium, Co and Se are important for animal nutrition.

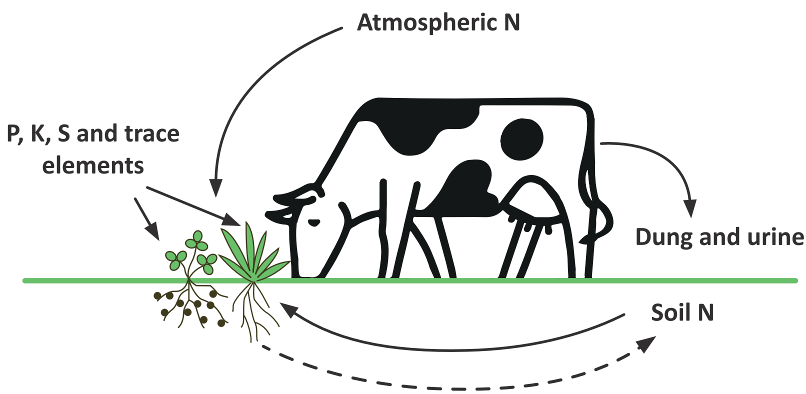
Soil nutrient status of dairy farms

Nutrient requirements of legume-based pastures

The legume, principally white clover, is the most important species in the New Zealand pastoral system. It supplies N, through biological fixation, that drives pasture production and provides high quality forage for milk production.

Grazing animals eat the clover and return about half 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, K, S, trace elements and lime are essential for good legume growth and N fixation. There are, however, periods of the year when animal feed requirements exceed pasture growth and N fertilisers, used tactically, will increase pasture production and profitability.

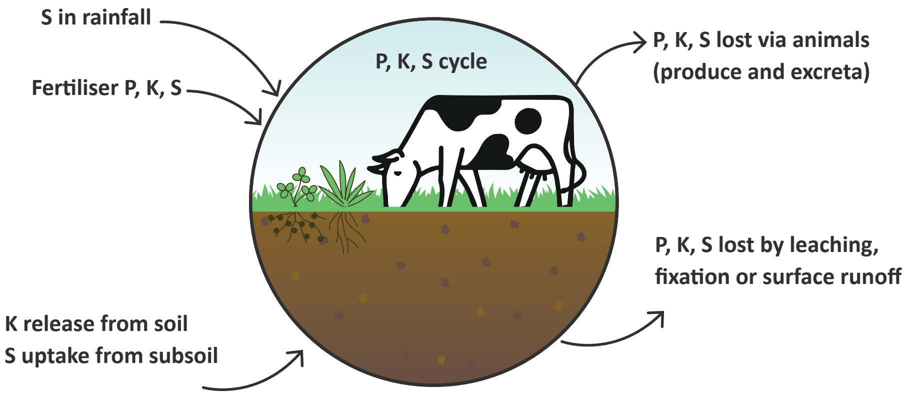


P, K, S, and trace element fertiliser nutrients are applied to encourage clover growth and biological N fixation. This N becomes plant available through dung and urine returned to the soil and through plant death and decay.

Building soil nutrient status

In their natural state, New Zealand soils have a low essential nutrient status for healthy and productive pasture and animals. When building soil nutrient status, capital inputs of fertiliser nutrients, 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. During this development process, pasture production and quality improves as the soil nutrient status increases. This development process may take many years.

Eventually a soil nutrient status will be reached at which near maximum pasture production occurs. At this stage only maintenance fertiliser nutrient applications are required. 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 and from soils.



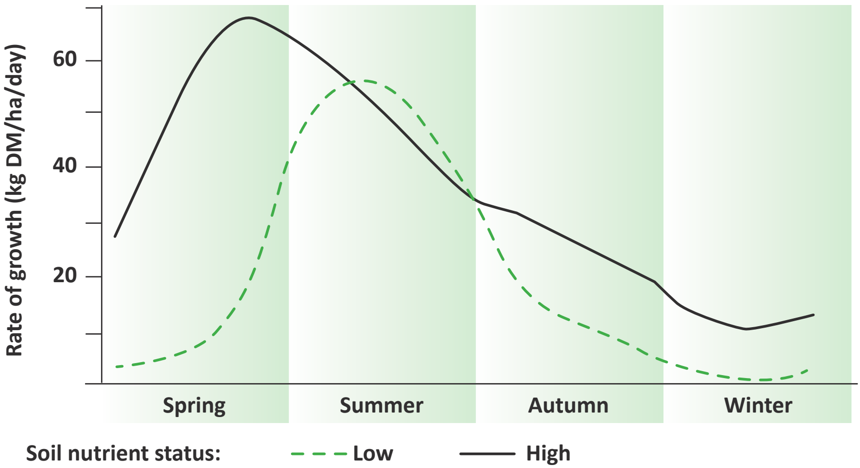
P, K and S cycles: Once soils have passed the capital development phase, lower maintenance applications are required to balance losses to maintain soil nutrient status.

Capital inputs of fertiliser nutrients or lime increase soil nutrient status or soil pH.

Maintenance inputs of fertiliser nutrients are defined as maintaining the current soil test levels by replacing the annual offtakes of nutrients from a farm.

The importance of nutrient application to pastoral farm systems

The use of fertiliser nutrient and lime inputs to support pasture production and quality affects the sort of livestock production systems you can run. Fertiliser and lime addition is one of the key factors in moving the annual pasture production curve from a low soil nutrient status/grass dominant system to a high soil nutrient status/grass-legume based annual pasture production curve.



Typical pasture growth characteristics in central Taranaki during the year, under high and low soil phosphorus levels.

In the diagram above, the two pasture production curves are from Taranaki farms in the same environment with the same soil characteristics. The principal difference is that the Olsen P level at the low soil nutrient status site (dotted line) ranges from 5 to 10 while at the high soil nutrient site (solid line) the Olsen P level ranges from 25-30. All other nutrients and pH were adequate and similar between sites. The increased pasture production and quality in the high nutrient status pasture means better productivity, the onset of calving can be earlier and drying-off of dairy cows can be later.

Assessing soil nutrient status

It is important to measure the existing soil nutrient status to assess nutrient requirements. Soil testing, and considering 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 (mg/L or µg/g).
- **Quick Test K (QTK)** – a measure of plant available K (QTU, quick test units).
- **Quick Test Mg (QTMg)** – a measure of plant available Mg (QTU, quick test units).
- **Quick Test Ca (QTCa)** – a measure of plant available Ca (QTU, quick test units).
- **Sulphate-S (SO4-S)** – a measure of the immediately plant available S (mg/kg or µg/g).
- **Organic-S (Org-S) or Total S** – a measure of the long-term supply of S (mg/kg or µg/g).
- **Reserve K or Tetraphenyl Boron K (TBK)** – a measure of K reserves in the soil (me/100 g).
- **Anion Storage Capacity (ASC)** – a measure of the capacity of a soil to store P and S (%).
- **Cation Storage Capacity (CSC)** – a measure of the capacity of a soil to store Ca, Mg, K and Na (me/100g). Also known as CEC.

Refer to the booklet, 'Fertiliser Use on New Zealand Forage Crops' for guidance on assessing available soil nitrogen, if introducing a forage crop.
See www.fertiliser.org.nz/site/resources/booklets

Soil Sampling

The best benefit from soil test information is achieved by regular testing over several years. 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 two to three years. Taking samples six to eight 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.

Soil test calibration curves

Soil tests are calibrated against pasture growth. This involves relating pasture growth to measured soil nutrient levels. Relative pasture production is used in these relationships. That is, 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 order have produced calibration curves for the nutrients P, K, S, Mg and for pH.

The soil test calibration curves allow soil test values to be selected that will ensure pasture productivity is close to what is required for optimal economic return. However, because of the variability in soil tests and the measurement of pasture production, there is no precise soil nutrient level that will guarantee a particular pasture production in all situations.

To take account of this variability, a target range is given as a guideline for soil test results that should be aimed for, to ensure consistently high production assuming drainage, temperature, moisture and management are not limiting. Variability (% error) of soil tests consists of spatial (space), temporal (time) and laboratory variability (error).

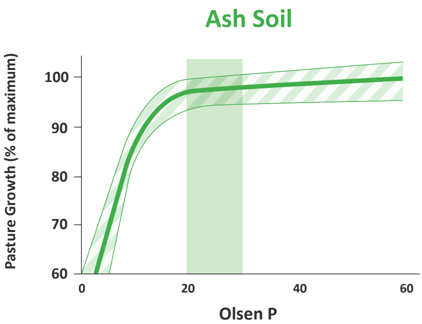
Soil test	Variability (% error)
pH	2-5
Ca	10-15
K	20-30
Mg	10-15
Olsen P	15-20
Sulphate-S	20-40

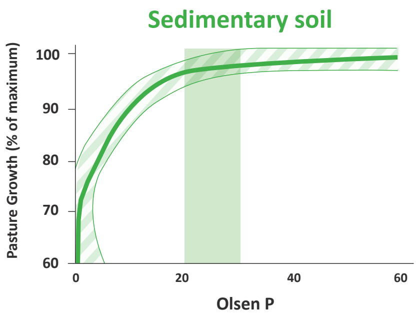
Target soil test ranges

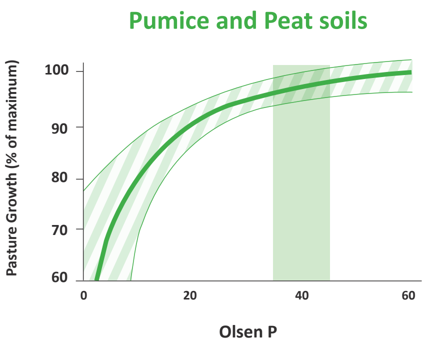
The target ranges given in this section of the booklet are a guide only. Target ranges for P, K, S and Mg encompass the soil nutrient levels which typically give at least 97% of relative pasture yield across all relevant trials. For P, which is the most expensive nutrient, where a farm should sit within the target range will be based on economic and environmental considerations. Raising soil P levels significantly above these ranges will result in only very small increases in annual pasture production and uneconomic increases in milk production. Where soils have a high risk of P loss, then the lower end of the target range will be more appropriate. For the other major nutrients, the general principle is to ensure that the nutrients are adequate i.e., within the target ranges, so as not to limit the pasture production response to P.

Soil Olsen P

The relationships between Olsen P and relative pasture production are different for the major soil orders of volcanic ash, sedimentary, and pumice and peat soils. Calibration curves (bold centre line) are presented as graphs for each major soil order. The thinner curved lines beside the solid curve indicate that there is a 95% probability that the relationship lies within this band. This also applies to the calibration curves for K and S.







Relationship between soil Olsen P and relative pasture production for a range of soil orders. The shaded boxes represent the target ranges.

Olsen P target ranges which will produce at least 97% of relative pasture production.

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

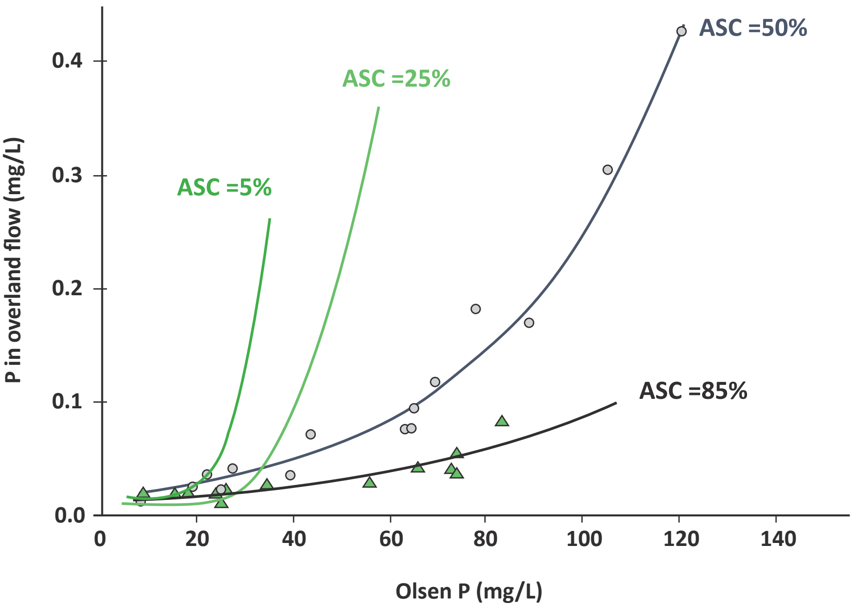
Environmental considerations

Careful consideration of where a farm sits in the target Olsen P range is required. Each catchment will have identified contaminants that are priorities under the Freshwater Farm Plan regulations. Farmers and/or Certifiers will identify the specific farm risks that need to be managed. The Code of Practice for Fertiliser Nutrient Management will help identify ways to assist with fertiliser P management. The Code is available at www.fertiliser.org.nz

Research has shown that, where there are direct connections to surface water on farm, increasing soil P status has a correlation with instream P concentrations. Where instream P concentrations have been identified as an issue in the catchment context, a farm's target Olsen P levels will need to take this into consideration.

The key points relating to P losses from susceptible production areas are:

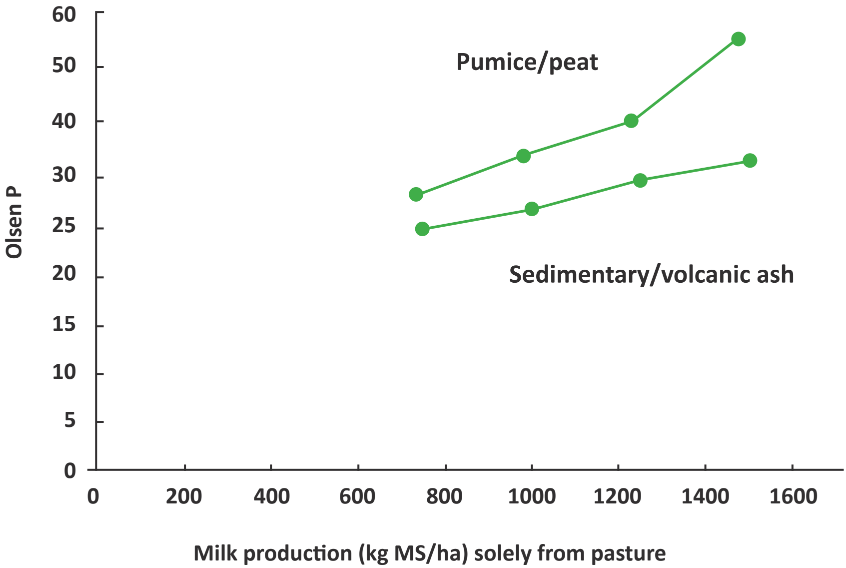
- P losses are generally small in well structured, well drained soils where there is no overland flow.
- Leaching of P can occur where there is drainage in soils with low anion storage capacity.
- Greater P losses occur from heavy textured soils as there is potentially greater runoff from the compacted surface, and mole or 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 mole or pipe drained soils.
- Consider the use of slower release P fertilisers (e.g., serpentine super, reactive phosphate rock) which can reduce direct fertiliser losses where this is applied in higher risk situations.
- P concentrations in overland flow increase as soil Olsen P levels increase, especially in soils with anion storage capacity less than 15%. This is illustrated in the following graph:



P loss accelerates with increasing Olsen P levels. The loss is influenced by the soil ASC. For lower ASC soils the P loss can be high even within the recommended Olsen P target range. For soils with ASC less than 15%, it is recommended to operate at the low end of the target range.

Economic responses in pasture production at higher Olsen P levels

Pasture production responses reduce as Olsen P increases. At Olsen P levels greater than the target ranges, small increases in pasture production (1-2 t DM/ha) may occur which may be profitable. Whether or not higher soil Olsen P levels will result in an economic return will be determined primarily by the relationship between the cost of applied P and returns from milk solids produced. In the graph below, the economically optimal soil Olsen P has been calculated based on the longer term cost of fertiliser P ($3.75/kg P applied) and returns for milk solids ($7.50/kg MS).



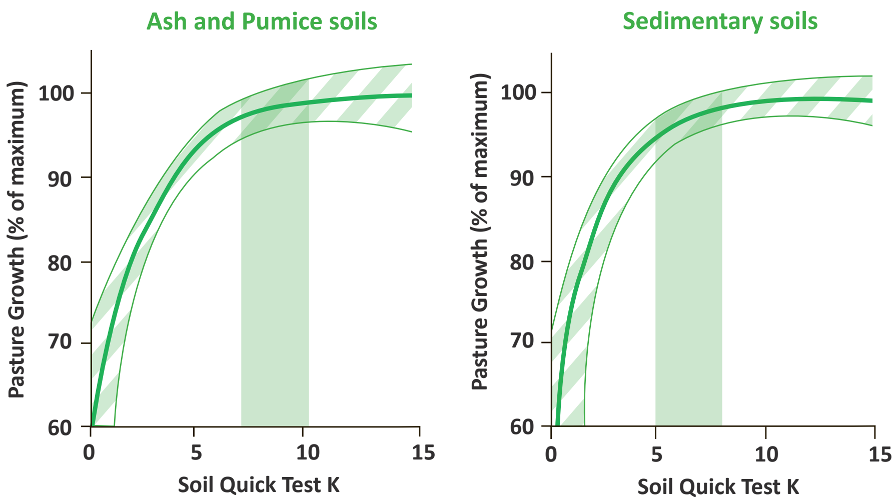
Increasing Olsen P above the target range may be economically justified, where the extra pasture is converted to milk solids. The economically optimum Olsen P is influenced by fertiliser and milksolid prices.

The management system required for this to be profitable 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 also for this to occur.

A qualified consultant can assist with the economic decision on whether the cost of additional fertiliser P to produce extra pasture is warranted based on production targets, fertiliser and milk solid prices and environmental risk.

Soil test K

Potassium, unlike P, is a nutrient which is more mobile in the soil and soil order differences are less important. A similar relationship between soil test K and pasture production applies across volcanic ash and pumice soils.



The relationship between soil Quick Test K and relative pasture production for ash, pumice and sedimentary soils. The shaded boxes represent the target ranges.

Soil Quick Test K target ranges which will produce at least 97% of relative pasture production.

Soil	Target range
Ash and 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 a 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.

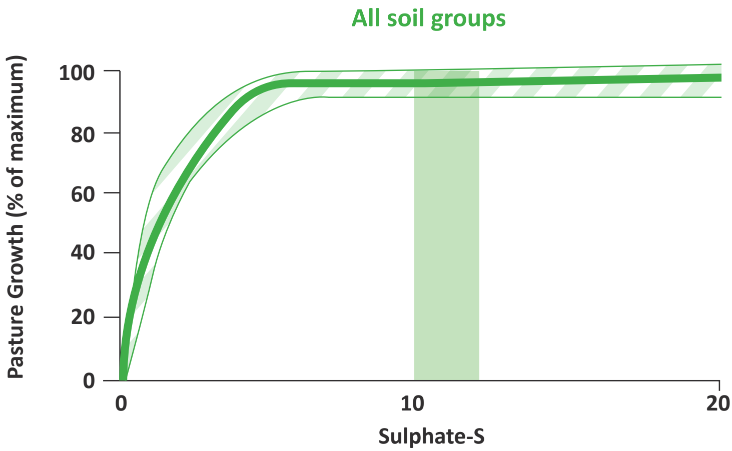
Some sedimentary soils, particularly some recent soils and pallic soils, supply considerable amounts of K for pasture growth. This K is provided by continual weathering of clay minerals and is not measured by Quick Test K. A measure of this reserve is given by the ‘reserve K test’ also known as the Tetraphenyl Boron K test.

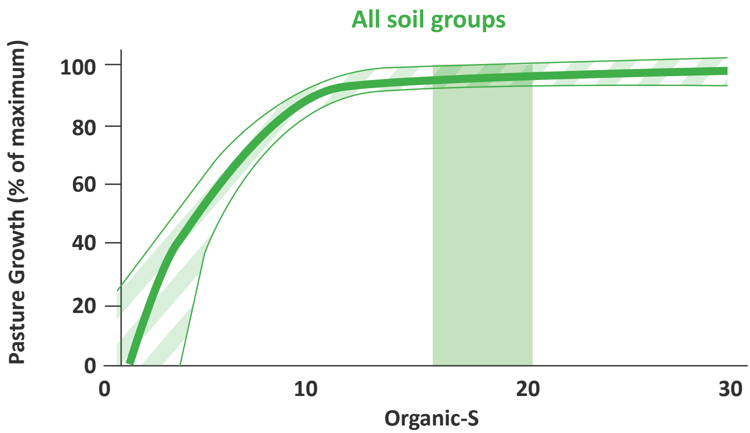
Reserve K test range which will produce at least 97% of relative pasture production on sedimentary soils.

Soil	Target TBK
Sedimentary	**0.8 - 1.2**

Soil test S

Like K, S is a nutrient which moves readily through most soils and soil order differences are of lesser importance. There are two types of soil tests for S, one which measures immediately available S (Sulphate-S test) and the others which measure the slowly available S (Organic-S and Total S tests). Analysis of trial data shows that soil type does not impact on the relationship between pasture growth and soil test S values.





The relationship between soil sulphate-S (ppm) or organic-S (ppm) and relative pasture production for all soil orders. The shaded boxes represent the target ranges.

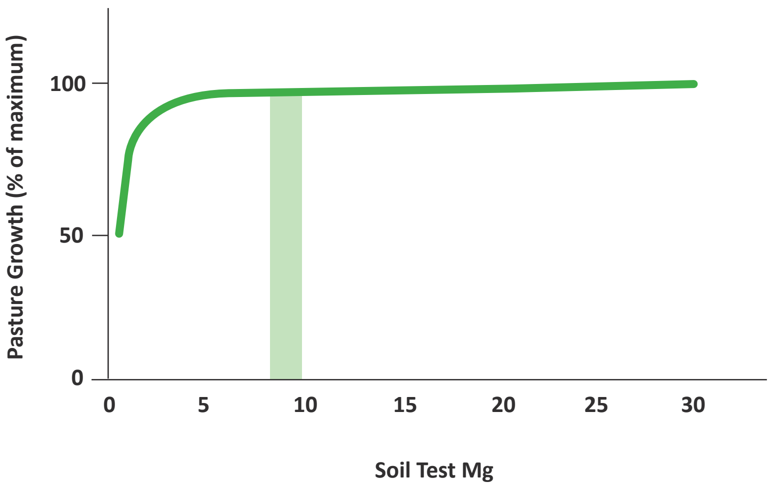
Soil test S target ranges which will produce at least 97% of relative pasture production.

Soil	Target Ranges		
	Sulphate-S	Organic-S	Total-S
All soils	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. Increasing the S status of sedimentary and pumice soils requires a long period of time because of their lower anion storage capacity. Higher levels of organic-S or total-S and sulphate-S indicate that a lower rate of S fertiliser is required to ensure that a deficiency does not occur. On some soils with low anion storage capacity, such as podzols and peats, it is not possible to increase sulphate-S into the target ranges shown above. In these situations, elemental S or two to three applications per year of sulphate-S should be applied.

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. Increasing soil Mg levels result in higher pasture Mg concentrations. Ideal soil levels are 25-30 because this will maintain herbage Mg levels at 0.22% or better, which supports animal health. However, even then Mg supplementation of dairy cows in the spring may be necessary if pasture feeding levels are inadequate.



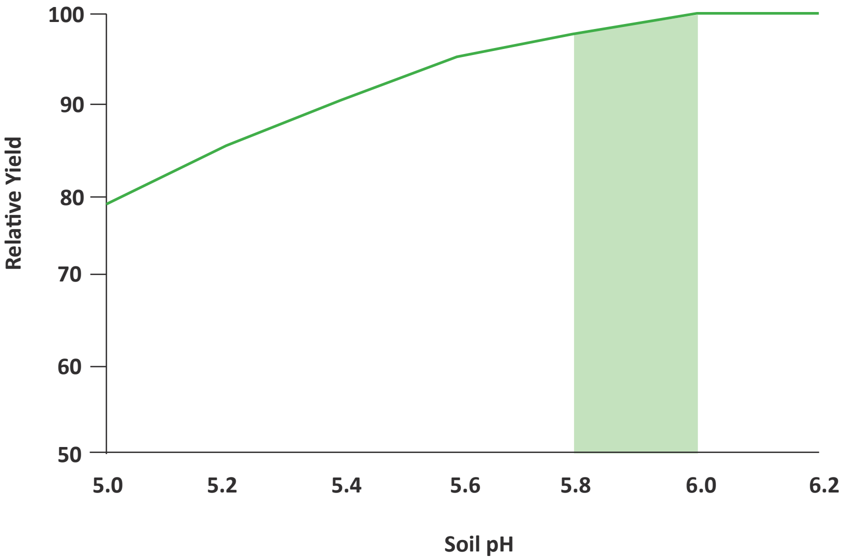
The relationship between quick test magnesium and relative pasture production for all soil orders.

Mg target range which will produce at least 97% of relative pasture production.

Soil	Target range
All soils	8-10

Soil pH

Soil pH is important because it impacts on the availability of many soil nutrients as well as affecting soil microorganism activity. Application of lime increases soil pH. As the soil pH increases, the size of the response to lime decreases. 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 pasture production, from liming soils to a pH greater than 6.0.



The relationship between soil pH and relative pasture production for mineral soils. The shaded box represents the target range.

Peat soils are a special case. If the topsoil pH (at depth 0-75 mm) is already above pH 5, responses to liming will be quite small. Larger responses are likely at soil pH less than pH 5 in which case, liming is usually worthwhile for both pasture development and maintenance. For good pasture production a subsoil pH (75 to 150 mm) of at least 4.5 is best. Lime applied to the surface of peat soil does not move down to the subsoil, therefore lime should be incorporated into the subsoil to at least 150 mm depth.

Target soil pH levels which will produce at least 97% of relative pasture production.

Soil	Depth (mm)	Target soil pH
Ash, Sedimentary, Pumice	0-75	5.8-6.0
Peat	0-75 75-150	5.0-5.5 4.5-5.0

Summary of target soil test ranges which will produce at least 97% of relative pasture production.

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
Total S	900-1000	900-1000	900-1000	900-1000
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 nutrient status

If soil test results show that your soils are below the target range, as identified in the previous section, consideration needs to be given to how best to raise soil nutrient levels. Capital fertiliser rates refer to the amount of P or K fertiliser required to lift soil Olsen P or QTK into the target range.

Increasing Olsen P

Field trials indicate that the following capital rates of P are required to raise Olsen P by 1 unit. These rates should be added to any maintenance rates required to replace the annual losses from the farm:

Amount of capital fertiliser P to raise Olsen P

Soil	Range of application rates (kg P/ha) to raise Olsen P by 1 unit	Average application rates (kg P/ha) to raise Olsen P by 1 unit	Average application expressed as superphosphate (kg/ha) to raise Olsen P by 1 unit
Ash	7-18	11	122
Pumice	4-15	7	78
Sedimentary	4-7	5	57
Peat	6-9	-	-

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 K are required to increase the K soil test by 1 unit:

Amount of capital fertiliser K to raise soil Quick Test K

Soil	Application rates (kg K/ha) to raise soil Quick Test K by 1 unit	Average application rates (kg K/ha) to raise soil Quick Test K by 1 unit	Average application expressed as potassium chloride kg/ha) to raise soil Quick Test K by 1 unit
Ash	45-80	60	120
Pumice	35-60	45	90
Brown	35-60	50	100
Peat	35-60	45	90

Correcting soil S deficiency

There are no data available on the rates of S required to raise soil S test levels. However, trial results show that S deficiencies do not occur with application of moderate inputs of S, even in situations where the soil S levels are low. Thus, maximum pasture production can be obtained providing inputs of S are applied as follows:

Amount of fertiliser S to ensure that an S deficiency does not occur.

Soil	S application rates (kg/ha/yr) to ensure a deficiency does not occur.	Average S application rates (kg/ha/yr) to ensure a deficiency does not occur.	Average application as superphosphate (kg/ha) to ensure a deficiency does not occur.
Ash	20-30	25	235
Pumice	40 -50	45	425
Sedimentary	30-40	35	330
Peat	20-40	30	285

Correcting soil Mg deficiency

Soils which are initially low in Mg (QTMg < 5) 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 (at least 50% by weight with particle diameter < 0.5 mm and 90% less than 2 mm). If local limestones have lower calcium carbonate contents than 80%, then proportionately higher rates of lime will need to be applied to raise or maintain soil pH. Peat soils should be limed according to the following:

Amount of lime 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
Half surface applied and half incorporated	0-75	16
	75-150	34

Summary amounts of nutrients required to raise soil test by one unit

Parameter	Ash	Pumice	Sedimentary	Peat
Phosphorus (kg P/ha)	11	7	5	6-9
Potassium (kg K/ha)	60	45	50**	45
Sulphur (kg S/ha)*	25	45	35	30
Lime (t/ha)	10	10	10	***

*To ensure that a deficiency does not occur **Brown soils ***Depends on depth - see above or www.fertiliser.org.nz/site/resources/booklets

Maintaining soil nutrient status

The term 'maintenance' fertiliser requirement, as distinct from capital fertiliser requirement, refers to the amount of nutrients required to maintain the current soil test levels. Once target soil test levels have been achieved, how much fertiliser is required to maintain soil nutrient status? A modelled estimate based on pasture growth trials is provided below. However, more precise farm-specific maintenance rates can be calculated from establishing trends in soil test levels over time. Once the trend in soil test level is neither rising nor falling this indicates that the rate of nutrient used is meeting maintenance requirements. At this stage soil sampling may be undertaken at least once every two to three years.

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

Stocking rate (cows/ha)*	Maintenance rate		
	Phosphorus	Potassium	Sulphur
2	29-47	20-50	10-23
2.5	33-51	25-58	13-30
3	37-55	40-70	16-35
3.5	41-59	50-82	19-40
4	45-63	60-95	22-45

*1 cow at 460 kg liveweight producing 375 kg milk solids/yr.

Examples of information used to determine maintenance requirements

A qualified nutrient management adviser can use tools such as OverseerFM to model the nutrient cycle on the farm and help to understand maintenance requirements for P, K, S and lime for the current steady-state farm production system. With this information, a fertiliser recommendation can be developed. Using OverseerFM, maintenance requirements for P, K and S have been calculated for dairy farms on ash and sedimentary soils with average milk solids production/ha. Input data and predicted requirements are shown in the following table.

Scenarios for maintenance requirements for an average dairy farm

Parameter	Ash soil	Sedimentary soil
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)
MS (kg/ha/yr)	1000	1000
Stocking rate (cows/ha)	2.7	2.6

Based on these scenarios, the maintenance requirements (in kg/ha) across the two soil orders are calculated as follows:

Parameter	Ash soil	Sedimentary soil
P	38	30
K	64	32
S	25	30

In this example, the soil test results are within the target range for Olsen P and QTK, and below the target range for organic-S for sedimentary soils. The calculated maintenance rates will maintain near maximum pasture production provided that an effective S fertiliser programme is employed. There is no financial advantage in increasing soil P, K, S values further by applying higher rates of fertiliser nutrients.

In the absence of more detailed modelling or product removal estimates, a general rule-of-thumb can be used:

Volcanic ash and pumice soils

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

Sedimentary soils

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

To gain the most accurate information, farmers are best to monitor their soil nutrient levels over the long term and adjust their fertiliser programme accordingly.

Once target soil test levels have been reached, maintenance fertiliser applications are appropriate.

Withholding fertiliser P, K and S

Fertiliser is a major expense in most dairy farm budgets and needs to be managed well. Serious consideration should be given to the following when farm costs and returns means that nutrient applications need to be restricted in the short term. Compared to the cost of fertiliser, soil tests are relatively inexpensive. When making decisions around reducing or with holding taking more soil tests to define where your soil nutrient status currently sits across all the different land management areas of the farm will be a good investment. Actions to consider include:

1. If you are above the target soil nutrient levels for your farm, completely withhold P, K or S fertiliser or apply sub-maintenance levels, for one year and then reassess. This cost saving should not affect the long-term financial viability of your business. Remember that the application of other nutrients if required should remain unchanged unless soil nutrient levels are above the target range for your situation.

2. If you are at or below the target soil nutrient levels, wherever possible, apply enough of the required nutrients to maintain your current soil nutrient status.

3. If you are not able to apply full maintenance nutrient requirements due to financial constraints, then sub-maintenance rates will be 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 test all blocks or paddocks of the farm to determine areas of high and low soil nutrient status and redistribute your fertiliser applications to bring all areas together to the target soil nutrient levels.

Timing of P, K and S 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 nutrient moves through the soil
- The ability of the soil to 'hold' the nutrient
- The amount of rainfall
- The texture of the soil
- Managing for environmental risk

The Code of Practice for Fertiliser Nutrient Management addresses how environmental risks of fertiliser application can be managed.
(See: www.fertiliser.org.nz)

Phosphorus

When applying P fertiliser, the risk of P losses should be considered. The Code of Practice for Fertiliser Nutrient Management identifies risks such as erodible slopes, areas where nutrients applied could end up in drains or streams, and soils with low anion storage capacity.

Soil P moves slowly through soils, a consequence of its incorporation into organic matter and binding onto soil minerals (often referred to as phosphate retention). From a production perspective 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. Where ash soils require a capital dressing (e.g., to raise Olsen P by 9 units or more) application rates of greater than 100 kg P/ha (1100 kg superphosphate/ha) in a single application, are not recommended. If higher capital inputs are required, then the dressing should be split. In low anion storage capacity soils (<15%), capital applications should also be split.

From an environmental point of view, apply soluble P fertilisers when the risk of rainfall causing runoff/drainage within the days or weeks after application is less likely.

Fluoride

To minimise the risk of fluoride poisoning, animals should not graze pastures where phosphate fertiliser has been applied until at least 25 mm of rain has fallen, to wash phosphate fertiliser particles off the leaves and onto the soil.

Potassium

In contrast to P, K moves quickly through the soil and leaching can occur more readily. However, timing of applications and use of split applications of K fertiliser is only important on coarse textured soils when rainfall is high (above 1500 mm) or on all soils when applications are greater than 50 kg K/ha.

Ash and pumice soils with annual 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 through livestock urine deposits, reducing the opportunity for K leaching.

Ash and pumice soils with annual 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. 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 (30-60 kg K/ha).

For all soils

Avoid applying K before and during calving as it increases the risk of 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 can move rapidly 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.

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 > 90%)

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

Ash soils: poorly drained (ASC < 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 (e.g., superphosphate, ammonium sulphate) and fine elemental-S (particle diameter < 500 µm) 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 sedimentary 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 for pasture production. However, avoid applying fertiliser when rain is forecast which is likely to cause overland flow or drainage below the rootzone. No more than 100 kg P/ha (1,100 kg/ha superphosphate) should be applied in a single dressing, and capital applications on soils with low ASC (<15%) should be split.**
- **Split applications of K fertiliser are only important on coarse textured soils when rainfall is high (> 1500 mm) or on all soils when greater than 50 kg K/ha (100 kg/ha potassium chloride) 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 1500 mm on free draining soils.**

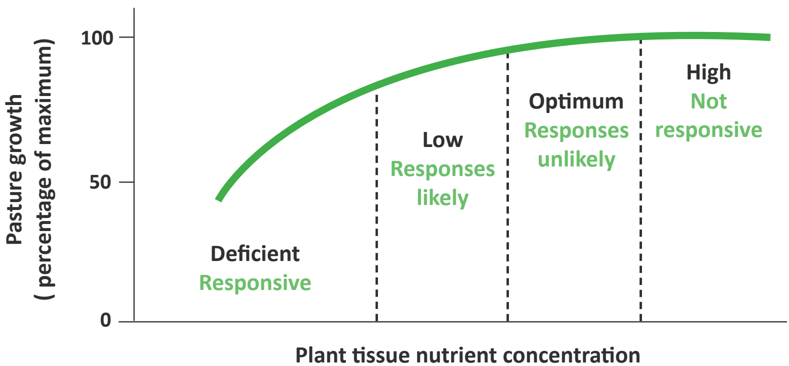
Pasture analysis

Pasture 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 soil or a fertiliser application. Pasture analysis is also useful to check on trace element status.

Pasture samples should be taken from 3-4 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. Trace elements are present in small quantities in the soil making the relationship between soil level and plant and animal requirements hard to define. 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.

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).

Plant nutrient response



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 for 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. Additional information can be found in Use of Trace Elements in New Zealand Pastoral Farming www.fertiliser.org.nz/site/resources/booklets

Interpreting mixed pasture nutrient analysis for plant health.

Nutrient	Deficient	Low	Optimum	High
	(% of Dry Matter)			
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
Nutrient	**Deficient**	**Low**	**Optimum**	**High**
	(Parts Per Million)			
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 below 4.5%.

Mixed pasture containing the optimum mineral contents will generally also supply animal requirements, provided the grazing animals are fully fed. However, for Na, Cu, Co and iodine (I), the pasture concentrations required to meet the animal's nutritional needs are greater than for the plant alone.

Critical* pasture concentrations for mineral nutrition of a lactating cow

Mineral	Pasture concentration
Na	0.11%
Cu[1]	10 ppm
Co	0.06 ppm
Se	0.03 ppm
I[2]	0.25 ppm

*Trace element levels must be above these levels to avoid clinical disorders

[1] Depends on Mo and Fe concentrations. High Mo or Fe in feed can reduce Cu absorption: see correction of trace element deficiencies.

[2] 2 ppm I in pasture is recommended if feed contains goitrogens (e.g., forage kales, other brassicas).

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.

Further information on trace elements can be found in the booklet Use of Trace Elements in New Zealand Pastoral Farming www.fertiliser.org.nz/site/resources/booklets

Trace element applications sufficient to overcome clinical deficiencies

Additive[1]	Timing	Rate	Frequency
Cobalt sulphate [2] (21% Co) [3]	Capital application in late spring	350 g/ha	Annually for 5-10 years
	Capital application in summer	240 g/ha	Annually for 5-10 years
	Maintenance in spring	60-100 g/ha	Annually
Copper sulphate [4] (25% Cu)	Capital application in autumn	5-10 kg/ha	Initially
	Maintenance application in autumn	5 kg/ha	Every 4-5 years
Sodium molybdate (40% Mo) [5]	Spring	50-100 g/ha	Every 4-5 years after testing clover
Selcote Ultra prills (1% Se) [6]	Spring or autumn	0.5-1 kg/ha	Annually
Selprill Double (2% Se) [6]	Spring or autumn	0.5 kg/ha	Annually
Sodium borate (15% B)	Spring	5-10 kg/ha	Initially
	Spring	5 kg/ha	Every 4-5 years

[1] Always check supplier's product specification for appropriate concentration and rate.
[2] Depends on soil Mn levels. If above 1 ppm, soil Mn can lower availability of soil Co.
[3] Where Granular Co (10% Co) is used, apply twice the rate.
[4] Effective where pasture Mo levels are less than 1 ppm. Where pasture Mo is greater than 1ppm, animal supplementation can be more effective. Consult with veterinary advice to adjust for any other supplementation.
[5] Where granular Mo (10% Mo) is used, apply four times the rate.
[6] Application rates should not exceed 10 g/ha of selenium (as sodium selenate). Consult with veterinary advice to adjust for any other supplementation.

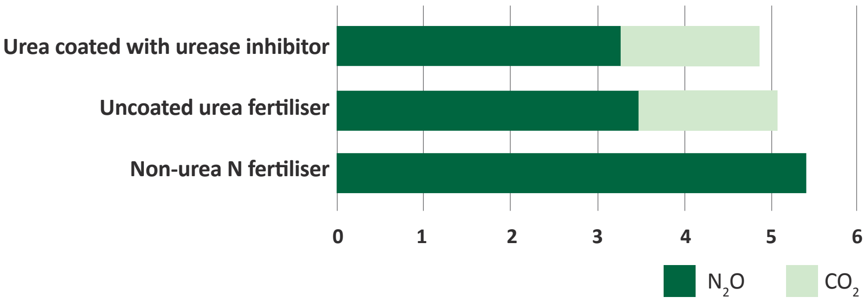
Nitrogen fertiliser for pasture

Regulatory controls on N fertiliser use

Regional council and national regulatory controls apply to N fertiliser use on pastoral farms. These must be understood and complied with. For example, the Resource Management (National Environmental Standards for Freshwater) Regulations 2020 place an annual limit of 190 kg N/ha of mineral N fertiliser applied to grazed pastoral land. For dairy farmers there are additional record keeping and reporting requirements. This national regulation is in addition to any controls and regulation which are applied by regional councils.

Nitrogen fertilisers are also a source of greenhouse gases which will need to be accounted for in assessment of agricultural emissions. The amount emitted varies with product type.

Emissions per tonne of fertiliser N in tonnes of CO_2-eq.



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 is minimised when there is rapid N uptake by actively growing pasture. This is achieved by not exceeding recommended application rates and applying N at the suggested times to match pasture and crop requirements. Direct leaching from N fertiliser is greatest in winter when there is high drainage.

The Code of Practice for Fertiliser Nutrient Management provides clear, principle-based guidance on supplying nutrients, while at the same time avoiding or minimising losses to the environment. (See: www.fertiliser.org.nz)

The role of nitrogen fertiliser on pasture

Pasture legumes fix atmospheric N which, when converted to soil N drives pasture production. Maximising legume production and function requires an adequate soil nutrient status in terms of P, K, S, lime and trace elements. Once this nutrient 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 6°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

Nitrogen fertiliser should only be applied after a feed deficit has been identified and the extra pasture grown can be efficiently utilised by the livestock.

To maximise response from N fertiliser:

- Use appropriate application rates based both on the size of the pasture deficit and the frequency of application:

  Grazed pasture e.g., 25-46 kg N/ha; silage and hay e.g., 40-60 kg N/ha
- Apply to pastures with some regrowth e.g., 1600-1800 kg DM/ha (50 mm height) 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.

Apply N fertiliser when conditions are suitable to support pasture growth.

Avoid applying N fertiliser when the temperature is too low, or soil is too dry for plant growth. For example, nitrogen should not be applied to pasture when the 10 cm soil temperature at 9 am is less than 6°C and falling (at these low soil temperatures, ryegrass growth and nitrogen uptake is very slow and there is greater risk of leaching loss).

In normal circumstances do not apply fertiliser when pasture height is less than 25 mm.

Spring/late spring applications of 20-40 kg N/ha to rapidly growing pastures allows full feeding of lactating cows, lifting cow condition, and increasing milk production. Use lower rates when on a short rotation (e.g., ~18-24 days) and higher rates when on a longer rotation (~27-30 days). 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.

The response to early-spring N application will be increased if a soluble-S fertiliser is included at 10 – 15 kg S/ha.

Summary of good management practices for N 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/mass as non-N fertilised pasture.
- With N fertiliser use, 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 to support pasture growth responses from N.

Complying with the Code of Practice for Fertiliser Nutrient Management (www.fertiliser.org.nz) and obtaining the advice of a certified consultant will help ensure good practice guidance are met for best advantage from responsible N fertiliser use while minimising losses to the environment.

Applying farm dairy effluent to land

Benefits

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

- It contains valuable nutrients N, P, K, S and trace elements which can substitute for some fertiliser nutrients.
- 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, several 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, 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.

Additional detailed information on the management and use of dairy effluent is provided by DairyNZ.

Always work to the Four Rs

Acknowledgments

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

The work of field researchers, past and present, who have conducted field trials under the auspices of the Agricultural Research Division (MAF), MAF Technology and latterly AgResearch, is gratefully recognised.

Fertiliser Association

Shaping profitable and sustainable farming