


Fertiliser Use on New Zealand Forage Crops

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FERTILISER USE ON NEW ZEALAND FORAGE CROPS

The principles and practices of soil fertility and fertiliser use on forage crops in New Zealand

This first edition is created by
Fertiliser Association of New Zealand

Edited by Jeff Morton, MortonAg

Fertiliser Association
Shaping profitable and sustainable farming

Contents

Foreword

The pastoral industry has been the backbone of New Zealand's economy for many years. It has been well served by its efficient, low cost grazing systems predominantly based on perennial ryegrass and white clover to meet livestock nutrient and energy demands. Sophistication of science and understanding of plant and animal nutrition have brought us a long way since our pioneering days, with greatly improved production and capability. However, continued pressure to compete internationally and to increase our export potential are driving the demand for increased productivity and land use intensification. In response, there has in recent years been a rapidly growing trend within the New Zealand pastoral industry towards mixed farming systems. Forage cropping has been introduced to supplement periods of seasonal deficits in pasture production, and in-turn, support increased stocking rates and improved utilisation of available feed during periods of maximum pasture production. In addition, within the farming system, forage cropping has a valuable role to play in a pasture renewal programme.

In recognition of the increasing use of forage crops in the pastoral system, the Fertiliser Association of New Zealand with support of its member companies, Ballance Agri-nutrients and Ravensdown, have published this booklet. It is intended as a compact, easy to read guide to enhance understanding of the principles and details of nutrient management to support successful forage crop production. The fertiliser industry has a strong science based foundation, and this booklet provides a valuable addition to resources developed over the years on fertiliser use for dairy farms, sheep and beef farms, and cropping farms.

As well as addressing the nutrient requirements for common forage species, this booklet provides information on soil groups, assessment of soil fertility status, principles of crop nutrition, advice on seedling establishment and choice of fertiliser product type. Animal health and environmental considerations remain a key component of successful forage crop utilisation and this booklet provides an invaluable overview of essential knowledge to support farmer decision making.

Farmers will gain maximum benefit from this booklet by combining the information in it with their own experience, and calling on the help of a certified nutrient management adviser, or other qualified consultant, to develop a soil fertility programme tailored to their particular properties and objectives.

John Henderson
Chairman
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Introduction

Forage cropping on New Zealand farms has increased rapidly in recent years as part of the intensification of farming practices necessary to maintain profitability. The traditional brassica crops have been supplemented by herbs, chicory and plantain, often grown with clovers or in monoculture stands of clover. In addition, the area in lucerne has increased greatly.

The objective of this booklet is to bring all available information on fertiliser requirements of forage crops into one source for farmers and their advisers. Where possible, the information is based on research results which are more comprehensive for the established brassicas, lucerne, clovers and annual ryegrass than the more recent fodder beet and herbs. Forage cereals are well covered in the booklet 'Managing Soil Fertility on Cropping Farms', available through the Fertiliser Association of New Zealand so are not included in this publication.

Forage cropping is only successful if both economic and environmental sustainability are achieved. The cost per unit of feed grown is lowest where a realistic potential yield is chosen and fertiliser nutrients applied to the economic optimum. Because of soil disturbance, high rates of fertiliser and return of excreta by grazing animals, there are large potential losses of nutrients, sediment and pathogens from forage crops. These losses should be minimised by adopting good management practices and mitigations as outlined in this booklet.

Major soils

There are four major groups of soils where forage cropping is carried out in New Zealand:

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

- ***Brown*** soils on terraces or easier hills in all areas of New Zealand with generally free-drainage.
- ***Pallic*** soils on terraces and rolling downs in the South and Lower North Island with poor drainage.
- ***Recent*** soils formed near rivers in all areas of New Zealand with imperfect to free-drainage.

Other sedimentary soils are poorly-drained *Gley* soils on alluvial plans, free-draining *Sands* near the coast, poorly-drained *Podzols* in Northland and Westland and free-draining *Semi-Arid* soils in Central Otago. Sedimentary soils have a medium organic matter content, low to medium anion and cation storage capacity and low to high potassium reserves.

Ash soils are mainly formed from allophane and basalt and include free-draining *Allophanic* soils in Waikato, King Country and Taranaki, free-draining *Granular* soils in Northland and South Auckland and poorly-drained *Gley* soils formed from volcanic ash. They have a high organic matter content and anion and cation storage capacity and low potassium reserves.

Pumice soils and *Gley* soils formed from pumice on the Central Plateau and in the Bay of Plenty are formed from volcanic rhyolite. They are free draining and have medium organic matter content and anion and cation storage capacity and low potassium reserves.

Peat or *Organic* soils with varying amounts of mineral matter, are formed from mainly plant residues and occur throughout New Zealand, with the largest area mainly in the Waikato. Peat soils are generally acidic, poorly-drained, have high organic matter content and cation storage capacity and low to medium anion storage capacity depending on their mineral content.

Essential elements in plants

Plant tissue consists of carbon (C), hydrogen (H), oxygen (O) and 13 other essential elements. The first three (C, H, O) together with nitrogen (N), phosphorus (P) and sulphur (S) make up most of the living matter in plants.

The major and minor trace elements that are considered essential for plant growth are:

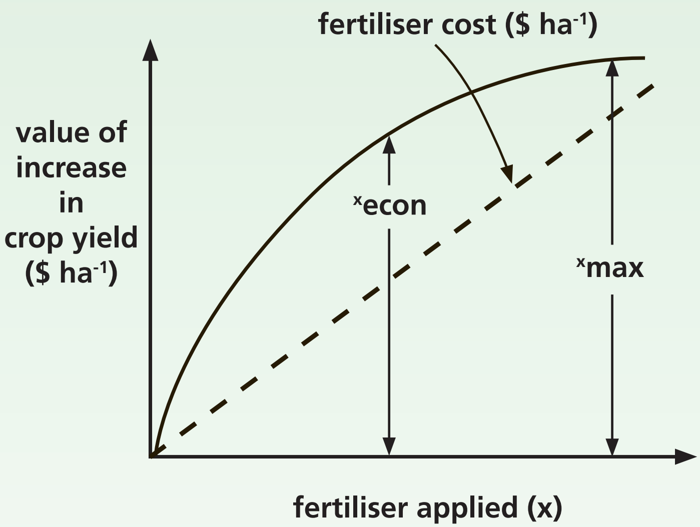
Major elements		***Minor elements***	
Nitrogen	(N)	Boron	(B)
Phosphorus	(P)	Iron	(Fe)
Potassium	(K)	Manganese	(Mn)
Sulphur	(S)	Copper	(Cu)
Calcium	(Ca)	Zinc	(Zn)
Magnesium	(Mg)	Molybdenum	(Mo)
Sodium	(Na)	Chlorine	(Cl)

(Sodium is essential only for fodder beet)

Principles of crop production

The amount of fertiliser required to obtain the maximum crop yield is unlikely to be the same as the amount that will give the highest economic return. This principle is illustrated in the figure below. The cost of fertiliser as denoted by the dashed line increases linearly with the amount applied but the increase in the value of the crop in the solid line follows the curvilinear pattern of the yield response of the crop. The optimum economic rate of fertiliser application will therefore be that at which the difference between the cost of fertiliser and the increase in the value of the crop is at its greatest (x_{econ} in the figure below). A reduction in the unit cost of fertiliser or an increase in the value of the crop will justify the application of a higher rate of fertiliser and vice versa.

Principles of economic return on fertiliser application



The optimum economic rate of fertiliser can be derived from decision support models that are available to some advisers. These models include Brassica Crop Calculators for swedes, turnips and kale. Because the yield response to fertiliser nutrients of a particular crop cannot be accurately predicted, sensible fertiliser management is to apply a rate that is intermediate between the estimated optimum economic rate and the rate required for maximum yield.

Assessing soil nutrient status

Soils contain plant-available nutrients from weathering of rock minerals, mineralisation of organic matter and previous applications of fertiliser. Therefore, the first step is to measure this by soil testing.

The soil tests that are suitable for forage crops include:

Available soil nutrients

- **pH** – a measure of soil acidity and hence an indication of lime requirement.
- **Olsen P** – a measure of plant-available P.
- **Quick test K (QT K)** – a measure of plant available K.
- **Quick test Mg (QT Mg)** – a measure of plant available Mg.
- **Quick test Ca (QT Ca)** – a measure of plant available Ca.
- **Quick test Na (QT Na)** – a measure of plant available Na.
- **Sulphate-S** – a measure of immediately available plant available S.

Other Important soil characteristics regarding nutrient supply

- **Tetraphenyl Boron K (TBK)** – a measure of K reserves.
- **Anion storage capacity (ASC)** – a measure of the capacity of the soil to store P and S (previously referred to as phosphate retention, PR).
- **Cation storage capacity (CSC)** – a measure of the capacity of the soil to store K, Mg, Ca and Na (also referred to as cation exchange capacity, CEC).
- **Available N - (AN)** – also referred to as anaerobic mineralisable nitrogen (AMN)
- **Mineral N** – immediately plant available N

Soil sampling

Soil sampling should be carried out 6-12 months before sowing to allow applied lime sufficient time to break down and increase soil pH. Soil samples should be taken to 150 mm depth before cultivation for brassica and fodder beet crops and lucerne. These plants are deeper rooting than pasture and measured crop yields have been calibrated with soil nutrient levels to this depth.

Sampling of crop paddocks on your farm

- Sample paddocks with suspected low pH 6-12 months before sowing to allow applied lime sufficient time to break down and increase soil pH
- Soil samples should be taken to 150 mm depth before cultivation for brassica and fodder beet crops and lucerne
- Herbs, legumes and annual ryegrass should be sampled to 75 mm depth

- Sample each paddock while still in pasture in the autumn before a spring-sown crop and the early spring before an autumn-sown crop
- Walk the paddock in a W pattern, avoiding excreta patches, shelter belts, fence lines, gateways and troughs and take 15 – 20 cores at regular intervals

Available soil nitrogen test (AN)/Anaerobic Mineralisable Nitrogen (AMN]

This test is a measure of the amount of N mineralised under specific laboratory conditions (anaerobic incubation at 40° C for 7 days). It represents an estimate of N that will be potentially mineralised in the field throughout the season, which will depend on factors such as soil temperature and moisture. AN is measured only in the top 150 mm of soil as this is where much of the organic matter is present. It does not measure the immediately plant available component of soil N.

Mineral N

This test is for the immediately available nitrate and ammonium in the soil but because the mineralisation of organic N to these forms of N varies rapidly according to soil temperature and moisture there is a large error around the estimate.

For forage crops, AN is measured mainly in brassicas and fodder beet which have a higher demand for N.

The results are reported as kg N/ha for Available N (AN) and Anaerobic Mineralisable N (AMN).

Plant analysis

Plant analysis can be used to monitor major nutrient concentration N, P, K, and S or diagnose specific deficiencies such as Mg, Ca, Mn, Zn, Cu and B. The accuracy of plant analysis is improved if green, leafy tissue is sampled when the crop is vigorously growing and not limited by environmental factors such as low moisture and temperature. Dry or cold soil conditions can limit the uptake of nutrients even if the soil levels as indicated by testing are adequate. In this case, the problem is one of nutrient uptake rather than nutrient supply. When diagnosing a nutrient deficiency, comparative plant tissue analysis where samples are collected from both good and affected plants, provides valuable information. Twenty sub-samples from each paddock are required to make up the sample.

Normal nutrient ranges for leaf tissue analysis of turnips, kale, and fodder beet are presented in the table below. Normal nutrient range represents the levels typically found in plant samples, but does not necessarily reflect optimum ranges for production, as determined by calibration trials. Sufficient data for an optimum range is available for swedes only.

Nutrient	***Normal range for brassicas and fodder beet and optimum range for swedes***			
	Turnips	**Kale**	**Fodder beet**	**Swedes**
Nitrogen	3.5 – 5.0%	3.0 - 5.5%	3.0 – 5.5%	3.0 – 4.0%
Phosphorus	0.30 – 0.70%	0.26 - 0.70%	0.25 – 0.50%	0.30 – 0.60%
Potassium	2.5 – 5.0%	2.0 - 5.0%	2.5 – 5.0%	2.8 – 4.5%
Sulphur	0.35 – 0.80%	0.30 - 0.80%	0.30 – 0.50%	0.3 – 0.5%
Calcium	1.80 – 4.0%	0.50 - 4.0%	0.70 – 1.6%	0.70 – 2.0%
Magnesium	0.30 – 0.60%	0.20 - 0.70%	0.40 – 0.90%	0.2 – 0.6%
Sodium	0.00 – 0.35%	0.00 – 1.00%	0.5 – 3.0%	
Iron	50 – 150 ppm	50 – 200 ppm	60 -140 ppm	50 – 150 ppm
Manganese	30 – 300 ppm	25 – 300 ppm	25 – 200 ppm	40 – 100 ppm
Zinc	20 – 100 ppm	20 – 200 ppm	15 – 70 ppm	20 -80 ppm
Copper	5 – 25 ppm	5 – 25 ppm	5 -12 ppm	6 – 12 ppm
Boron	30 – 150 ppm	25 – 150 ppm	35 – 70 ppm	25 - 80 ppm
Molybdenum			0.2 – 0.6 ppm	

Optimum ranges for vegetative growth of lucerne, white clover and ryegrass are shown in the second table below. Red clover is likely to be similar to white clover.

Nutrient	***Optimum ranges***		
	Lucerne	**White clover**	**Ryegrass**
Nitrogen	4.5 – 5.0%	4.8 – 5.5%	4.5 – 5.0%
Phosphorus	0.26 – 0.70%	0.35 – 0.40%	0.35 – 0.40%
Potassium	2.5 – 3.8%	2.0 – 2.5%	2.0 – 2.5%
Sulphur	0.26 – 0.50%	0.27 – 0.32%	0.27 – 0.32%
Calcium	0.51 – 3.0%	0.4 – 0.5%	0.25 – 0.30%
Magnesium	0.31 – 1.0%	0.18 – 0.22%	0.16 – 0.20%
Iron	45 – 60 ppm	50 – 65 ppm	50 – 60 ppm
Manganese	25 – 35 ppm	25 – 30 ppm	25 – 30 ppm
Zinc	12 – 18 ppm	16 – 19 ppm	14 – 20 ppm
Copper	5 – 9 ppm	6-7 ppm	6 – 7 ppm
Boron	15 – 20 ppm	15 – 20 ppm	15 – 20 ppm
Molybdenum	0.7 – 0.9 ppm*	0.15 – 0.20 ppm*	0.3– 0.4 ppm

****   N content also needs to be greater than 4.5%.***

Nutrient requirements of individual crops

Brassicas

The major brassica crops grown in New Zealand include Kale, Rape, Swedes, Turnips and Leafy Turnips (Pasja/Hunter). Kale and swedes are mainly grown as winter fodder crops, turnips as summer forage crops and rape as either winter or summer crops.

As for all crops, the major factors that determine the nutrient requirements for brassicas include:

- The amount of plant-available nutrients supplied by the soil
- The yield potential of the crop as determined by soil type and climate

High yielding brassica crops have large mineral nutrient requirements. The nutrient concentration (%) of each brassica crop (average for leaf, stem and bulb) from a range of trial sites is shown in the table below.

Crop	*Nutrient concentration (%)*				
	N	P	K	S	Mg
Swedes	2.0	0.30	1.5	0.56	0.17
Turnips	2.0	0.30	3.5	0.56	0.12
Kale	2.0	0.28	2.5	0.56	0.12
Rape	2.5	0.28	2.5	0.56	0.17
Leafy turnip	2.0	0.30	1.6	0.56	0.17

These nutrient concentrations need to be multiplied by crop DM yield to give a crop nutrient uptake value.

The fertiliser nutrient requirement will then equal crop nutrient uptake minus soil nutrient supply.

Nitrogen

Nitrogen is the nutrient that is required in the largest quantities by brassica crops. Brassica crop requirements for fertiliser N in relation to N supply from the soil and potential yield are shown in the table below:

Soil Available N (ppm)	*Potential crop yield (t DM/ha)*		
	5-10 (Leafy turnip, Rape, Turnips)	10-15 (Rape, Swedes Kale)	15-20 (Swedes, Kale)
100	30-100	100-200	200-300*
150	20-50	50-150	150-250
200	0-30	20-100	100-200

First year crops in this situation would be unlikely to achieve a high yield because of general low soil fertility associated with the lack of organic matter.

Timing of N

In relation to fertiliser N requirements in the above table, the optimal timing of N is shown in the table below:

Soil Available N (ppm)	Potential crop yield (t DM/ha)		
	5-10 (Leafy turnip, Rape, Turnip)	10-15 (Rape, Swedes, Kale)	15-20 (Swedes, Kale)
100	At sowing/prior to second grazing	At sowing and side dressing at 4-6 weeks	At sowing and side dressings at 4-6 and 10-12* weeks
150	Prior to second grazing	At sowing and side dressing at 4-6 weeks	At sowing and side dressing at 4-6 weeks
200	Prior to second grazing	At sowing	At sowing and side dressing at 4-6 weeks

Only apply second side dressing if sufficient soil moisture to gain response to fertiliser N.

Placement of fertiliser

At sowing, where the starter fertiliser contains P as is generally the case, there are advantages in early growth of the crop from placing the fertiliser close to the seed. The seedling has more ready access to P which is not very mobile in the soil. This benefit can be greater at low soil Olsen P levels and with shallow rooting crops such as Pasja. Where the starter fertiliser is placed close to the seed, a lower rate of P can be applied compared to where the starter fertiliser is broadcast.

Phosphorus

After N, P is the most important nutrient required by brassica crops, especially for root and early shoot development. Kale with its more extensive root growth has more ability to extract P from the soil than other brassicas.

Phosphorus fertiliser is required to grow the crop and also to replace the nutrient that is not returned to the soil. Since nearly all brassica crops have nutrients returned in animal excreta when they are grazed, complete replacement of the nutrients taken up by the crop is not required. Also at high soil Olsen P levels, some P can be supplied from the soil. At crop yields ranging from 5 to 20 t DM/ha, 20 – 60 kg P/ha will be needed to replace the amount of P taken up to grow the crop and replace what P has been removed.

The P requirements (kg/ha) for high yielding brassica crops at different Olsen P ranges for the major soil groups are shown in the table below:

Soil Olsen P	Sedimentary and ash soils	Pumice and peat soils
10 – 15	40 - 60	80 - 100
15 – 20	20 - 30	40 - 60
20 – 25	0*	20 - 30
25 – 30		0*

If a second brassica crop is grown, a base dressing of P may be required

Even at high soil Olsen P, a low rate of P placed close to the seed can benefit early growth

The higher optimal Olsen P range for pumice and peat soils is because they have a lower bulk density and when the laboratory sample is taken on a volumetric basis, a lesser mass of soil is sampled.

Potassium

Brassica crops can take up large amounts of K from the soil (75 – 350 kg/ha). If high rates of K fertiliser are applied to the crop, brassicas especially kale can take up K in excess of what is required. When the crop is grazed, this K is concentrated in urine patches from which the K can be leached.

Therefore sufficient K should be applied to grow the crop and replacement K, if required, applied after 0 – 75 mm soil sampling is carried out before pasture is resown.

The rate of K (kg/ha/yr) required to grow a high yielding brassica crop will mainly depend on the soil QT K and soil K reserves as measured by the TBK test as shown in the table below:

Soil QT K	***Soil TBK (meq%)***	
	<1.0	**>1.0**
3 - 4	50 - 100	30 - 50
5 - 6	30 - 50	0 - 30
7 or greater	0	0

Sulphur

Brassicas can grow adequately at low levels of soil sulphate-S (> 3 ppm) and fertiliser S is not required unless soil levels are lower than this. High S availability in combination with high rates of N can cause high SMCO levels in the leaf (see p 22).

Magnesium

Many sedimentary, peat and ash soils will have adequate Mg to grow a high yielding brassica crop. However, on some pumice soils and other soils where QT Mg levels may be 6 or less, 20 – 30 kg Mg/ha in a soluble form such as Kieserite will be required.

Calcium

Calcium will be supplied in adequate amounts from both soil and that contained in lime and superphosphate to satisfy the requirements of a high yielding brassica crop.

Boron

Brassicas have an essential requirement for B and unless soil B levels are high (> 1.5 ppm), B should be applied at sowing at 2 kg/ha of elemental B. A shortage of B can restrict growth and in extreme conditions can cause brown heart in swedes and turnips and stem disorders in kale and rape.

Copper

Adequate Cu for high yielding brassica crops can usually be supplied from the soil. Trials have shown that applying Cu in fertiliser does not increase Cu uptake so animal requirements need to be met by administering Cu to the animal before they are put on the crop.

Molybdenum

Yield responses to Mo are rare in brassicas and it will only be required if soil pH at sowing is low (< 5.5) and the crop is grown on soils formed from greywacke.

pH

A soil pH of 6.0 – 6.2 is required for optimal brassica growth and lime should be applied 3 - 6 months before the crop is sown to allow sufficient time for the lime to break down and elevate soil pH. As a general rule, application of lime at 1.5 – 2.0 t/ha will increase the pH by about 0.1 units in the top 0 – 150 mm of the soil.

Fodder beet

Nitrogen

As for brassica crops, N fertiliser requirements (kg/ha) for fodder beet vary according to the amount of potentially available N (PAN) in the soil and potential yield. PAN* can be measured by the Anaerobically Mineralizable N (AMN) or the Available N (AN) test. Fodder crop yields are generally in the range of 20 – 25 t DM/ha. Recommended N rates for crops with these yields are:

PAN less than 120 kg/ha – apply 100 kg N/ha: 50 kg/ha at sowing and 50 kg/ha pre-canopy closure

PAN greater than 120 kg/ha – apply 50 kg N/ha at sowing

The measurement of PAN in a soil with high organic N levels can result in a saving of 50 kg N/ha as fertiliser to give environmental and economic benefits.

Phosphorus

Phosphorus requirements are similar to those for brassica crops for soil samples taken at 0–150 mm depth:

Sedimentary and ash soils

Olsen P less than 15 – apply 50 kg P/ha at sowing, preferably placed close to the seed

Olsen P greater than 15 – apply 20 kg P/ha, preferably placed close to the seed

Pumice and peat soils

Olsen P less than 20 – apply 50 kg P/ha, preferably placed close to the seed

Olsen P greater than 20 – apply 20 kg P/ha, preferably placed close to the seed

Phosphorus does not move far in the soil so there is better early growth by placing it close to the seed.

Potassium

High yielding fodder beet crops can take up high rates (more than 500 kg/ha) of potassium from the soil. However, this is luxury uptake and does not affect the yield of the crop. A crop yield response to K fertiliser has only been measured on some volcanic soils with QT K less than 5 or sedimentary soils with QT K less than 3 and TBK less than 1.0 me/100g. For a grazed crop:

Soil QT K less than 3 and TBK less than 1.0 me/100 g - apply 100 kg K/ha at sowing

Soil QT K 3 – 5 and TBK 1.0 – 1.5 me/100 g – apply 50 kg K/ha at sowing

Soil QT K greater than 5 – apply no K

If the crop is lifted rather than grazed in-situ, there is more K removed and K rates for the next crop will need to be higher.

*** PAN = AMN (μg/g) x soil depth (cm) x 0.1 x Soil Buk Density (w/v)**

Sodium

Soil QT Na less than 5 – apply 150 kg/ha of sodium chloride at sowing

Soil QT Na greater than 5 – apply no sodium

Sulphur

Soil sulphate-S less than 5 – apply 20 – 30 kg S/ha at sowing

Soil sulphate S greater than 5 – no need for S

Calcium

Soil QT Ca less than 4 – apply Ca using lime or superphosphate

Soil QT Ca greater than 4 – no need for Ca

Magnesium

Soil QT Mg less than 8 – apply 25 – 30 kg Mg/ha at sowing

Soil QT Mg greater than 8 – apply no Mg

Boron

Soil B less than 1 ppm – apply 1.5 kg B/ha at sowing

Soil B greater than 1 ppm – apply no B

pH

The optimum soil pH for fodder beet is 6.0 – 6.2 and about 1.5 – 2.0 t/ha of lime is required to increase soil pH in the top 150 mm of the soil by 0.1 units.

Legumes

Lucerne

Lucerne is a tap-rooted legume that can extract nutrients, especially P from deep in the soil profile. As a legume it fixes its own N from the atmosphere so does not require N fertiliser. Lucerne can either be grazed or cut for hay and silage with differing nutrient requirements with emphasis on K, depending on which option is taken. Under good management, lucerne stands can persist for 7 – 10 years.

Phosphorus

Soil Olsen P levels in the top 0 – 150 mm of the soil should be 15 – 20 for sedimentary and ash soils and 20 – 25 for pumice and peat soils. If they are below these ranges, 30 – 60 kg P/ha will be required at sowing. With yields of 10 – 15 t DM/ha, maintenance requirements will range from 15 – 25 kg P/ha/yr under grazing and 20 – 30 kg P/ha/yr under cutting.

Sulphur

Being a legume, lucerne requires an adequate supply of S. To overcome a deficiency, 30 – 40 kg S/ha/yr is required on sedimentary soils, 20 – 30 kg S/ha/yr on ash soils, 30 – 40 kg S/ha/yr on pumice soils and 20 – 40 kg S/ha/yr on peat soils. Elemental S is more suited to autumn applications to reduce S leaching over winter and sulphate-S, as required, in spring applications to ensure a form of S which is readily available.

Potassium

There will be sufficient K in most soils for lucerne establishment so fertiliser K will not be required at sowing. For optimal growth of lucerne, soil QT K levels in the top 0 – 150 mm should be 5 – 8.

Lucerne crops yielding 10 – 15 t DM/ha/yr will take up 200 – 300 kg K/ha/yr from the soil. On sedimentary soils with high TBK levels (> 1 meq %) where all the lucerne is harvested and removed, 50 – 100 kg K/ha will be required per year. On all soils with low TBK levels (< 1 meq %), 100 – 250 kg K/ha/yr, will be required in total, applied after the first two cuts and at the end of the harvest season.

Under total grazing, apply 20 – 30 kg K/ha/yr on low TBK soils. No fertiliser K will be required on high TBK soils.

Magnesium

Many sedimentary and ash soils have adequate Mg (QT Mg 8 - 10) for lucerne requirements. Soil magnesium levels can be low in pumice soils and if so, 20 – 30 kg Mg/ha as Kieserite should be applied at sowing. Continual harvesting of a lucerne stand may necessitate maintenance applications of Mg (10 – 20 kg/ha/yr) if soil QT Mg levels decline over time.

Molybdenum

If the lucerne stand is on a farm where Mo is required for clover growth, then 100 g/ha of sodium molybdate (40% Mo) or 400 g/ha of Granular Molybdenum (10% Mo) should be applied at sowing and thereafter every 4 – 5 years. Lucerne stands on recent alluvial soils should not require Mo.

Boron

Boron will be mainly required at sowing on pumice soils, free draining soils and for seed production. Apply 1 – 2 kg of elemental B per ha.

Copper

Except for pumice and peat soils where 5 kg/ha of copper sulphate may be required at sowing, there should be adequate Cu in the soil to satisfy plant requirements. Copper levels in lucerne can be low for stock (< 8 ppm) and since Cu from fertiliser is only retained in the plant for short periods, if required for stock it should be administered directly to the animal.

pH

Because rhizobia associated with lucerne have a low tolerance for soil acidity, a soil pH of 6.2 – 6.4 in the top 150 mm of soil is required at sowing. Apply lime 6 -12 months before sowing to achieve this. To increase the soil pH by 0.1 units, 1.5 – 2.0 t lime/ha will be required.

Red and white clover

Nearly all of the research on nutrient requirements has been focused on white clover but they can be assumed to be similar for red clover. Under good management white clover swards will last for 5 – 10 years and red clover swards for 2 – 3 years.

Phosphorus

Soil Olsen P levels are required to be in the range of 20 – 30 on sedimentary and ash soils and 35 – 45 on pumice and peat soils for near-maximum production. For a grazed high yielding crop (10 – 12 t DM/ha/yr), maintenance P requirements will be 20 – 30 kg/ha/yr.

Sulphur

The amount of S (kg/ha/yr) required to overcome a deficiency is 30 – 40 kg/ha/yr on sedimentary soils, 20 – 30 kg S/ha/yr on ash soils, 40 – 50 kg S/ha/yr on pumice soils and 20 – 40 kg S/ha/yr on peat soils. Ideally, soil sulphate-S levels should be 10 – 12 ppm but these are mainly achieved on high ASC ash soils while 6 – 10 ppm is adequate on other lower ASC soil groups.

Potassium

Soil QT K levels should be in the range 5 – 8 on sedimentary and peat soils and 7 – 10 on volcanic (ash and pumice) soils for near-maximum production. To raise the soil QT K test by one unit, 30 kg K/ha over and above maintenance is required on peat soils, 45 kg K/ha on pumice soils and 60 kg K/ha on sedimentary brown and ash soils. To maintain soil QT K levels in the target ranges above under grazing, 30 – 50 kg K/ha/yr will be required on low TBK soils (< 1 meq%) and 0 – 30 kg K/ha/yr on high TBK (> 1 meq%) soils.

Magnesium

On all soil groups except pumice, soil QT Mg levels should be above the target range of 8 – 10 for near- maximum pasture production. If soil QT Mg levels are below 6, apply 20 – 30 kg Mg/ha/yr as Kieserite. Magnesium losses need to be replaced by 10 – 15 kg/ha/yr if soil test QT Mg levels decline over time.

Trace elements

To maximise nitrogen fixation, Mo levels should be above 0.3 ppm and N levels above 4.5%. If below these optima, apply 100 g/ha of sodium molybdate or 400 g/ha of Granular Molybdenum. Copper at 5 kg/ha at sowing may be required on peat soils but there should be sufficient supply of all other trace elements from the soil.

pH

At sowing, soil pH should be in the target range of 5.8 – 6.0 and can be elevated by application of 1 t of lime/ha for each 0.1 unit increase. Soil pH can be maintained in this range with 2.5 t lime/ha every 3 – 5 years.

Herbs

Chicory and Plantain

There has been little research carried out on the nutrient requirements of chicory and plantain but it is currently assumed that they have similar requirements to annual ryegrasses. Chicory normally lasts 1 – 2 years and plantain 2 – 3 years before renewal is required.

Nitrogen

The N requirements of chicory and plantain will depend on the clover content of the crop. Where the herbs are sown as single species, 90 – 150 kg N/ha/yr will be required in 3 – 6 applications of 30 kg N/ha. If there is a significant proportion of clover (> 30%), 60 kg N/ha/yr applied over early spring and mid-autumn will be sufficient.

Phosphorus

For successful establishment and early growth, soil Olsen P levels in the top 0 – 75 mm need to be in the range of 20 – 30 for sedimentary and ash soils and 35 – 45 for pumice and peat soils. Crops yielding 8 - 12 t DM/ha/yr will require 25 – 35 kg P/ha/yr to replace losses during grazing and maintain soil Olsen P levels.

Sulphur

To overcome an S deficiency, 30 – 40 kg S/ha/yr is required on sedimentary soils, 20 – 30 kg S/ha/yr on ash soils, 40 – 50 kg S/ha/yr on pumice soils and 20 – 40 kg S/ha/yr on peat soils.

Potassium

For mixed herb/legume stands, maintain soil QT K levels within the range 5 – 8 for sedimentary and peat soils and 7-10 on volcanic and pumice soils by application of 20 – 40 kg K/ha/yr. Pure herb stands will require a lower soil QTK range (4 – 6) and maintenance K requirement (15 – 25 kg K/ha/yr).

Magnesium

If soil QT Mg levels are below 6 which may occur on pumice soils, apply a soluble Mg fertiliser such as Kieserite at 20 – 30 kg Mg/ha/yr. If soil QT Mg levels begin to trend below 10, replace Mg losses by applying 10 – 15 kg Mg/ha/yr.

Trace elements

Trace element levels such as Cu and Zn tend to be high in these plants so application is not required.

pH

If necessary, elevate soil pH to 5.8 – 6.0 by applying 1 t lime/ha for each increase of 0.1 units.

Annual ryegrass

Annual ryegrasses are either sown in autumn as the only species or spring-sown with a brassica such as turnips for a summer crop. As such they usually have a six month to one year duration so rapid establishment and early growth is essential.

Nitrogen

Pasture growth responses to N fertiliser will be large (15 – 25 kg DM/kg N) provided soil temperature and moisture are adequate. Nitrogen should be applied either at sowing or soon after plant emergence at 30 – 50 kg N/ha and again in early spring for a pure sward or after the first grazing for a brassica/ryegrass mix.

Phosphorus

For optimal early growth, P should be placed near to the seed at 20 – 30 kg/ha. If this is not feasible, this rate of P should be broadcast at sowing.

Sulphur

To maximise the response to N fertiliser in early spring, S in a readily-available sulphate form should be included with the N at 15 – 20 kg/ha. At this time, the soil is too cold for mineralisation of organic S or oxidation of elemental S.

Cations

If QT K levels are below the optimal range of 5 – 8 for sedimentary and peat soils and 7-10 for volcanic and pumice soils, 30 – 50 kg K/ha should be applied at sowing. Soil Ca and Mg levels will generally be adequate for annual ryegrasses.

pH

Because the pure stand or crop has only a short life, it is essential that soil pH in the top 75 mm is near or in the optimal range of 5.8 – 6.0 by application of lime three to six months before sowing, if required.

Seedling establishment

Seed burn occurs when fertilisers in close proximity to the seed start to dissolve and take up moisture so that the seedling becomes desiccated due to osmotic stress or burnt through ammonia toxicity.

Fertiliser rankings according to risk are shown below:

Least risk

- Serpentine superphosphate, dicalcic phosphate, lime reverted superphosphate
- Single superphosphate
- Triple superphosphate
- YaraMila and Nitrophoska range, potassium chloride
- Monoammonium phosphate
- Diammonium phosphate, Cropzeal and Cropmaster range
- Ammonium sulphate
- Urea, boron fertilisers

Most risk

Smaller seeds such as clover, rape, turnips, swedes and kale are more sensitive to seed burn. The risk of seed burn is greater as the rate of starter fertiliser is increased.

To minimise the risk of seed burn, the following guidelines should be observed:

- If planting sensitive species with small seeds with a fertiliser containing sulphate of ammonia, either separate the starter fertiliser granule from the seed by having each in separate boxes feeding separate nozzles on the drill or using special coulters i.e., T coulter (aka Baker boot).
- Only mix the seed directly with serpentine superphosphate, reverted or dicalcic super.
- Take special care to ensure correct placement when sowing fertilisers with seed on dry sandy soil.
- Urea or urea based products should not be placed near germinating seedlings.
- Superphosphate and DAP are generally safe if used at normal rates (< 30 kg P/ha) under conditions of good soil moisture.

Soil acidification and lime use

To elevate soil pH in the top 75 mm, a silt loam on average requires 1 tonne/ha of good quality lime (80% $CaCO_3$ equivalent or better) for each 0.1 unit increase. For the top 150 mm of soil, about 1.5 -2.0 tonne/ha of good quality lime is required for each 0.1 unit increase in pH. Clay loams will require greater amounts of lime to elevate soil pH because of greater buffering capacities.

Lime with a smaller particle size (Fine lime – 90% less than 0.1 mm) will increase soil pH faster than AgLime (50% < 0.5 mm, 90% < 2 mm) but at the same rate applied will produce a similar change in soil pH. However, with fine lime the duration of the lime response to a single application will be less than the equivalent amount of AgLime. This is because the larger particles of AgLime will take longer to dissolve and hence increase the length of time the soil pH stays elevated.

Normally 1 - 2.5 tonne/ha of lime is required every 3-5 years to neutralise soil acidification and maintain soil pH. The frequency will increase with greater grazing intensity, rainfall, irrigation and use of N fertiliser.

Nitrogen fertilisers acidify soil through the oxidation of ammonium to nitrate ions.

Least effect ↓ Most effect	kg lime to neutralise 100 kg of fertiliser
Calcium ammonium nitrate	30
Diammonium phosphate	40
Urea	50
Ammonium sulphate	210

Volatilisation of N fertilisers

Ammonia losses from N fertilisers (5 – 20 % of the applied N) may occur when the fertiliser is hydrolysed to ammonium. The rate of volatilisation is enhanced by windy conditions, high soil temperatures and the lack of vegetative cover as in bare ground. The volatilisation risk also increases at higher rates of N fertiliser.

Urea when converted to ammonium, increases the localised soil pH around the granule which further increases the volatilisation rate. Hence ammonia losses from urea are about twice that from diammonium phosphate and ten times greater than from ammonium sulphate.

The timing of urea application so that there is 5 – 10 mm of water applied through rainfall or irrigation within 8 hours of application will minimise volatilisation by dispersing the granule and reducing the surface area available for the reaction to occur. Unfortunately such rainfall events only occur on 10 – 15% of days and few irrigation systems apply sufficient water so this is not a practical solution on most farms. This requirement for water straight after urea application is especially important if the soil is moist since this small amount of moisture is sufficient to start the breakdown of urea to ammonium but insufficient to completely disperse it by washing it into the soil.

Urease inhibitors that coat the urea granule and slow down the rate of volatilisation (e.g., SustaiN and N Protect) can reduce the amount of N lost by 50%. The return on urease inhibitors for the extra cost is maximised in situations where high rates of N are used such as side dressings before full canopy closure (bare soil) as they provide a means of reducing risk of ammonia loss and increasing flexibility in the timing of application.

Animal health considerations

Nitrate poisoning

When a prolonged dry spell is followed by significant rain, the accumulated organic N in the soil is quickly mineralised to nitrate-N which is readily taken up by plants as they respond to favourable growing conditions. High levels of nitrate-N are toxic to stock and multiple sudden deaths can occur under extreme conditions. These conditions occur mainly in autumn but also in spring when plant growth can be rapid. Newly established annual ryegrass and brassica crops are most at risk as they will grow at a fast rate. Overcast, cloudy weather will also exacerbate the situation by delaying the conversion of nitrate-N to amino acids in the plant. The situation can be exacerbated by excessive use of very high rates of N fertiliser.

Management strategies to minimise the risk of nitrate poisoning include:

- At high risk times analyse the leaf for high nitrate levels.
- Restrict grazing time in high risk situations until the animals are acclimatised to the feed.
- Limit daily access to the crop by feeding hay or balage prior to giving them a break on the crop.
- Only apply N at rates that will gain a response according to soil temperature and moisture.

SMCOs

SMCOs (S-methyl-cysteine-sulphoxides) are compounds that form in brassicas and when ingested in significant quantities by grazing stock can cause haemolytic anaemia (red water). The risk of SMCOs is greater when excessive N fertiliser is applied.

If soil sulphate-S is 3 ppm or lower, apply sufficient S fertiliser to grow the crop but at 4 – 10 ppm, no S fertiliser will be required. At sulphate-S of 10 ppm and greater it does not matter how much S fertiliser is applied as soil S levels are already high enough to cause SMCOs if excessive N fertiliser is applied. Regardless of the soil S level, only enough N fertiliser should be applied to satisfy the potential yield of the crop.

Environmental considerations

Establishing and growing a forage crop increases the likelihood of N, P, pathogen and sediment losses from the soil to water bodies through leaching and runoff. Therefore forage crops can act as Critical Source Areas for these potential contaminants. Regional Councils have recognised this and require action plans that minimise the risk of these entering waterbodies in Farm Environmental Management plans. Farmers and contractors need to focus on implementing the management strategies outlined below. These losses can be minimised by consideration of the following management practices and mitigation strategies:

Nutrient management

- Undertake regular soil testing including Available N and use decision support tools if available to match fertiliser nutrient rates to the crop demand (according to potential yield) and the soil available nutrients.
- Do a nutrient budget using the fodder crop option to assess the impact of the crop on nutrient losses from the block and farm.
- Time fertiliser N applications to meet crop demand by using split applications.

Cultivation management

- Reduce soil cultivation by adopting strip tillage or direct drilling, and minimising the number of passes over the paddock.
- Cultivate along contours (rather than up and down the slope) where slopes are greater than 3 degrees to reduce runoff.

Riparian management

- Leave grass buffer strips (2m or more) on cultivated land next to waterways to intercept runoff.

Irrigation

- Avoid overwatering so that excess drainage does not occur.

Grazing management

- Use controlled grazing regimes on winter crops (back-fencing and on-off grazing) to minimise soil compaction that increases runoff losses of nutrients, sediment and pathogens.
- Where there are waterways within the paddock, use directional grazing so the crop adjoining the waterway are the last strips to be grazed so that they have a riparian function.

Post-crop management

- Reduce fallow time by sowing another crop/grass catch crop to harvest soil nutrients and reduce losses.

More information about industry guidelines specific to grazed forage cropping can be found at the following links:

Risk Management Guide for Intensive Winter Grazing on Arable Farms
https://www.far.org.nz/research/farm_systems/forage_systems/impacts_of_dairy_grazing

Reducing surface runoff from grazed winter forage crop paddocks by strategic grazing management
https://www.dairynz.co.nz/media/3207637/strategic-grazing-management.pdf

Forms and types of fertilisers

N fertilisers (examples of fertilisers commonly used in forage cropping)

Fertiliser	%			
	N	P	K	S
Urea (or SustaiN and N Protect)	46	0	0	0
Ammonium Sulphate	21	0	0	24
Ammo 31/NrichAmmo 30N	30	0	0	14
Diammonium Phosphate (DAP)	18	20	0	1
Cropmaster DAP Boron Plus	16	19	0	1
Monoammonium Phosphate	10	22	0	1
Cropmaster 15	15	10	10	8
Cropmaster 20	19	10	0	13
Cropzeal 15P	14	15	13	1
Cropzeal 20N	19	10	0	12
Cropzeal Boron Boost	17	20	0	0

P fertilisers (refer also to N fertiliser list)

Fertiliser	%					
	N	P	K	S	Ca	Mg
Superphosphate	0	9	0	11	20	0
Triple Superphosphate	0	20	0	1	16	0
Serpentine Superphosphate	0	7	0	8	15	6

S fertilisers (refer also to N and P fertiliser list)

Fertiliser	%				
	N	P	K	S	Ca
Ammonium Sulphate	21	0	0	24	0
Sulphur 90/Sulphurgain Pure	0	0	0	90	0
Sulphur Super 15/Sulphurgain 15S	0	9	0	15	20
Sulphur Super 20/Sulphurgain 20S	0	8	0	21	19

K fertilisers (refer also to N fertiliser list)

Fertiliser	%				
	N	P	K	S	Ca
Potassium chloride	0	0	50	0	0
Potassium sulphate	0	0	42	18	0

Mg fertilisers (refer also to P fertiliser list)

	% Mg	*%S*	*Liming value*	*Availability*
Magnesium oxide	50 - 55	0	Yes	Moderate
Dolomite	11	0	Yes	Moderate
Kieserite	16	22	No	Fast

For a complete list of fertiliser products contact your local fertiliser supplier.

Liquid (foliar) fertilisers

- There are a variety of products derived from fertilisers, seaweed extracts, fish waste, and blood and bone for example.
- Although some of these have similar ratings to other fertilisers, dilution before application means that actual amounts of nutrients applied are very low.
- However liquid fertilisers e.g., Liquid urea (20% N) may have a place in meeting the short term requirements of a crop, where soil conditions do not allow ground application and fertiliser can be included with a chemical spray.
- Evenly spread solid fertilisers will give similar yield responses to their liquid equivalents.
- Trace element sprays can be an effective way of overcoming deficiencies, especially those linked to conditions such as dry soils and high pH. Ideally sprays should be used in the early vegetative stage.

NOTES:

NOTES:

Fertiliser Association

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