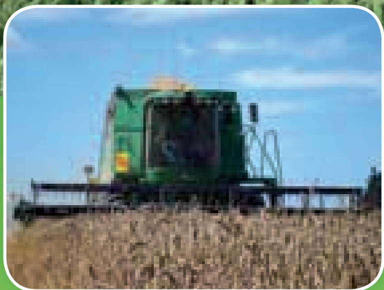

Managing Soil Fertility on Cropping Farms

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Previous edition (1998) produced by New Zealand Fertiliser Manufacturers' Research Association Inc. (NZFMRA) and New Zealand Pastoral Agriculture Research Institute Ltd.

First published 1998,
Reprinted 2000,
Revised June 2009
Reprinted 2012

This revised booklet is published by New Zealand Fertiliser Manufacturers' Research Association (NZFMRA)

New Zealand Fertiliser Manufacturers' Research Association Inc. (NZFMRA)

ISBN 978-0-9864528-6-4 (Print)
ISBN 978-0-9864528-9-5 (Electronic)

MANAGING SOIL FERTILITY ON CROPPING FARMS

(revised edition 2009)

Fert Research

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Foreword

Broadacre cropping is dominated by the production of cereal grains and pulses which are the staple crops for our population. As such society demands a reliable supply of high quality products. To meet these requirements while achieving an economically viable livelihood arable farmers have tended to invest in heavily mechanised high input crop production systems for which the maintenance of strong soil fertility is critical.

The members of the New Zealand Fertiliser Manufacturers' Research Association Inc. (NZFMRA), Ravensdown Fertiliser Co-operative Ltd and Ballance Agri-nutrients Ltd, have published this book as a compact, easy to read guide to good soil fertility management on cropping farms. The authors have drawn on a wide range of information sources in compiling the book in order to ensure that it is as up to date as possible. At the same time they have carefully checked that the information they have used complies with high standards of scientific methodology and accuracy. We are grateful to the authors for what they have accomplished and to the organisations and publications they have drawn upon for their material.

A major part of this book deals with nutrient requirements of the individual crop groups and the fertilisers which are used in present day practice to meet those requirements. However, it is important that readers should not concentrate solely on this part. The maintenance of optimum soil fertility and the efficient use of fertilisers is also dependent on the other aspects of good crop husbandry and monitoring outlined in the book.

Farmers will gain maximum benefit from this book by combining the information in it with their own experience and calling on the help of accredited fertiliser company nutrient management advisers or other qualified consultants to develop a soil fertility programme tailored to their particular properties and objectives.

Bill McLeod
Chairman
New Zealand Fertiliser Manufacturers'
Research Association Inc

Introduction

Soil fertility is an important part of profitable crop production. Since fertiliser is one input that can be directly controlled by the grower, it is important that the correct amounts of nutrients are applied in the appropriate form to ensure efficient and responsible use of nutrients. This booklet provides growers with a simple and concise summary of the role of soil fertility and fertilisers in crop production.

Information in the booklet is restricted to the main arable crops: wheat, barley, oats, peas, brassica seed, maize, grass seed and white clover seed. A limited amount of information was available for each crop when this booklet was first published. Over successive years new research and technologies have advanced the understanding of soil fertility on crop performance, and new agronomic management has consequently evolved.

For ease of access, each crop is treated separately in terms of nutrient requirements. In addition, there are sections on soils, general soil fertility management, plant analysis, and other relevant topics.

The information presented represents a generalisation over a range of conditions. However, every farm and crop is an individual situation and putting these recommendations into practice will require modification. If in doubt you should seek guidance from an accredited agricultural advisor or agronomic consultant.

Major Soils

The main cropping areas in New Zealand are usually on what are termed sedimentary soils. The largest group of these is the Pallic soils (Yellow Grey Earths), but also included are their related intergrade soils - the Brown soils (Yellow Brown Earths), and the more recent soils on river terraces. A second classification of soils is the Allophanic soils (volcanic ash soils) of the Bay of Plenty and Waikato, where maize is the predominant crop. Maize is also grown on peat soils in the Waikato.

From a practical point of view, the soils on which arable farming is carried out can be categorised according to soil drainage. Soil drainage is an important property for arable crops as it influences water supply to the crop and flexibility in cultivation and harvesting.

Free draining soils

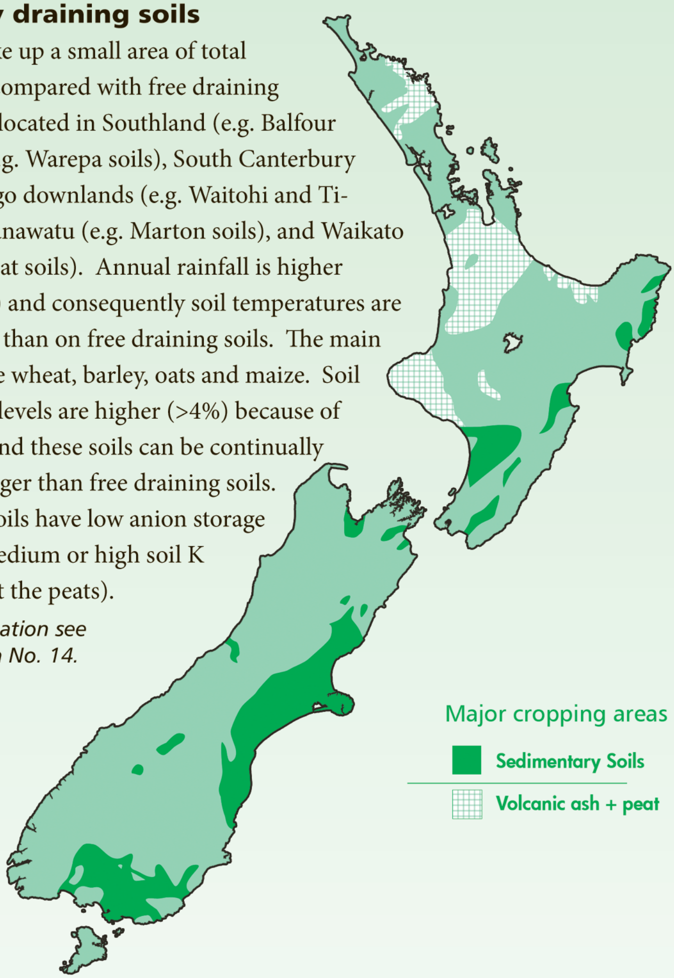
These make up most of the cropping area in New Zealand. They are located mainly on the Canterbury Plains (e.g. Lismore and Templeton soils) with smaller areas in North Otago (e.g. Pukeuri soils), Marlborough, Nelson (e.g. Tasman soils), Wairarapa (e.g. Manawatu soils), Hawkes Bay (e.g. Takapau soils), Poverty Bay (e.g. Matawhero soils), Bay of Plenty (e.g. Pongakawa peats), and Waikato (e.g. Rukuhia peat and Horotiu ash soils).

High summer/autumn temperatures make these areas ideal for cereals and most other crops, but low annual rainfall (500-1000 mm) in the eastern regions can mean that irrigation is needed for high yields. Soil organic matter levels are medium to high (3-5% organic carbon) when first cultivated from pasture but are often depleted under continual cropping. Most sedimentary soils have low anion storage capacity and high potassium (K) reserves. In contrast the volcanic ash soils (Bay of Plenty, Waikato) have high anion storage capacity and low K reserves. High anion storage capacity increases the amount of fertiliser P required to increase soil Olsen P level. A soil with high K reserves has a nil or low requirement for fertiliser K. More information on anion storage capacity and K reserves is given later in this booklet.

Imperfectly draining soils

These soils make up a small area of total cropping land compared with free draining soils. They are located in Southland (e.g. Balfour soils), Otago (e.g. Warepa soils), South Canterbury and North Otago downlands (e.g. Waitohi and Timaru soils), Manawatu (e.g. Marton soils), and Waikato (e.g. Kaipaki peat soils). Annual rainfall is higher (700-1200 mm) and consequently soil temperatures are generally lower than on free draining soils. The main crops grown are wheat, barley, oats and maize. Soil organic matter levels are higher (>4%) because of better rainfall and these soils can be continually cropped for longer than free draining soils. Most of these soils have low anion storage capacity and medium or high soil K reserves (except the peats).

For more Information see FAR Arable Extra No. 14.



Essential Elements in Plants

Plant tissue consists of carbon (C), hydrogen (H), oxygen (O), and about 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)	

Basic Principles

Cropping places high demands on the soil and its ability to supply nutrients. This is due to a combination of:

- high nutrient removal in crop harvest.
- high seasonal demand for nutrients from rapidly growing crops, particularly during spring.
- degradation of soil structure and organic matter through cultivation and harvest machinery which reduces the soil's ability to provide nutrients in the long term. However, many nutrients may be released initially from the mineralisation of organic matter in the short term.
- reduced earthworm populations and microbial activity which are important for nutrient availability.
- susceptibility of leachable nutrients (e.g. N, S) to loss through winter drainage.

Fertility management programmes take into account not only the replacement of nutrients, but also a more complete soil monitoring programme. Under high levels of nutrient input and output:

- pH can fall rapidly, affecting nutrient availability within one to two years.
- soil reserves of nutrients, previously thought adequate, can become inadequate within one to two years.
- nutrient imbalance may develop.

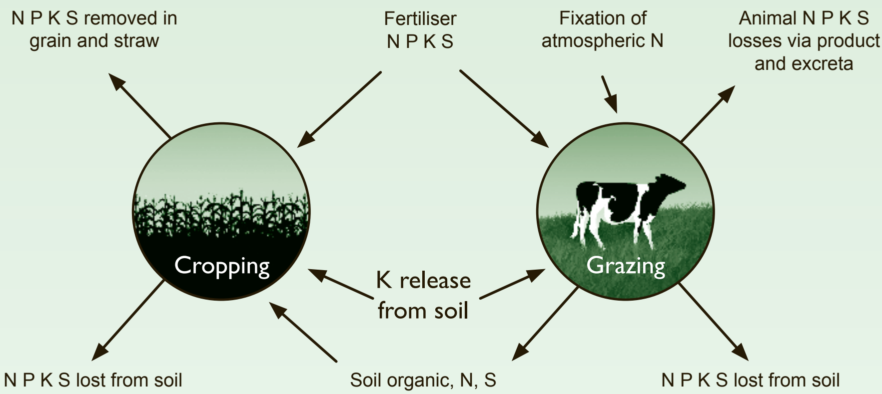
Under continual cultivation, soil structure and stability can degrade. Periodic monitoring by examining profiles and observation (see soil quality chapter) can give useful information on the need for restorative phases under pasture, alterations to cultivation practice, or remedial action such as subsoiling. Degraded soils have lower water holding capacity, reduced organic matter levels, and reduced air movement, all of which reduce microbial activity and hence nutrient availability.

Successful fertility management in an arable situation is a combination of continually monitoring soil nutrient status (e.g. pH, P, K, S), readily available soil mineral nitrogen, soil nutrient reserves (e.g. TBK, organic sulphur), soil organic matter status (organic carbon), and soil structure. Maintaining fertility then becomes a balance between fertiliser input, cultivation programmes, crop residue returns, and crop rotations (grass and clover seed, pasture) to restore soil fertility. Because crops have different nutrient requirements, it makes good sense to maintain soil nutrients at levels required for the higher demanding crops or the pasture phase, even if these have higher requirements than other crops in the rotation.

The level of soil fertility monitoring is a reflection of the intensity of the cropping system; more intensive production systems with high inputs and outputs require more intensive monitoring.

Nutrient cycles under cropping and grazing

The diagram below shows the cycling of nutrients under cropping and grazing.



With the exception of soil N which accumulates under grazing and is generally depleted under cropping, similar nutrient gain and loss processes occur under both systems. Under grazing, N from clover fixation accumulates in soil organic matter.

Cropping Rotations

Crop phase

The nutrient required in the largest quantity for cereal crops is nitrogen (N). N can be supplied from either fertiliser, legume crops or soil organic matter. Cultivation allows soil micro-organisms to release N from the soil organic matter so that it can be taken up by plant roots. With continual cropping, soil organic matter generally becomes depleted. This not only reduces the supply of N and other nutrients but also results in poorer soil structure. Good soil structure is essential for the movement of water and air to plant roots for optimum crop yield. Degraded soil structure is associated with reduced soil water holding capacity. The most effective method of restoring soil organic matter is by including grazed pasture in the cropping rotation.

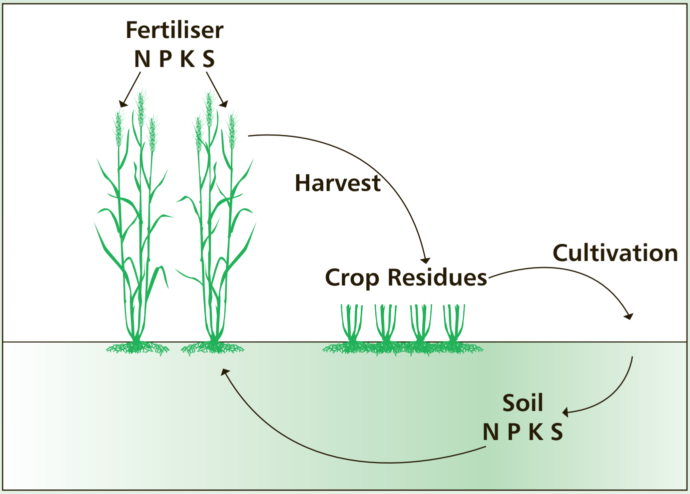
Most other nutrients can be supplied by the soil reserves but some, particularly P and S, must be supplied in fertiliser. Just as for soil organic matter, soil nutrient reserves also become depleted over time as nutrients are removed in grain and straw. They must be replaced by fertiliser nutrients if the nutrient reserve is to be sustained or once they drop below a level that is adequate for crop requirements. Adjustments may need to be made to allow for the removal or incorporation of previous crop residues.

Pasture phase

Grazed pastures are important in the cropping rotation to restore and maintain soil organic matter and soil structure. Legumes in pasture, principally white clover, fix N from the atmosphere. Animals ingest the clover and excrete a large proportion of the N in dung and urine. Some of the excreted N is taken up by plants and some is incorporated into the soil organic matter. The decay of ungrazed plant material also adds to this pool of N. Some of this organic N then becomes available through mineralization, which is stimulated by cultivation and increasing soil temperature combined with optimal soil moisture levels.

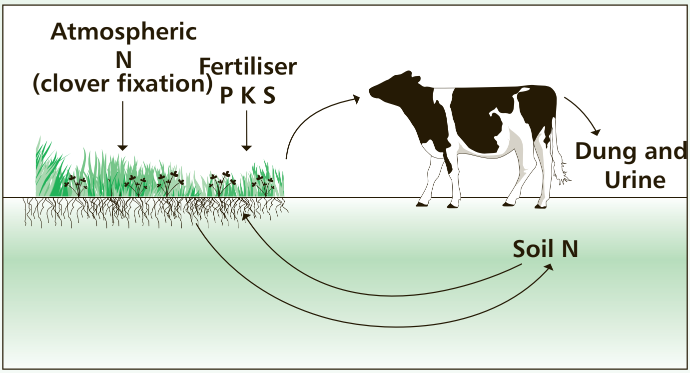
The soil organic matter binds soil particles in such a way that there is space between them for water and air movement. Grass /plant roots are a source of organic matter, on which populations of micro-organisms develop. Micro-organisms produce compounds that help bind soil particles while roots help to enmesh and bind soil particles. Earthworm populations increase under pasture because of organic matter inputs and lack of cultivation. Earthworms help to improve soil structure.

Cereal crop



In the cropping part of the rotation, fertiliser N, P, K and S are applied and crop plants also use nutrients made available from soil organic matter and crop residues after cultivation.

Grazed pasture



In the grazing part of the rotation, fertiliser P, K and S are applied for clovers to fix atmospheric N. Fixed N is recycled through the animal, or is released to the soil as the plant material decays. Some of this N plus other nutrients accumulate in the soil organic matter.

Crop rotations involve growing a series of different crops in one paddock in a sequence over a number of seasons.

Depletive and restorative crops

Different crops in the rotation either deplete or restore the soil nutrient status and the organic matter status.

Depletive	Wheat[1], Maize, Brassica seed crops (including oil seed rape), Barley, Oats
Partially restorative	Grazed forage and green manure crops, Peas, Beans, Grass seed crops[2], White clover seed crops
Restorative	Grazed pastures with legumes

A pasture phase or alternating different crops is also important for control of plant diseases and weeds.

[1] Wheat may be partially restorative if a large root mass and residues are retained, but soil nutrient status is depleted.

[2] Grass seed improves soil organic matter and structure but depletes soil N.

For more information read FAR Arable Extra No. 2.

Soil Quality

The soil physical qualities are vital to the ecological and economic sustainability of the land. They control the movement of water and air through the soil, and the ease with which roots can penetrate the soil. Damage to the soil can change these properties and reduce plant growth, regardless of nutrient status. A decline in the physical quality of the soil can take considerable expense and many years to correct.

High quality cropping soils:

- supply nutrients sufficient to meet crop demands
- maintain stable soil structure
- provide good porosity and aeration to crops
- maintain high water storage capacity and availability
- support high numbers of beneficial soil organisms.

Soil organic matter

Soil organic matter typically occurs at just 3- 5 % in many New Zealand arable soils, but plays an important role by binding together soil particles into cohesive aggregates contributing to desirable soil structure. Organic matter also plays a very important role in the retention and exchange of essential nutrients. For this reason pasture rotations form a valuable part of arable soil management. As discussed in the previous chapter, cultivation results in mineralisation of organic matter. Over time cultivation will gradually bring about a significant loss of soil organic matter and the important characteristics it contributes to soil quality.

Laboratory testing for total carbon can provide an estimate of soil organic matter and how it is changing over time. In combination with 'total nitrogen' an indication is provided of the nature of the organic matter and its potential rate of decomposition.

Soil structure

Soil structure describes the arrangement of the solid parts of the soil and of the pore space located between them. Good structure improves:

- Water infiltration
- Aeration
- Uptake of water and nutrients
- Potential for a good yield

Loss of soil structure, for example through pugging by livestock or compaction under machinery, results in structural breakdown and consolidation of soil components. The detrimental effects of this breakdown are reduction in porosity and therefore water infiltration (and drainage), reduction in air and nutrient movement, a reduction in plant rooting potential, and a reduction in water holding capacity – all of which may lead to decreased productivity. Loss of soil structure is usually associated with a loss of soil organic matter.

Preventing soil structure breakdown:

1. Minimise cultivation intensity & frequency
   a. Practice rotations requiring less tillage
   b. Reduce passes, avoid powered implements
   c. Minimise the depth of cultivation
2. Maintain soil cover (residues or crops)
3. Achieve high organic matter returns
   a. Retain crop residues
   b. Avoid fallow periods
   c. Include green manure or cover crops rather than fallow periods
4. Avoid compaction
   a. Avoid cultivation and harvesting when soils are wet
   b. Keep stock off paddocks in wet conditions
   c. Establish and use traffic management plans for farm machinery
   d. Use reduced tillage practices where possible and vary the depth and frequency of cultivation to help reduce the formation of tillage pans
   e. Use surface and subsurface drainage on persistently wet soils
   f. Fracture compacted soils by subsoiling
   g. Compaction risk is higher where soil calcium levels are low.

For more information read FAR Arable Extra No. 75.

Restoring topsoil structure

1. Incorporate high dry matter crop with surface cultivation
2. Sow restorative crops
   a. Ryegrass/clover pasture
   b. Grass seed crops
3. Limit grazing to dry periods
4. Minimise cultivation.

Soil structure can be measured using **Soil Quality Management System (SQMS)** developed by Crop & Food Research, or the **Visual Soil Assessment (VSA)** developed by Landcare Research.

For more information visit www.crop.cri.nz/home/products-services/crop-production/sqms/decision.htm or search www.plantandfood.com and/or www.landcareresearch.co.nz/research/soil/vsa/fieldguide.asp . Also see Understanding Soil Water, Environmental Topic, Hawkes Bay District Council.

Assessing Soil Nutrient Status

Assessing the soil nutrient status is the first step in determining how much fertiliser is required. The soil nutrient status can be used together with other information (soil type, cropping history, target crop yield) to make this decision. Soil testing to monitor trends over the rotation is equally important. For selected crops, this can be complemented by plant analysis at specific growth stages (page 19) to check that a sufficient amount of the applied nutrient has been taken up by the crop.

There are a wide range of soil tests available from most commercial laboratories.

These soil tests can be divided into two types:

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 (QTK)** – a measure of plant available K
- **Quick test Mg (QTMg)** – a measure of plant available Mg.
- **Mineral-N (NO_3^- + NH_4^+)** – a measure of readily plant available N
- **Sulphate-S (SO_4-S)** – a measure of immediately plant available S.

Long-term soil nutrient supply

- **Tetraphenyl Boron K (TBK)** – a measure of the K reserve in some sedimentary soils.
- **Organic-S (Org-S)** – a measure of the long term supply of S.
- **Organic-C (OC)** – a measure of the organic matter content of the soil.
- **Anion storage capacity (ASC)** – a measure of the capacity of a soil to store P and S (previously referred to as phosphate retention, PR).
- **Cation storage capacity (CSC)** – a measure of the capacity of a soil to store nutrients such as Ca, Mg, and K (also referred to as cation exchange capacity, CEC).
- **Available N test (avail N)** – useful to estimate the possible mineralisation of organic N, particularly following pasture or to give a background estimate of soil N supply.

Soil sampling

Soil sampling should be carried out well before planting. Soil samples should be taken to 15 cm depth in cultivated soil (deeper for soil mineral-N, see next chapter)
The best benefit from soil test information is achieved by regular testing over a number of years.

Setting up a soil monitoring system on your farm

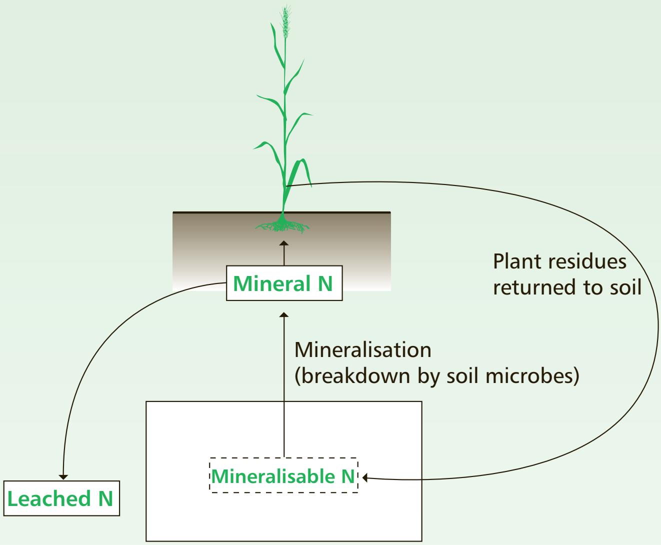
- identify different soil types.
- select at least 3-4 paddocks that are representative of each soil type or farm block. (For detailed monitoring it is recommended that every paddock which is going to be cropped is tested every season.)
- set up a transect in each paddock by painting posts and take 20 cores at equal intervals along the transect. Or use 20 GPS waypoints (in a W shape) and take cores from the same spots whenever the paddock is sampled.
- sample the same paddocks every year and analyse for soil pH, P, K, Mg, Ca and sulphate-S. Every 2-4 years, analyse for soil TBK, organic-S and organic-C.
- take the samples in the same month of each year (when there is the most constant moisture status).

Using the monitoring results from your farm

- plot the trends in soil pH and available nutrient levels over time.
- use the trends in soil pH and available nutrient levels (at least four sampling occasions) to assess whether fertiliser nutrient application is inadequate (levels going down – below optimum), adequate (levels staying constant – at optimum) or excessive (levels going up – above optimum).
- make appropriate corrections to fertiliser nutrient application rates.
- plot out soil TBK, organic-S and organic-C levels over time to assess what effect your management is having on soil nutrient reserves. Fertiliser K is required to replace crop losses so that soil reserves are not depleted. Soil organic matter (as indicated by organic-C) should be maintained or increased by including grazed pasture in the rotation. Cultivation practices may need to be reviewed if soil organic-C shows a downward trend.

Soil Nitrogen Tests

Measuring soil mineral-N is essential for knowing how much is in the soil and determining if too little or too much fertiliser is being applied. Inaccuracies can reduce profits and/or result in nitrate leaching to the groundwater. There are several soil tests available, and it's not always easy to tell which one is best. It is important to understand what each test tells you so you know you are ordering the correct test.



Mineral Nitrogen (Min-N)

Also referred to as "Deep Soil Mineral N", this test measures nitrate-N and ammonium-N content of freshly collected soil. It represents the N immediately available to plants at the time of sampling and does not include any measure of potentially mineralisable N. It is frequently used for cropping soils at a range of sampling depths often to 60 cm depth (preferably to 90 cm if soil profile allows) and is incorporated into crop models/calculators to estimate N fertiliser requirements for the growing crop. The best time to sample autumn sown crops is late-August which gives a compromise between a sufficient amount of time to allow for any winter leaching events, but before spring mineralisation ramps up or spring fertiliser is applied. Randomly take about 8-12 samples per paddock and keep away from gate areas and stock camps etc.
Samples must be chilled, but NOT frozen, to prevent mineralisation occurring in the sample while in transit to the laboratory. Samples must arrive at the laboratory at less than 4°C.

Generally lab results come back with a measurement for each of ammonium-N and nitrate-N. The results are often reported as ppm, µg/g or mg/kg and need to be converted to kg N/ha for most applications.

This ppm, µg/g or mg/kg result needs to be multiplied by 1.1 (g/cm3 representing the typical bulk density of most soils) for the top 30cm of a silt loam soil and 1.3 for the 30-60cm depth section of a silt loam. If the samples were taken from 0-60cm in one core, use 1.2. Further multiplying by 0.1 gives the correct units (kg/ha).

ammonium-N + nitrate-N (mg/kg) x *depth of soil sample (cm)* x *relevant bulk density (g/cm^3)* x *0.1 = kg N/ha*

e.g. (11.9 + 6.0)mg/kg x *60 cm* x *1.2 g/cm^3* x *0.1 = 129 kg N/ha*

The Bulk Density of lighter sandy soils may be closer to 1.1 and for heavier soils with high clay content (or deeper subsoils) it may be closer to 1.5 g/cm^3.

Available Nitrogen (AN) [also known as Anaerobic Mineralisable Nitrogen—AMN]

This test is a measure of N mineralised under specific laboratory conditions (anaerobic incubation at 40°C for 7 days). It represents an estimate of nitrogen that will be potentially mineralised in the field throughout the season, which will depend on factors such as soil temperature and moisture. AN is usually only measured in the top 15 cm of soil as this is where the organic matter is most concentrated. It does not measure the immediately plant available component of soil nitrogen.

The results are reported as kg N/ha for available-N (AN), or µg/g for anaerobic mineralisable-N (AMN).

Organic Nitrogen

This test measures the organic component of the soil which comprises of 98-99% of all nitrogen in the soil. Most organic-N is locked up in the soils organic matter and not available to plants.

Total Nitrogen (tN)

This test measures the total N including mineral-N and organic-N and is useful in determination of Carbon: Nitrogen ratios, but is generally not a test used by growers.

For more information regarding Soil Nitrogen Tests, refer to the information sheets provided by your accredited soil testing laboratory, also FAR Arable Extra No.37.

Plant Analysis

Plant analysis can be used to monitor N, P, K and S levels or diagnose specific deficiencies, such as Mg, Ca, Mn, Zn, Cu, and B. For example, regular monitoring can be a useful method to identify the need for additional N over and above that supplied by the soil or previous fertiliser applications. Plant testing includes whole plant or leaf analysis. Accurate diagnosis depends on the use of appropriate standards and correct sampling procedures. Complementary soil testing and comparative plant tissue analysis, where plant samples are collected from both good and affected plants, provide valuable information when diagnosing a nutrient deficiency.

Optimum nutrient ranges for wheat plant tissue analysis.

Whole shoots – GS30, ear at 1cm		
Nutrient	**Unit**	**Optimum Range**
Nitrogen	% w/w †	3.5 – 5.5
Phosphorus	% w/w	0.3 – 0.6
Potassium	% w/w	3.3 – 5.5
Sulphur	% w/w	0.2 – 0.4
Calcium	% w/w	0.4 – 1.0
Magnesium	% w/w	0.1 – 0.3
Sodium	% w/w	0 – 0.1
Iron	mg/kg	30 - 100
Manganese	mg/kg	35 - 100
Zinc	mg/kg	25 - 70
Copper	mg/kg	7 - 15
Boron	mg/kg	6 - 12

Whole shoots - GS32, second node detectable		
Nutrient	**Unit**	**Optimum Range**
Nitrogen	% w/w †	2.7 – 4.5
Phosphorus	% w/w	0.2 – 0.5
Potassium	% w/w	2.9 – 4.5
Sulphur	% w/w	0.1 – 0.4
Calcium	% w/w	0.3 – 1.0
Magnesium	% w/w	0.1 – 0.3
Sodium	% w/w	0 – 0.1
Iron	mg/kg	30 - 100
Manganese	mg/kg	30 - 100
Zinc	mg/kg	20 - 70
Copper	mg/kg	5 - 10
Boron	mg/kg	5 - 10

Source: ARL. For further data across a range of crop types and growth stages, refer to an accredited fertiliser company representative or accredited laboratory.

† weight of nutrient expressed as a percentage of dry weight of plant material

Optimum nutrient ranges for barley plant tissue analysis.

Whole shoots – GS30, ear at 1cm		
Nutrient	**Unit**	**Optimum Range**
Nitrogen	% w/w †	2.5 – 5.0
Phosphorus	% w/w	0.3 – 0.6
Potassium	% w/w	3.0 – 5.5
Sulphur	% w/w	0.2 – 0.5
Calcium	% w/w	0.3 – 1.0
Magnesium	% w/w	0.1 – 0.3
Sodium	% w/w	0 – 0.1
Iron	mg/kg	50 - 150
Manganese	mg/kg	30 - 100
Zinc	mg/kg	20 - 60
Copper	mg/kg	6 - 12
Boron	mg/kg	6 - 12

Whole shoots - GS32, second node detectable		
Nutrient	**Unit**	**Optimum Range**
Nitrogen	% w/w †	2.0 – 4.0
Phosphorus	% w/w	0.3 – 0.5
Potassium	% w/w	2.5 – 4.5
Sulphur	% w/w	0.2 – 0.5
Calcium	% w/w	0.2 – 1.0
Magnesium	% w/w	0.1 – 0.3
Sodium	% w/w	0 – 0.1
Iron	mg/kg	50 - 150
Manganese	mg/kg	25 - 100
Zinc	mg/kg	15 - 60
Copper	mg/kg	5 - 10
Boron	mg/kg	5 - 10

Source: ARL. † weight of nutrient expressed as a percentage of dry weight of plant material

Optimum nutrient ranges for maize plant tissue analysis.

Plants 40cm height – youngest fully expanded leaf		
Nutrient	**Unit**	**Optimum Range**
Nitrogen	% w/w †	3.5 – 5.0
Phosphorus	% w/w	0.3 – 0.6
Potassium	% w/w	3.0 – 4.5
Sulphur	% w/w	0.2 – 0.4
Calcium	% w/w	0.3 – 1.0
Magnesium	% w/w	0.2 – 0.5
Sodium	% w/w	0 – 0.3
Iron	mg/kg	50 - 200
Manganese	mg/kg	40 - 100
Zinc	mg/kg	30 - 70
Copper	mg/kg	7 - 15
Boron	mg/kg	7 - 15

Early silking – ear leaf		
Nutrient	**Unit**	**Optimum Range**
Nitrogen	% w/w †	2.3 – 3.3
Phosphorus	% w/w	0.2 – 0.3
Potassium	% w/w	1.7 – 2.3
Sulphur	% w/w	0.1 – 0.3
Calcium	% w/w	0.2 – 0.5
Magnesium	% w/w	0.1 – 0.3
Sodium	% w/w	0 – 0.3
Iron	mg/kg	20 - 250
Manganese	mg/kg	20 - 150
Zinc	mg/kg	20 - 70
Copper	mg/kg	6 - 20
Boron	mg/kg	6 - 20
Molybdenum	mg/kg	0.1 - 0.5

Source: ARL. † weight of nutrient expressed as a percentage of dry weight of plant material

Procedure for sampling wheat crops

About 20-40 individual tillers should be collected from around the paddock, taking one or two tillers at each sampling site. Tillers should be cut at ground level and all live and dead material should be included in the sample.

Specific Example: Monitoring N levels in wheat

(to determine N input for optimum yield and quality)

Regular monitoring is required because:

- there is a lot of variability within the paddock and between sampling times.
- the rate at which plant nutrient, particularly N, content is changing is at least as important as the value at any one sampling.
- monitoring enables you to build a picture of changes over the season which can be related to rainfall, yield potential, paddock history, and subsequent crops. Fertiliser management can be adjusted accordingly.

Nutrient Requirements of Crops

Wheat

Nitrogen (N)

The use of N will be primarily governed by the yield potential and the intended end use of the crop; this being determined by the limitations of moisture, soil type, and crop management. Paddock history, cultivar, plant establishment, and cultural practice are also important.

Yield potential can vary from 3 t/ha for a drought stricken wheat crop to 15 t/ha+ for autumn sown feed wheat. In addition, balance in N use is needed between that required to achieve the optimum yield and the carryover into grain N content (protein). While some wheat receive a premium for high protein content and therefore may receive additional applications of N to boost protein, others such as biscuit wheat (and malting barley) are penalised for elevated protein levels. Hence it is important to identify a realistic yield potential range and then manage the crop to that level.

The key to successfully managing a wheat crop is retaining some flexibility in the way the crop is managed according to the season. Variations in moisture supply and temperature mean that adjustments to the rate and timing of N input often must be made to reflect conditions.
Adjustments include:

- reduced inputs under dry or otherwise adverse conditions.
- using an additional application and/or increasing the rate of an application when favourable climatic conditions prevail, or there is an identified deficiency.

Nitrogen effects on crop canopy

Stage of development:	N uptake affects canopy size by promoting:
Before stem extension:	Tillering
During stem extension:	Shoot survival, with some increase in final leaf size
After stem extension:	Prolonged survival of yield forming leaves

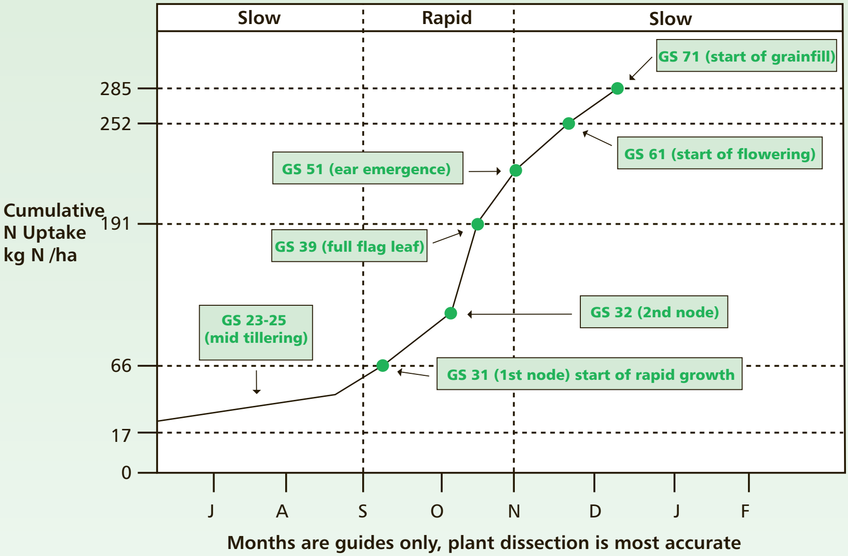
For more information refer to: 'The wheat growth guide' 2nd ed., 2008, HGCA.

Uptake of nitrogen by wheat

The nitrogen uptake curve below, indicates the rate of nitrogen uptake relative to different stages of the crop. Stem extension (GS31-51) is the phase of most rapid N uptake and is therefore the period for the greatest requirement of N for the wheat crop.

Typical nitrogen uptake by autumn sown wheat yielding 10 t/ha.

(Growth stage dates will vary with sowing date, cultivar and location/temperature).



Adapted from 'The wheat growth guide', 1st ed., 1998, HGCA; Crop & Food Research Broadsheet: Regency, 2003; FAR Arable Updates Cereals No.'s 154, 155, 172, 186; and the Sirius Wheat Calculator.

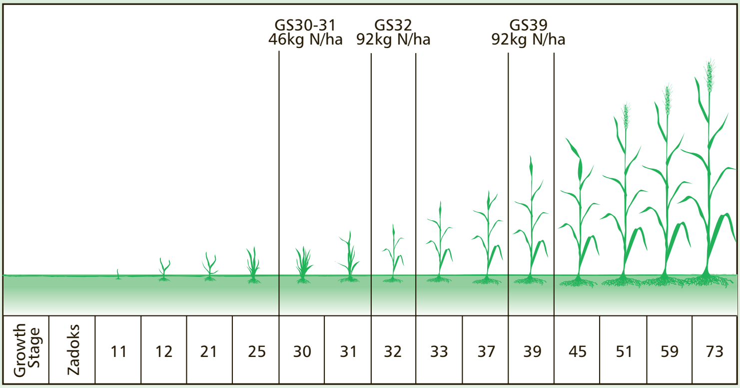
Timing of N

The following illustrations suggest timings of split applications of N fertiliser, but growers should recognise that the actual rate of N will be determined by soil-N status, season and target yield & grain protein level. Guidelines include:

- More early N is used in low soil-N situations, poor establishment, poor tillering, spring crops, or after a wet cold winter.
- Main yield applications are best timed at GS32 (second node) and GS39 (full flag leaf) as this is when the rate of nitrogen uptake is greatest.
- Traditional protein applications for bread wheat have been shown to be less relevant when the main yield application is applied at flag leaf. Flag leaf timings give the best of both yield and protein increases.
- Late N (after flag leaf) should not be applied to biscuit wheat. Biscuit wheat should not ideally be grown after pasture or clover.

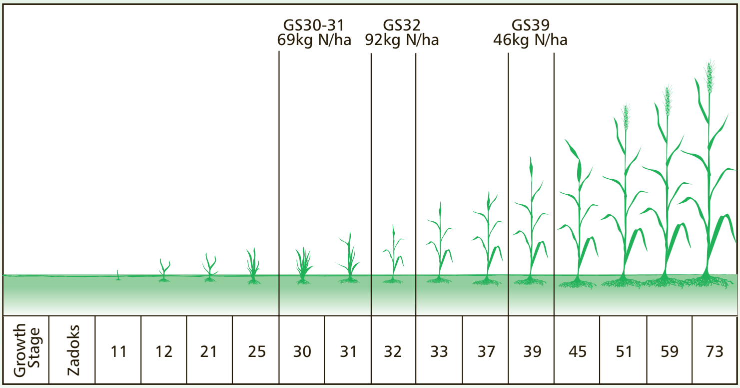
Indicative nitrogen fertiliser programmes for wheat

Autumn sown wheat - *feed*
12.5 t/ha yield potential with 100kg/ha background soil min-N



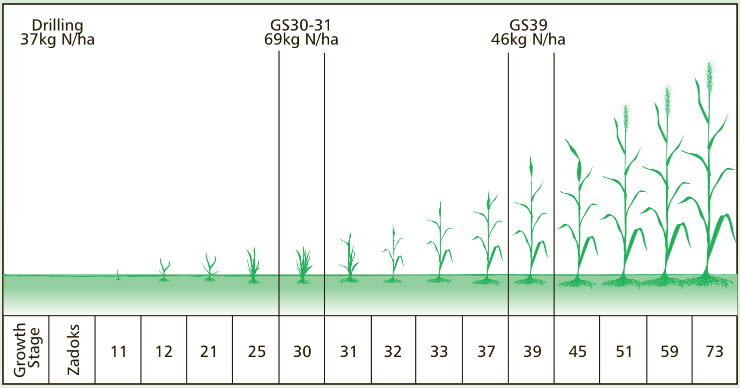
Preferably split N at application rates above 92 kg N/ha (200 kg/ha urea).

Autumn sown wheat - *biscuit*
12.0 t/ha yield potential with 100kg/ha background soil min-N



Apply biscuit N no later than GS39 flag leaf, applying more of the N early at GS32 second node.

Spring sown wheat - *bread*
7.5 t/ha+ yield potential with 100kg/ha background soil min-N



N can be applied pre-planting or drilling (e.g. 30-50 kg/ha) to avoid early topdressing. Modify N application according to moisture status.

For further reading see FAR Arable Updates 'Cereals' No.'s 154, 155, 172, 186.

Nitrogen application rates for wheat

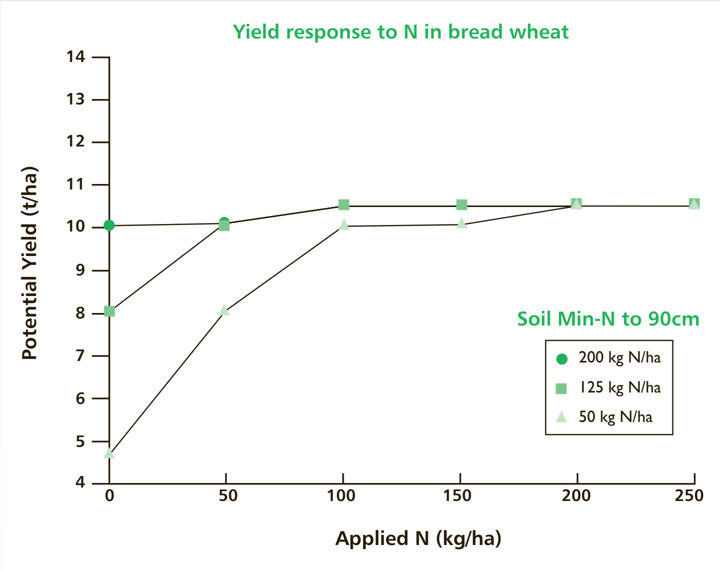
The following graphs estimate how much N needs to be applied over the entire season for a given residual soil fertility, target yield and target protein for bread wheat. These response curves are produced using the Sirius Wheat Calculator using typical Canterbury physical & climatic growing conditions.

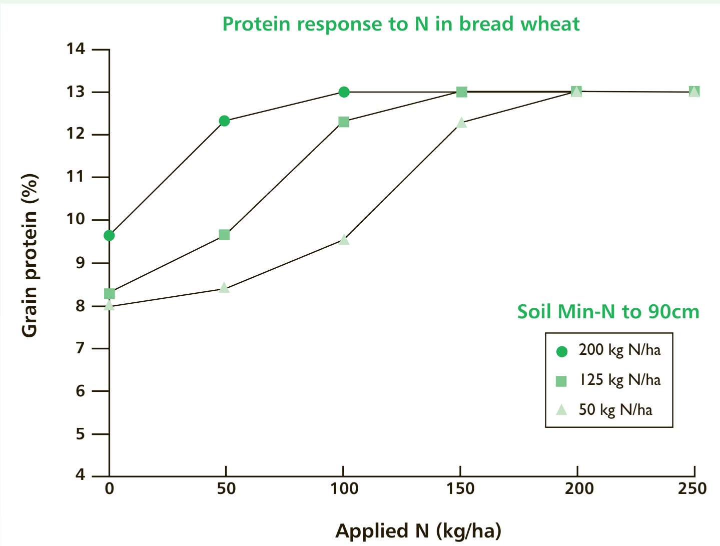
The graph legends refer to background soil mineral-N to 90cm soil depth in late winter before the application of any N fertiliser. Background N rates are quantified as:

- Low = 50 kg N/ha e.g. after four or greater previous years in depletive crops, or a very wet winter
- Medium = 125 kg N/ha e.g. after one to three previous years in depletive crops, or a mild winter
- High = 200 kg N/ha e.g. after two years white clover, or four or greater previous years in pasture

Autumn sown bread wheat – Yield and protein.

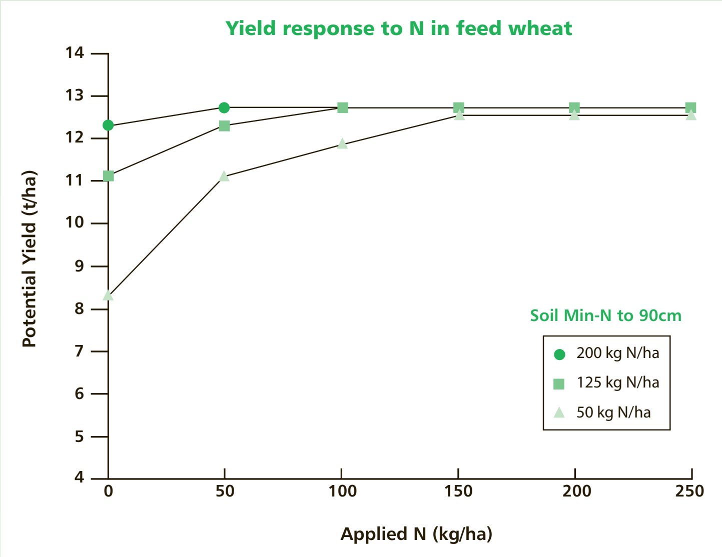
Assumptions: Regency, sown 15th May, Chertsey silt loam, irrigated, modelled using the Sirius Wheat Calculator





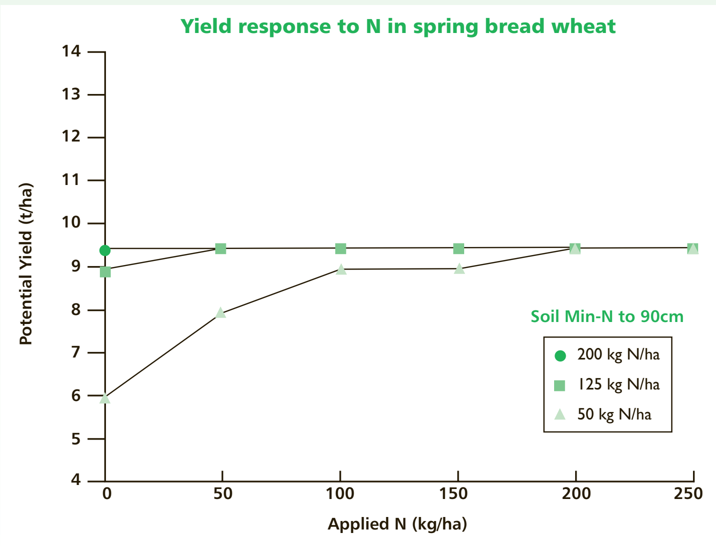
Autumn sown feed wheat.

Assumptions: Savannah, sown 15th April, Chertsey silt loam, irrigated, modelled using the Sirius Wheat Calculator.



Spring sown bread wheat.

Assumptions: Vanquish, sown 15th August, Chertsey silt loam, irrigated, modelled using the Sirius Wheat Calculator.



Soil pH

Wheat prefers a pH of 5.8-6.2 although it will tolerate slightly lower pH. Lime soils well in advance of planting but do not over lime as this can induce trace element deficiencies. Do not lime before 2nd year wheat crops as liming can cause an increase in the incidence of the fungal root disease Take-All.

Other nutrients

In this section, for wheat and all other crops, soil nutrient ranges are given for optimum crop yields. The term optimum refers to high crop yields that can be attained when other factors (e.g. soil moisture, weed, pest & disease, N supply) are non-limiting. Where other factors are limiting, soil nutrient levels below the adequate range will be sufficient. The optimum soil nutrient levels should be considered in terms of both the current crop requirements plus those for other crops in the rotation and the pasture phase.

Some nutrients (e.g. K, Mg) can usually be supplied from (sedimentary) soil reserves depending on the intensity of cropping. These reserves can either be allowed to run down or be replaced by fertiliser nutrient addition. The decision on which option to take is based on economic and other considerations. This comment holds for all crops.

Phosphorus (P)

P is required to ensure adequate root development. If soil Olsen P levels are below 15, fertiliser P must be placed close to the seed at planting. If soil Olsen P levels are higher, P can be broadcast and surface incorporated prior to planting.

In the small number of trials carried out, yield responses to P in wheat have not been measured above Olsen P 15. However since wheat is usually grown in a crop rotation, Olsen P levels should be maintained in the 20-30 range required for near maximum production for pasture and other crops.

Increasing soil Olsen P status

If soil Olsen P levels are below the optimum range, capital applications of P may be required. To increase soil Olsen P by one to a depth of 15cm (standard soil sampling depth for crops) unit on sedimentary soils, an average 10 kg P/ha (range 8-14) over and above maintenance is required. Higher rates (22 kg P/ha, range 14-36) are required for ash (high phosphate retention) soils. Note, for pastoral soils, where soil is sampled to 7.5cm depth, rates should be halved.

Maintaining soil Olsen P status

Crop P losses should be replaced to maintain soil Olsen P status. This will require 15-65 kg P/ha/yr depending on crop yield (see page 47 for examples which fall within this range).

Sulphur (S)

Sulphur is required mainly for growth, but a small amount is required for protein development in milling wheat. Although total requirements are only 15-25 kg S/ha/yr, sulphate-S is prone to leaching so an adequate supply must be maintained. In spring sown crops a single application of S at planting is usually sufficient. In autumn sown crops sulphate-S should be applied at planting, with a further spring application following a wet winter. Where S is not used at sowing the first N application should also contain S. Ideally soil sulphate-S levels should be 10-15.

For more information read FAR Arable Extra No. 10 & 18.

Potassium (K)

K has an essential role in plant structure (aiding straw strength) and flowering quality. Many sedimentary cropping soils have good reserves of K (TBK levels > 1.5) but volcanic ash soils do not. Soil QTK levels should be maintained in the optimum 6-10 range. Where soil QTK levels are <6, apply 0-30 kg K/ha on soils with high TBK levels (> 1.5), 50-60 kg K/ha on soils with medium soil TBK (1-1.5) and 60-80 kg K/ha on soils with low TBK (< 1). If necessary, to replace crop K losses and maintain soil QTK levels within the optimum range, an application of 25-70 kg K/ha/yr will be required, or 60-190 kg K/ha/yr if straw is removed from the paddock (see page 47 for examples).

For more information read FAR Arable Extra No. 18.

Magnesium (Mg)

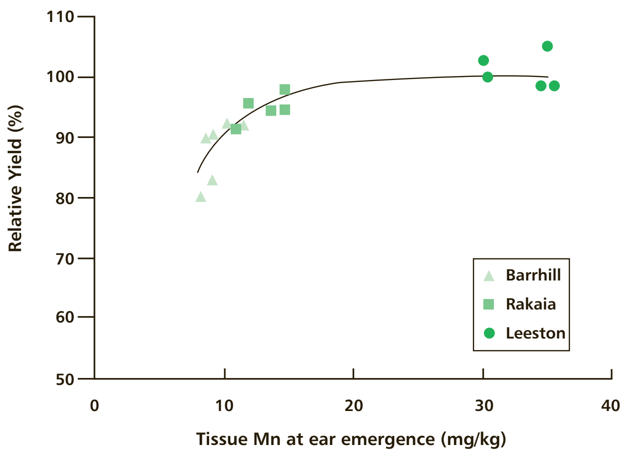
Mg deficiency is rare as cereals remove little Mg and their requirements can usually be met from soil reserves. However Mg is an essential macronutrient and is the building block of photosynthesis and also may help in the water use efficiency of crops, so low levels must not be overlooked. Yield responses may occur at soil QTMg levels below 10, and are more likely following depletive crops – particularly potatoes. In this situation apply 20-30 kg Mg/ha/yr.

For more information read FAR Arable Extra No. 18.

Trace elements

Manganese (Mn) is the most common trace element deficiency in wheat. Trials have shown up to 0.9 t/ha yield response to foliar Mn at sites on the south-side of the Rakaia River. Mn deficiency can be exacerbated by lime applications. Recent research suggests that Mn becomes yield limiting when the concentration (measured in whole, above ground plants at mid-late tillering) drops below 15 mg/kg (normal is 25-100 mg/kg). Leaf tissue testing for Mn gives more accurate information compared to soil testing

Wheat yield response to manganese.



Selenium (Se) levels are naturally very low in South Island soils, resulting in reduced Se intake from food grown on these soils. Low Se intake has a potential impact on human health.

5-7 g Se/ha applied as prills (check product application rates) mixed with fertiliser applied in spring at GS31 is the most cost effective application method. Alternatively foliar applied products may be employed. Application rates should not exceed 10 g of selenium (as sodium selenate) per hectare, as legislation requires the registration of products resulting in applications above this level. Growers should be aware that excessive application can result in toxicities.

For more information on trace elements and how to correct deficiencies see page 52.
For more information read FAR Arable Update 'Cereals' No. 152.

Barley

Nitrogen (N)

As for wheat, N requirements of barley depend on target yield and end use. Generally barley requires less N than wheat. In turn, malting barley requires less N than feed barley due to a requirement for lower grain N levels. Be careful growing malting barley following pasture or clover seed crops where background soil mineral-N is higher.

Rate of N – low to medium fertility

These rates are for a crop history giving low (50 kg N/ha) background soil mineral-N (4 or greater previous years in depletive crops, or after a wet winter).

Grain yield (t/ha)	Indicative total applied N (kg/ha/yr) requirement	
	Feed barley	Malting barley
4	10	0
5	30	10
6	55	35
7	80	60
8	100	80
9	125	**100**

Note: These figures assume 50 kg N/ha of readily available soil mineral-N prior to planting, plus another 50 kg /ha of N that mineralises during the growth of the crop. The malting barley rates aim to hold the protein to 12.5% or under.

The actual N fertiliser requirement will depend on the soil mineral-N supply. Soil mineral-N supply can vary from 50 kg/ha for a history of depletive crops to >200 kg/ha for permanent pasture or two years of white clover seed crops.

Timing of N

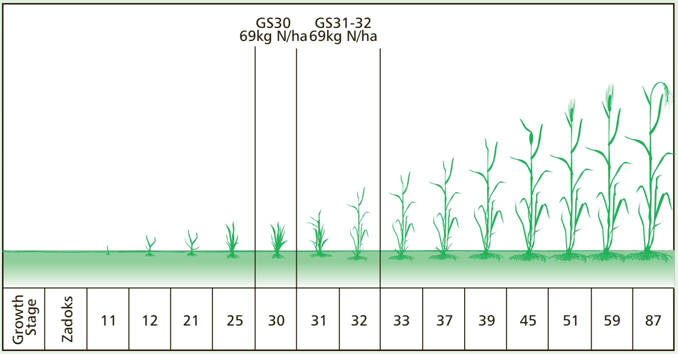
Barley crops generally need N fertiliser applied during early growth as:

- Early nitrogen encourages early tillering, hence strong growth and early canopy cover, limiting the potential for secondary tillers later.
- Applications at GS32 (second node) or later result in secondary tillers causing increased screenings, reducing grain quality - sometimes outside of contract specifications.
- Malting barley is rejected at grain protein levels over 12.5%, while under 10.0% can be undesirable also.

- There are not yet widespread premiums for high protein grain (encouraged by late N applications) in feed barley.
- Barley is usually sown in spring. All spring sown crops grow rapidly, hence the requirement for early N. Often large amounts of N are applied prior to drilling, and any balance applied at the mid-tillering stage.

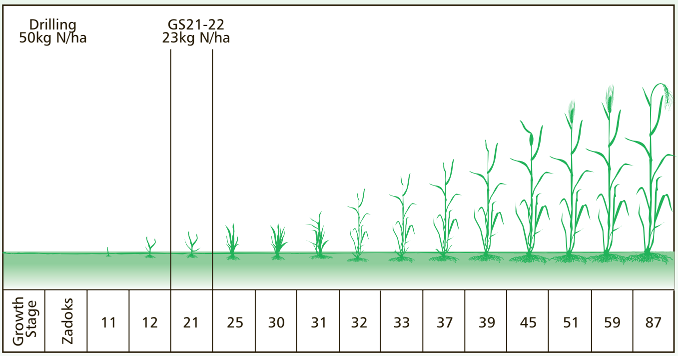
Indicative nitrogen fertiliser programmes for barley

Autumn sown barley - *feed*
10.0 t/ha yield potential with 100kg/ha background soil min-N



Autumn barley – tillering will occur in response to early sowing date. Delay N application until GS30, but all N must be applied in the short time period before GS32.

Spring sown barley - *malting*
6.5 t/ha yield potential with 100kg/ha background soil min-N



Malting – apply most of the N at planting/preplant. If irrigating, apply one third of total applied N after tillering where yield potential is high. If dryland, sidedress lightly during tillering if moisture conditions suit.
Feed – timing of balance (and planting) N is more flexible but generally apply early with a third to half of the nitrogen applied pre-drilling or at drilling (<50kgN/ha). Adjust to suit soil moisture supply and yield target.

For more information read FAR Arable Update 'Cereals' No. 150 & 187.

Soil pH

Barley is more sensitive than other cereals to low pH, and soil pH must be within the range of 5.8 - 6.2. Ensure lime is applied several months before planting.

Phosphorus (P)

For optimum yield with adequate moisture and N supply, an Olsen P of 20-25 is required. To maintain Olsen P within or above this range, apply 10-30 kg P/ha at planting, depending on yield potential.

Sulphur (S)

Sulphur requirements for barley are similar to wheat (15-25 kg S/ha). Soil sulphate-S levels should be maintained at 10-15 for optimum yield. In spring sown crops a single application of S at planting is usually sufficient.

Potassium (K)

To sustain soil K reserves, maintain soil QTK in the optimum 6-10 range by replacing crop K losses (20-100 kg K/ha/yr) depending on yield and management of crop residues (also see comments on page 29 in the wheat chapter). If soil QTK levels are below the optimum range with continuous barley, apply 20-30 kg K/ha/yr where soil TBK is >1.5, 40-50 kg K/ha/yr where soil TBK is 1-1.5 and 50-60 kg K/ha/yr where soil is TBK <1.

Magnesium (Mg)

Yield responses are unlikely unless soil QTMg levels are below the optimum 8-10. In these situations, apply 20-25 kg Mg/ha at planting.

Trace elements

Mn is the most common trace element deficiency in barley.

For more information see page 52.

Oats

Oats generally have lower nutrient requirements than milling wheat. Excessive levels of nutrients are uneconomic.

Soil pH

Oats grow best when the pH is in the range of 5.6-6.0, but they will tolerate acid soils to a pH of 4.5. If the pH is over 6.0, there is a possibility that zinc or manganese deficiency symptoms will appear.

Nitrogen (N)

Effective management of soil nitrogen reserve and additional inputs can be used to increase grain yield. Adding N may increase yield by increasing the number of heads and/or grains per head. Nitrogen requirements range from 55 kg N/ha at sowing for lower yields (<4 t/ha) to 80 kg N/ha (40 kg N/ha at sowing, 40 kg N/ha at tillering) for medium yields (6-7 t/ha), and split applications up to a total of 120 kg N/ha for high yields (8 t/ha).

Excessive N is uneconomic leading to increased lodging with resultant low test weights, increased screenings and harvest difficulties.

Phosphorus (P)

The optimum soil Olsen P range for high grain yields is 20. If the yield potential is lower, soil Olsen P levels of 15 are adequate. Maintenance requirements are 15-30kg P/ha/yr depending on yield and residue management.

Sulphur (S)

Maintain soil sulphate-S levels at 10-15 by applying 10-25 kg S/ha at planting.

Potassium (K)

Less K is required for oat grain than for other cereals, however a greater amount of K is accumulated in the straw. Maintain soil QTK levels at or above 4-6 with 10-20 kg K/ha/yr, or up to 250 kg K/ha/yr if crop residue is removed (see nutrient removal section, page 47 for examples).

Magnesium (Mg)

Mg QTK levels should be maintained at or above 8-10 by applying 20-30 kg Mg/ha/yr where necessary.

For more information read FAR Arable Extra No. 15 and FAR Arable Updates 'Cereals' No.178 & 181.

Maize

Maize can be divided into two main categories – grain (including sweetcorn) and silage. Maize (for grain) differs from many other crops in that it is often continually cropped in the same paddock for many years. The nutrient requirements of grain and silage are different – silage crops in particular remove more K and N because of the extra dry matter removal from the paddock. It is preferable that maize silage paddocks are rotated so that soil K depletion does not become excessive.

Nitrogen (N)

Nitrogen is the nutrient most required by maize crops. Nitrogen demands will vary with soil type, crop removal, climate, crop history, dairy effluent use, and potential yield. This leads to variation in requirements between regions. The following tables provide indicative nitrogen fertiliser requirements based on the given assumptions.

Maize grain crops

Assumptions: Long season hybrid, sown 20th October near Gisborne on a sandy silt loam (dryland), modelled using ***AmaizeN Lite***. The range of nitrogen rates for each yield bracket indicates variation across 'normal' to high rainfall seasons.

Background soil mineral-N	Indicative nitrogen fertiliser requirements (kg N/ha/yr)		
	Yield potential (t grain/ha)		
	Maize grain < 10	10-13	> 13
High (see below)	0	0	0-30
Medium	0	0-30	30-100
Low	60-85	85-210	120-230

Note: Nitrogen requirement covers both grain and stover growth

Background soil mineral-N to 60 cm depth may be explained as:

- **High** = 200 kg N/ha e.g. after two years white clover, or four or greater previous years in pasture
- **Medium** = 125 kg N/ha e.g. after one to three previous years in depletive crops, or a mild winter
- **Low** = 50 kg N/ha e.g. after four or greater previous years in depletive crops, or a very wet winter

Maize silage crops

Assumptions: Long season cultivar, sown 20th October near Te Awamutu on a clay loam (dryland), modelled using ***AmaizeN Lite***. The range of nitrogen rates for each yield bracket indicates variation across 'normal' to high rainfall seasons.

Background soil mineral-N	Indicative nitrogen fertiliser requirements (kg N/ha/yr)			
	Yield potential (t DM/ha)			
	Maize silage	< 18	18-22	>22
High (see pg 33)		0	0	0-80
Medium		0	0-50	50-160
Low		60-130	70-155	155-245

Where N requirements are high, split dressings will reduce the risk of leaching or volatilisation. A good portion of the N should be applied by planting (pre-spread and through the planter). For grain crops the balance should be side-dressed early, preferably no later than 50-60 days after planting. It is not advisable to use excessive N through the planter, even with placement of fertiliser away from the seed, as there is a risk of germination damage in dry conditions.

'AmaizeN Lite' (cofunded by MAF SFF, Fert Research, FAR & Environment Waikato) is available from FAR by phone on 03 325 6353.

Soil pH

Although maize can tolerate a reasonably wide pH range, the optimum is 5.6-6.2.

Phosphorus (P)

Grain maize trials within NZ rarely show an economic yield response to fertiliser P. However for grain crops continually grown on one area, economic yield responses to P occur when soil Olsen P levels are less than 10. Where soil Olsen P levels are >10, it is still beneficial to apply 20 kg P/ha as a starter to help plant establishment.

Where maize silage is grown in rotation with pasture, soil Olsen P levels should be 20-30. Maintenance requirements are 30-60 kg P/ha (allow about 4 kg P/tonne grain or 2 kg P/tonne silage). It is important to apply most P through the planter (the remainder can be applied before planting) as this places the fertiliser to the side and just below the seed. Avoid direct contact with the seed.

For more information read FAR Arable Update 'Maize' No. 23 & 40.

Sulphur (S)

Soil sulphate-S levels should be at least 6-10. However, maize may take up subsoil S so yield reduction at low soil sulphate-S levels does not always occur in many maize growing areas. Crop removal would normally be met by 10-25 kg S/ha/yr.

Potassium (K)

Grain maize trials within NZ rarely show an economic yield response to fertiliser K. On medium to high K reserve soils (TBK >1), responses are unlikely on grain crops unless QTK values fall below 4. On low K reserve soils (TBK <1) apply 50-100 kg K/ha, (split between pre-dressing and planting), although up to 120 kg K/ha may be required in some circumstances. K requirements for silage maize will be greater in some circumstances. K requirements for silage maize will be greater than for grain maize because of the dry matter removed from the paddock (e.g. 80-170 kg K/ha), some of which should be replaced immediately after crop removal.

For more information read FAR Arable Update 'Maize' No. 31

Magnesium (Mg)

Maize has a slight demand for Mg but this will normally be met by soil reserves. Maintain QTMg at 8-10 by applying 20-25 kg Mg/ha/yr.

Trace elements

New Zealand generally does not have widespread trace element problems. Maize may be prone to Zn, Mn and occasionally B deficiency especially if pH is excessive (>6.5). Maize grown on peats can also show Zn deficiency. Apply 3-5 kg zinc sulphate/ha (banded) or 5-10 kg/ha (broadcast). On soils with low B levels (usually light soils), where B may be advantageous in sweetcorn to maintain quality and maximize cob grain fill, broadcast fertiliser borate (pre-plant) at 10 kg/ha. Avoid seed contact with fertiliser when using B.

For more information see page 52.

Grass seed

While grasses respond well to fertiliser, responses are often masked by management considerations such as cultivar, grazing, use of plant growth regulators, irrigation, seed drying and harvest conditions. Yield potentials will also vary with season and location.

Nitrogen (N)

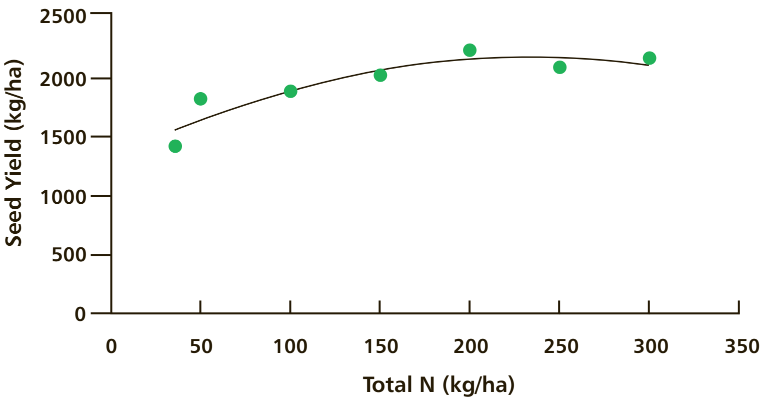
In recent years, new research has changed our understanding of nitrogen use by grass seed crops. Requirements for fertiliser nitrogen have been reduced. Consequently nitrogen programmes have changed markedly.

Grass growth is very responsive to N. Excessive, or poor timing of N will cause excessive vegetative bulk, increased disease susceptibility or lodging which reduce pollination and light interception.

Application rates for perennial ryegrass are based around the soil mineral-N level in late winter. Targets of 200 kg N/ha total N (soil + applied) are giving the best results when all factors are considered (seed yield, germinations and post harvest grazing). Second year perennial ryegrass crops may require up to 220 kg N/ha in total to encourage the older plants to out-compete the volunteer seedlings that may have struck since harvest.

For more information read FAR Arable Updates 'Herbage' No. 54 & 55.

Typical nitrogen rate response curve from FAR funded nitrogen rate response research.



Indicative nitrogen fertiliser programs for perennial and annual ryegrass.
Total 200 kg N/ha = applied N + soil mineral N.
(The table assumes 62 kg N/ha soil mineral-N in late August).

Crop	*Autumn N (kg N/ha)*		*Spring N (kg N/ha)*			
	First year Crop only	**Second or subsequent crop (post harvest)**	**Early Sept**	**Late Sept**	**Late Oct**	**Early/mid Nov**
Annual ryegrass	37	n.a.	46	46	46	0
Perennial ryegrass	37	55	0	46	46	46
Fescue	92	92	46	46	0	0
Browntop	37	46	0	46	46	46
Cocksfoot	37	46	46	46	46	0

Note: Autumn nitrogen is particularly for winter forage production and is not included in the recommended sum total of 200 kg N/ha total N. However autumn nitrogen is very important for tall fescue crops to promote autumn tillering.

Autumn N

- ***First year crops*** – although responses will vary with crop history, generally apply some N at planting to ensure vigorous establishment, especially if forage is required or the cultivar is a slower turf type. Annual ryegrass will respond more to autumn N than perennial ryegrass as it is more winter active. Add extra N if sowing is delayed.
- ***Post harvest N management*** – for second and subsequent crops, it is important to apply N after harvest (early autumn) to lift herbage N levels and to promote the reproductive tillers for the coming season. Encouraging crop cover at this stage may also encourage competition against volunteer ryegrass seedlings.

Spring N

- ***Early September*** – avoid early N on annual ryegrass as bulk tends to be generated. With perennial ryegrass delay application until GS30 (ear at 1cm). It is common to drip-feed light rates of N through early spring on tall fescue and later spring on browntop seed crops.
- ***Late September*** – Closing for perennial ryegrass is generally the third or fourth week of September. Ryegrasses usually receive their main application once livestock have been removed, then a further application 2-3 weeks later.
- ***Late October*** – Closing for annual ryegrasses is generally the third or fourth week of October. Apply one application at closing, then a further application 2-3 weeks later.

Grass seed often follows a depletive crop, but where grown following clover seed, N rates can be reduced, particularly in early spring. It is very important to measure readily plant available soil mineral-N in late-winter. Aim to control bulk, particularly prior to closing, and avoid very late N which can cause late tillering.
Closing of browntop is generally much later (October-November) with 50 kg N/ha applied each month from September to November inclusive.

pH

Grass will tolerate a lower pH than many crops, but should be generally limed for an optimum of 5.8-6.0. High soil pH (>6.2) may induce trace element deficiencies, particularly Mn and Zn in ryegrass (in Canterbury), and possibly Cu deficiency in cocksfoot.

Phosphorus (P)

On sedimentary soils, soil Olsen P levels should be 15-25. Annual maintenance requirements will be 20-30 kg P/ha but will vary according to the dry matter produced and whether the extra P demands caused by grazing or silage making need to be addressed.

Sulphur (S)

Ideally soil sulphate-S values should be at least 6-10. As grasses can extract S at depth, 15-20 kg S/ha applied at planting should be adequate. Adjust rates upwards if grazing or silage losses also need to be addressed.

Potassium (K)

For first year crops grown on high K reserve soils (TBK >1.5), the soil will normally supply sufficient K unless soil QTK levels fall below 6 (the optimum is 6-8). On medium K reserve (TBK 1-1.5) soils apply 20-30 kg K/ha/yr for maintenance and at least 50-60 kg K/ha/yr if QTK are below 1. Second year crops will have higher demands for K because of grazing, silage making and/or straw removed in the previous year's crop.

Magnesium (Mg)

Crop demands for Mg are not excessive and will normally be met by soil reserves.
If QTMg falls below 10, apply 20-25 kg Mg/ha at planting.

White clover seed

White clover seed crops have a limited requirement for applied fertiliser. In fact fertiliser application increases the risk of the crop becoming too vegetative, which shades stolons, reduces bud-set and reduces seed yield. Soil fertility at the lower end of most cropping situations is preferred for white clover seed production.

Nitrogen (N)

White clovers requirement for nitrogen is mostly satisfied by nitrogen fixation by root nodules. A poor establishment, late drilling or hard winter may warrant a low rate of nitrogen i.e. 30-50 kg/ha ammonium sulphate to be applied in late winter to encourage early spring growth and stolon run.

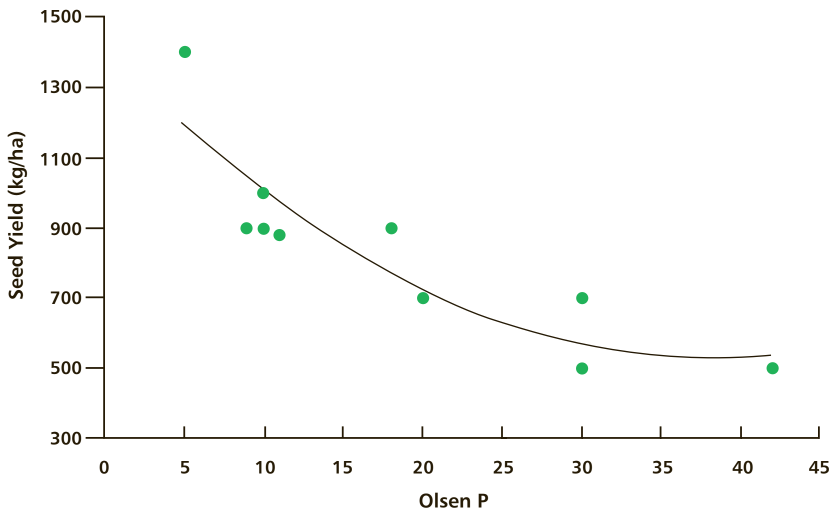
Soil pH

Nodulation and nitrogen fixation is maximised at pH 5.5-6.0. Boron deficiencies may be seen above pH 6.0 while molybdenum deficiencies may be seen below pH 6.0. pH higher than 6.0 may favour vegetative growth compared to reproductive growth, particularly at higher Olsen P values.

Phosphorus (P)

Olsen P of 10 is sufficient for establishment, assisting with root growth and N fixation. Increased available P increases vegetative growth. Olsen P above 15 can decrease seed yield due increased canopy size and stolon shading.

White clover seed yield response to Olsen P.



Sulphur (S)

Sulphur is important for white clover seed production. Sulphate-S soil values of 6 are required for general metabolism. In NZ, yield increases of 50% have been reported for application of 20 kg S/ha via gypsum. Apply sulphur in spring if soil values fall below 4. Deficiency can lower seed weights and photosynthetic capacity.

Potassium (K)

QTK levels of 4-8 are required to maintain photosynthetic activity and uptake of other nutrients. Increased available K increases vegetative growth, which can be detrimental to yield.

Boron (B)

Boron has been shown to increase pollen production resulting in more seeds per head. Boron is marginally deficient in some Canterbury soils. Boron deficiencies can be associated with low soil temperatures, or drought stress.

Molybdenum (Mo)

Molybdenum is required for nodulation and nitrogen fixation. Poor clover plants may result if nitrogen is not fixed due to molybdenum deficiency.

For more information read FAR Arable Update 'Herbage' No. 45.
For further reading: Clifford et al, 1990. 'Nutrient requirements for white clover seed production'. Journal of Applied Seed Production 8: 54-58.

Peas

These recommendations are for both field and garden pea cultivars.

Research throughout New Zealand has reiterated overseas research that peas will only respond to application of N, P or K fertiliser when soil fertility is very low. Consequently the practice of applying fertiliser to pea crops is often unnecessary and unprofitable. Commercial crops surveyed by FAR showed that fertiliser applied to peas consistently, but not significantly, reduced yield and emergence by an average of 6% and 11% respectively.

Nitrogen (N)

Although peas are legumes that can fix their own atmospheric N, the large amount of N removed when the crop is harvested (170 kg/ha in grain from a 5 t/ha yield) can be equal or greater than the amount fixed. When peas follow a high yielding cereal crop, some N may have to be applied. Only apply small amounts of N otherwise N fixation may be reduced by inhibiting nodule formation & function. In cold, wet conditions that limit N fixation, yield responses may be gained with low (10-30 kg/ha) rates of N. Some research around the world suggests that while an economic grain yield response to N may not occur, N fertiliser will promote vegetative growth that will increase vine yields for hay and encourage a more easily harvested upright crop. However a greater amount of both global and NZ research has shown no benefits for peas to nitrogen application or other macronutrients.

Soil pH

Optimal soil pH is 6.0-6.2. Lime should be applied 3-6 months before the crop is sown to maintain soil pH in this range.

Phosphorus (P)

Research shows there has been no yield responses measured above soil Olsen P 10. However if Olsen P is <10 then an economic response may occur, especially in crops with a high yield potential. Annual maintenance requirements are 12-20 kg P/ha depending on crop yield.

Sulphur (S)

Peas require S for the function of N fixation. Ideally soil sulphate-S levels should be 8-10 for optimum yield. These levels will be maintained with 15-20 kg S/ha/yr.

Potassium (K)

Research shows there have been no yield responses to applied potassium. However if QTK is <3 (i.e. severely depleted) then an economic response may occur, especially in crops with a high yield potential. Soil QTK levels should be maintained within or above the optimum 5-8. Where QKT levels are lower than this on soils with high TBK (>1.5), apply 15-30 kg K/ha, and on soils with medium TBK (1-1.5), apply 50-60 kg K/ha at planting.

Magnesium (Mg)

Peas have a low requirement for Mg. Mg is normally supplied from soil reserves, but if these are depleted with continual cropping apply 20-25 kg Mg/ha/yr to maintain soil MgQT levels at or above 8-10.

Molybdenum (Mo)

Peas require Mo for the proper functioning of the nodule bacteria. If Mo is required, based on leaf testing, it should be applied at 80-100 g/ha sodium molybdate every 4-5 years, during the pea phase of the rotation.

Boron (B)

Boron responses can occur particularly on light non-irrigated soils in drier seasons. Process crops are the most likely to respond. Apply 10 kg/ha/yr of fertiliser borate, pre-spread to avoid seed contact.

For more information read FAR Arable Update 'Pulses' No.6 & FAR Arable Extra No. 21.
For further information read 'Making Peas Pay' published by the Pea Industry Development Group (PIDG).

Brassica Seed Crops (including oilseed rape)

Nutrient requirements for green feed brassica crops are not included in this booklet. Examples of seed crops grown in New Zealand from the brassica family include: cabbage, kale, mustard, radish, rape (forage seed and oilseed), turnip, and swede. Small seeds such as brassicas are very prone to germination damage from fertiliser. In general broadcast basal fertiliser prior to planting unless the drill specifically separates seed from fertiliser.

The major nutrients removed by the crop are nitrogen and potassium. A 3.0 t/ha crop will remove 150 kg N/ha, 50 kg K/ha, and 20 kg P/ha. The canopy of a brassica crop must be large enough to intercept most of the available light, but not too thick which results in reduced yield.

Nitrogen (N)

Nitrogen builds leaf area and encourages branching which leads to a greater number of pods and seeds reaching maturity. A spring rapeseed crop accumulates 50-60 kg N for every tonne of seed produced. One tonne of harvested seed, with 42% oil and 38% protein in the meal, contains 35 kg N. The required rate is lower if restorative crops have been grown before oilseed rape is sown.

The main period of nitrogen uptake is when vigorous growth begins (early stem elongation/bolting) and when the crop is in late flower to pod set. The N to build the canopy must be applied early enough to allow the crop to take up most of it by flowering.

For spring crops high N rates should be split between sowing/early plant emergence and just prior to stem elongation. For autumn sown brassicas main nitrogen applications should be applied at bolting and yellow bud stage. If the crop is late sown, has poor establishment or is pest affected, autumn nitrogen may be required to encourage branching. Excessive N will reduce the oil extraction rate. For autumn sown brassica seed crops, the required N rates could be higher (120-200 kg N/ha) due to the longer period they are in the ground and the higher yield potential.

Soil pH

Brassica seed crops are relatively tolerant of a wide soil pH range but optimum is 5.8-6.3. Large applications of lime just prior to drilling may induce trace element deficiencies.

Phosphorus (P)

Brassicas are an efficient extractor of soil phosphate under moist conditions and can make use of residual soil phosphate, however a slight deficiency may restrict growth in the seedling and rosette stages. A soil Olsen P of 20-30 is required for optimum yields. Maintenance requirements are 20-40 kg P/ha/yr depending on yield.

Sulphur (S)

Brassica seed crops have a high S requirement. Sulphur deficiency may reduce yield and oil content. S should preferably be applied at 10-20 kg S/ha at sowing followed by another application in the mid vegetative stages e.g. 50 kg/ha ammonium sulphate. Soil sulphate-S levels of 10-15 are required for optimum yield.

Potassium (K)

On high K reserve soils (TBK > 1.5) apply 20-30 kg K/ha where QTK is 6 or below, and at least 50-60 kg K/ha on medium K reserve soils (TBK 1-1.5). Maintain soil QTK levels at or above the optimum 6-8 range with 20-30 kg K/ha/yr.

Boron (B)

Brassica seed crops are very sensitive to B deficiency. Boron deficiency can impair germination and retard early growth, causing rolled leaves which may be smaller than normal. Later there may be some distortion of the flowers and a poor seed set. Boron leaches readily on light soils so applications to previous crops may not be relied upon. B should be broadcast prior to sowing at 10-15 kg /ha borate fertiliser, to avoid contact with the seed.

Molybdenum (Mo)

Where soil pH is low (<5.7) or low leaf Mo levels are measured in the crop, apply 100 g/ha of sodium molybdate at planting or spray sodium molybdate with water on to the crop. Alternatively foliar fertiliser products are available which contain both boron and molybdenum.

Analyse leaves for boron, molybdenum, manganese and magnesium in spring and correct any shortfalls with foliar applications.

For more information read FAR Arable Extra No. 23.

Crop Nutrient Removal

The following figures can be used as a guideline for maintenance nutrient requirements provided the soil supply can be adequately estimated. If you wish to sustain the nutrient supply of your soil, then the amount of nutrient removed should be totally replaced. This will consist of all of the nutrient in grain and a portion of that in the straw depending on whether crop residues are baled, burnt or incorporated in the soil.

Typical nutrient removal by crops.

		Yield (t/ha)	N[1] (kg/ha)	P (kg/ha)	K (kg/ha)	S (kg/ha)
Wheat	Grain	5.0	87-118	17	22	7
(low yield)	Straw[2]	5.5	38	4	75	8
	Total		125-156	21	97	15
Wheat	Grain	12.0	240	40	53	17
(high yield)	Straw	10.0	69	8	135	13
	Total		309	48	188	30
Barley	Grain	5.0	100	20	35	5
(low yield)	Straw	4.5	21	2	64	6
	Total		121	22	99	11
Barley	Grain	8.0	160	32	56	8
(high yield)	Straw	5.5	25	2	79	8
	Total		185	34	135	16
Oats	Grain	7.0	112	21	35	14
	Straw	8.5	50	5	198	9
	Total		162	26	233	23
Maize	Grain	12.0	168	36	48	10
	Silage	21.0	273	63	210	13
Peas	Grain	5.0	170	19	47	10
Ryegrass	Seed	2.0	48	8	16	4
	Straw	8.0	90	9	122	12
	Total		138	17	138	16
White clover	Seed	1.0	52	6	13	2
Oilseed rape	Seed	2.0	74	15	15	13

1 Actual amounts of N in the grain will depend on the desired protein level.
2 Actual amounts of straw will vary with cultivar, sowing date and the use of a plant growth regulator.

For more information read FAR Arable Extra No. 16 & 36.

Soil pH and Lime Requirements

For optimal yield, all crops mentioned in this booklet require soil pH to be in the range 5.7-6.2. Ryegrass, oats and wheat can be at the lower end and barley and peas at the higher end of this range.

To elevate soil pH, a silt loam on average requires 1 tonne /ha of good quality lime (80% $CaCO_3$ equivalent), for each 0.1 unit increase. Clay soils will require greater amounts of lime to elevate soil pH. If the $CaCO_3$ content of the lime is less than this, a higher rate will be required.

The fineness of the lime will affect the speed of reaction with the soil and hence how quickly soil pH is increased.

Normally 2.5 t/ha of lime is required every 3-5 years to maintain soil pH. The frequency increases with greater rainfall, irrigation and use of N fertiliser.

Ideally lime should be applied 3-6 months before the crop is sown. Soil incorporation will speed up the reaction of lime with the soil.

Acidifying effects of N fertilisers

Least effect → Most effect	kg lime to neutralise 100 kg of fertiliser
Calcium ammonium nitrate	30
Diammonium phosphate	40
Urea	50
Ammonium sulphate nitrate	70
Ammonium sulphate	210

Forms and Types of Fertilisers

N Fertilisers (examples of fertilisers commonly used in arable cropping)

%	N	P	K	S	Form of N[1] (%) Nitrate	Ammonium
Urea	46	0	0	0		100
Ammonium Sulphate	21	0	0	24		100
Ammo 36	36	0	0	10		100
Calcium Ammonium Nitrate (CAN)	27	0	0	0	50	50
Diammonium Phosphate (DAP)	18	20	0	1		100
Monoammonium Phosphate (MAP)	11	22	0	1		100
Cropmaster 20	20	10	0	13		100
Cropmaster 15	15	10	10	8		100
Crop Zeal 15P	14	15	13	1		100
Crop Zeal 16N	16	8	10	10		100
Ravensdown 12-10-10	12	10	10	2	33	67

[1] Nitrate-N is more susceptible to leaching than Ammonium-N

P Fertilisers (refer also to N fertiliser list)

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

S fertilisers (refer also to N fertiliser list)

%	N	P	K	S	Mg	Ca
Superphosphate	0	9	0	11	0	20
Gypsum	0	0	0	18	0	23
Ammonium sulphate	21	0	0	24	0	0
Sulphur super 30	0	7	0	30	0	16
Maxi sulphur super (South Island only)	0	5	0	47	0	11

K fertilisers (refer also to N fertiliser list)

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

Mg fertilisers

%	Mg	S	Liming value	Availability
Magnesium oxide	50-55	0	√	Moderate
Dolomite	11	0	√	Moderate
Kieserite	16	22		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, blood etc.
- although these have similar ratings to other fertilisers (e.g. 10-4-5-0), dilution before application means that actual amounts of nutrients applied are very low, and as such should only be used to complement solid fertilisers.
- however liquid fertilisers may have a place in meeting the short term requirements of a crop and where adverse weather conditions make solid fertiliser applications inefficient.
- trace element sprays can be effective ways of overcoming deficiencies, especially those linked to soil conditions such as dry soils and high pH. Ideally sprays should be used in the early vegetative stage.

Calculating fertiliser application rates

The N-P-K-S rating indicates the percentage amount of plant nutrients in a particular fertiliser. For example Cropmaster 15 is rated as 15-10-10-8 and so contains 15% N, 10% P, 10% K, 8% S.

To calculate the quantity of fertiliser needed to apply a given rate of nutrient, the following formula can be used:

$$\text{Rate of fertiliser application (kg/ha)} = \frac{\text{rate desired for nutrient (kg/ha)} \times 100}{\text{nutrient in fertiliser (\%)}}$$

Example: A Canterbury cropping farm requires an application of 30 kg N/ha, 20 kg P/ha, 20 kg K/ha and 16 kg S/ha. What rate of Cropmaster 15 (15-10-10-8) should be applied?

N : rate of fertiliser $= \frac{30 \times 100}{15} = 200$ kg/ha

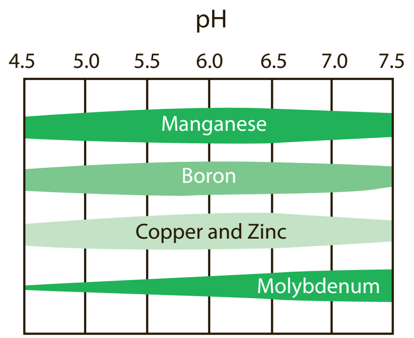
P : rate of fertiliser $= \frac{20 \times 100}{10} = 200$ kg/ha

K : rate of fertiliser $= \frac{20 \times 100}{10} = 200$ kg/ha

S : rate of fertiliser $= \frac{16 \times 100}{8} = 200$ kg/ha

Trace Elements

Trace element deficiencies are diagnosed by observing plant symptoms, reinforced by plant and soil analysis. To correct any deficiency only small amounts of trace elements in fertiliser are required. Excess applications of one trace element can reduce the availability of another. This is true for iron (Fe), manganese (Mn), zinc (Zn), or copper (Cu).



Available nutrients in relation to pH

Although rarely found, possible trace element deficiencies in arable crops include:

- Mn deficiency in cereals is characterised by very pale-green or yellow plants often with a wilted appearance. Specks develop between the leaf veins. These are brown in barley, white in wheat, and grey in oats. When it does occur it is sometimes due to high soil pH (>6.5) caused by over liming. Mn deficiency occurs mainly on terraces near the major Canterbury rivers, particularly in dry seasons. To correct spray 8-10 kg $MnSO_4$ in 200 L water/ha.
- Cu deficiency in cereals is characterised by leaf tips becoming white, narrow and twisted (wither tip) and, in extreme cases, failure of grain development causing "blind ear". There is general plant ill-health and lack of vigour. Cu deficiency can occur on light well drained soils or peats. If required use 1 or 2 sprays of 0.5 kg $CuSO_4$ in 200 L water/ha, 10 days apart.
- Zn deficiency symptoms are similar to those of Mn and are usually associated with high soil pH (>6.5) in cereals and grass seed crops. If required, spray 3-10 kg $ZnSO_4$ in 200 L water/ha. Raw peats have naturally low levels of soil Zn.

- Mo deficiency in peas causes plants to become pale green and stunted. It is most common at soil pH below 5.5 and is normally corrected by applying sodium molybdate (40% Mo) at 80-100 g/ha at planting.
- B deficiency causes red tingeing of the leaves (legumes) or general leaf paleness or brown leaves (brassicas). It is more common on light, sandy soils, particularly in dry seasons. Normally apply 5-15 kg/ha of fertiliser borate prior to planting depending on crop type and rainfall or if symptoms persist boron sprays may be effective.

Note that a range of foliar fertiliser products are now available, so the above suggestions are not exhaustive.

For more information read FAR Arable Extra No. 4.

Seedling Establishment

Placing fertiliser too close to germinating seeds can reduce seedling emergence. Germination injury is caused by ammonia release from N fertilisers or the osmotic (salt) effect of a fertiliser. Maximum damage from seed and fertiliser in close proximity occurs on soils with moderate moisture. In this situation there is sufficient moisture to commence fertiliser dissolution and seed swelling but insufficient to disperse and dilute the fertiliser through a larger soil volume. Ideally with at risk crops seed and fertiliser should be drilled or banded so that they are placed at least 2-5 cm apart.

In general the smaller the seed, the greater the likelihood of injury. The most likely order in terms of proneness to injury is brassicas (including oilseed rape), clover, peas, grasses, cereals, and oats. Avoid banding with maize planters.

Fertiliser rankings according to risk are shown below:

Least risk

↓

Serpentine super, dicalcic superphosphate, lime reverted superphosphate
Superphosphate
Nitrophoska and Hydro range, potassium chloride
Monoammonium phosphate
Diammonium phosphate, Cropmaster 15
Cropmaster 20, ammonium sulphate
Urea, boron fertilisers

↓

Most risk

General recommendations:

- Do not sow more than 20 kg N/ha as urea with the seed. For other N fertilisers sow no more than 30-50 kg N/ha with the seed.
- Use reverted superphosphates with small seed crops (e.g. clover, brassicas).
- Broadcast fertiliser before drilling if high N rates are used at planting.

For more information read FAR Arable Extra No. 13.

Code of Practice for Nutrient Management

Farmers are natural managers of environmental resources. The land is their livelihood, and like all good business people protecting their asset (in this case the land from deterioration) is fundamental to their future wellbeing.

To assist farmers with safe, responsible and efficient use of fertilisers, Fert Research developed a **Code of Practice for Nutrient Management**. It provides practical advice to farmers on the overall processes for effective nutrient management and Best Management Practices for the most efficient use of nutrients. It helps farmers and land owners achieve their production goals.

The code does not contain prescriptive practices (or "rules" about use), but focuses on outcomes. As such it provides flexibility and allows for site specific solutions.

Using the code will assist farmers in meeting their responsibilities under the Resources Management Act.

Some of the more significant environmental considerations the code focuses on are:

- Determining the land's requirements for nutrients.
- Nitrate leaching to ground water.
- Surface water contamination from fertiliser runoff.
- Contamination of surface water from direct application
- Potential effects on third parties.

Among the general considerations needed to be taken into account are:

Determining the land's needs for nutrients

- Apply fertiliser to achieve an identified response or objective (not as a "routine" procedure).
- Prepare a Nutrient Budget and operate a Nutrient Management Plan in consultation with your farm or fertiliser nutrient management adviser.
- Test soil, and plant and animal tissue.
- Have a working understanding of the principles underlying fertiliser use.
- Use the Code of Practice for Nutrient Management and the Fact Sheets included.

Nitrate leaching to groundwater

- Match nitrogen application to plant requirements and rate of uptake.
- Split fertiliser applications, applying smaller amounts more often.
- Avoid application if heavy rain is forecast or if the ground is saturated.

Surface water contamination through run off

- Split fertiliser applications, applying smaller amounts more often.
- Avoid application if heavy rain is forecast or if the ground is saturated.
- Set realistic growth rate targets, and match application to requirements.
- Be fastidious about accurate application.
- On steep slopes (say >15°) or where natural drainage runs toward open water, consider establishing riparian strips and extend the buffer zone between water and application site.
- Ensure pasture/crop is 25 mm high (or 1000 kg DM/ha) at time of application. For pastoral situations seek to achieve at least 80% ground cover at time of application. For horticulture and arable situations apply an appropriate amount for plant requirements e.g. young plants require different amounts to mature plants.

Contamination of surface water from direct application

- When windy (anything greater than 5 kph) apply when it is blowing away from open water.
- Be fastidious about accurate and uniform application, and containing fertiliser to application zone.
- Use fertiliser with larger particle sizes (particles of less than 1mm have poor ballistic properties).
- Establish a riparian strip or allow for a realistic buffer zone.

Third party effects

- Consider noise implications, and choose appropriate time.
- Consider sensitive times and places (for example schools, or neighbour practicing organic farming) and choose appropriate time and application techniques.
- Winds above 5 kph can create wind drift. So consider particle size and application method.
- Be fastidious about accurate application.
- Be neighbourly and tell others in advance, and of changes to plans.

The *Code of Practice for Nutrient Management* replaces the *Code of Practice for Fertiliser Use*.
It highlights some key considerations, and farmers are advised to refer to the Code for more detailed information.

For more information on the Code and for the series of Fact Sheets relating to the Code, visit
www.fertresearch.org.nz

Nutrient Management Plans & Nutrient Budgeting

A nutrient management plan (NMP) is a written plan that describes how the major plant nutrients (nitrogen, phosphorus, sulphur and potassium, and any others of importance to specialist crops) will be managed annually on a particular area or property. This plan will be implemented to optimise productivity, to reduce nutrient losses and to avoid, remedy or mitigate adverse effects on the environment. It is recommended that advice is sought from a trained and accredited nutrient management adviser, for the development of the Nutrient Management Plans and Nutrient Budgets.

A good NMP:

- ensures that nutrient management meets all legal and industry requirements
- includes a nutrient budget which compares nutrient inputs from all sources with all nutrient outputs
- achieves desired changes in nutrient levels and production (e.g. increasing soil fertility from a poor base to maintain or improve production capacity; altering soil nutrient status to suit future crops)
- minimises the cost of supplying nutrients and avoids wasteful spending on unnecessary or unused nutrients
- promotes efficient and effective nutrient use
- minimises the risk of adverse environmental effects, and
- considers the land manager's personal objectives.

A sample NMP template is available at
www.fertresearch.org.nz/code-of-practice/appendices/nutrient-management-plan-template-and-user-guide

A Nutrient Budget compares overall nutrient inputs to nutrient outputs for a given level of production. It helps to identify production or environmental issues arising from nutrient excesses or deficiencies, and is therefore a useful way to evaluate a nutrient recommendation and make adjustments before it is implemented.
Nutrient input sources could include those:

- supplied through breakdown of organic matter (including post-harvest crop residues, applied compost or naturally occurring organic matter) and continued weathering of soil materials
- applied as fertiliser
- deposited in urine and dung
- returned through the irrigation of dairy effluent
- added through the importing of supplementary feed
- nitrogen fixed from the atmosphere by clovers and other legumes
- deposited aerially

Nutrient outputs could include:

- nutrients taken off in products (e.g. fruit, vegetables, grain, logs, meat, wool, milk)
- crop residues removed from the paddock e.g. baled or burnt on site
- losses through erosion, leaching, surface flow or return to the atmosphere
- hay and silage sold off farm
- transfers by livestock to unproductive areas (e.g. raceways, stock camps)

Nutrients are essential for healthy plant and animal production, and deliberate nutrient inputs are often required to enhance productivity and address animal health issues. However, poor nutrient management can lead to consequences that are highly undesirable, environmentally, socially and economically. Implementing nutrient management planning will help land managers to maximise the efficiency of their use of nutrients, which will in turn avoid or minimise adverse environmental impacts and increase overall production efficiency.

OVERSEER® Nutrient Budgets Model

OVERSEER® is a computerised nutrient budget model which supports decision making on farms and is jointly owned and managed by Fert Research, AgResearch and MAF. It has been developed using detailed research on farming systems under New Zealand conditions and is a valuable tool for producing nutrient budgets and developing nutrient management plans.

Overseer uses readily available farm system information to estimate nutrient budgets based on long term annual averages. A nutrient budget is a summary of all nutrient inputs and outputs from a farm or block within a farm. Within the programme there are three separate models; pastoral, arable or vegetable and fruit crops.

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

Overseer provides a means to examine the impact of nutrient use and nutrient cycling within a farm (as fertiliser, effluent, supplements or transfer by animals) on nutrient use efficiency and possible environmental effects. The model also provides for evaluating different scenarios and investigating mitigation options to reduce the environmental impact of nutrients within a land use.

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

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

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

For more information ***visit http://www.agresearch.co.nz/overseerweb/*** or ***www.fertresearch.org.nz***

Spreadmark and Fertmark

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

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

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

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

Spreadmark: ***Ground spreading***

The Spreadmark programme was established by the NZ Ground Spread Fertilisers Association in 1992. It was subsequently expanded to a group with representatives from Federated Farmers, the NZGFA, fertiliser companies and Fert Research, and came under the Fertiliser Quality Council in 2002.

It has as its objective the placement of fertilisers in locations where they can be of the most agricultural benefit and the least environmental harm. The scheme registers spreading companies provided they have certified spreading machinery that can operate with accuracy within defined bout widths, trained operators and an appropriate quality management system which ensures that farmer/land manager requirements are met and environmental sustainability is protected. Overall systems are subject to an independent audit.

Spreadmark: ***Aerial Application***

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

Proof of placement :

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

For more information refer to: Code of Practice for Nutrient Management - Fact sheet 4, 2007 www.fertresearch.org.nz/code-of-practice/fact-sheets or Fertiliser Quality Council www.fertqual.co.nz

Ask for Fertmark registered fertilisers spread by Spreadmark accredited operators.

Nitrate Leaching

Leaching of nitrate-N from the soil is important as it represents both an economic loss to the farmer and a threat to the environment through ground water contamination. Nitrate leaching occurs if there is excess nitrate-N (above crop requirements) released from the breakdown of soil organic matter, or fertiliser N in the soil, when drainage occurs following rainfall or irrigation. Significant drainage and therefore nitrate-N leaching usually occurs between late autumn and early spring.

How to minimise nitrate leaching

Cultivation

- minimise the time between harvest and establishment of the next crop so that there is only a short fallow period.
- avoid winter fallow, particularly after pasture or clover seed.
- minimise depth and extent of cultivation to reduce breakdown of organic matter. Direct drilling or minimal tillage will reduce this.
- plough as late as possible (late April to May) as lower soil temperatures slow the rate of soil biological conversion of organic N to nitrate-N.

Sowing

- sow autumn crops early to maximise production, absorb nitrate-N, and minimise drainage through greater transpiration.

Fertiliser N application

- apply as little N fertiliser as possible in autumn and winter, and no more than the crop can utilise at that time.
- split N fertiliser applications to match plant N requirements with soil N supply.
- avoid excess irrigation soon after the application of N fertiliser.
- if soil temperature is low, apply low rates of N.

For more information read FAR Arable Extra No. 17 and the 'Code of Practice for Nutrient Management' (Fert Research).

Crop Calculators

Sirius Wheat Calculator (SWC)

Used as a decision support tool, the Sirius Wheat Calculator optimises nitrogen and irrigation strategies to maximise yields. It can produce irrigation and N fertiliser schedules, provide application timing information and can also predict N leaching.

The SWC software allows a farmer to input a wide range of variables such as expected seasonal weather conditions, cultivars used, sowing dates, water availability and nitrogen availability.

The calculator forecasts yield and quality parameters as well as providing the ability to ask "what if" questions so that the program can accurately simulate yield in a wide variety of conditions.

The SWC was developed by Crop & Food Research and funded by Ballance Agri-Nutrients, FAR and MAF Sustainable Farming Fund.

CD-ROM copies of the SWC and weather station update files are available from the FAR office, phone 03 325 6353

AmaizeN Maize Calculator

AmaizeN Lite is a yield and nitrogen-fertiliser forecaster designed to help maize growers maximise return from fertiliser inputs as well as meet regulatory requirements.

Growers enter crop and soil details and ***AmaizeN Lite*** calculates the most economic N fertiliser applications for their crops based on average weather conditions. Actual weather data for 2002 through to 2007 is included meaning growers can compare ***AmaizeN Lite*** with their actual yields. Recent weather data updates are available.

Nitrogen fertiliser requirements are calculated by a soil N model, which takes into account the potential yield of the crop as well as the existing soil N pool and that which will be released during the season. This allows growers to use the supply of 'free' soil nitrogen before paying for fertiliser N.

Importantly, the forecaster not only predicts when growers can save money by not applying fertiliser, it has also highlighted where specific crops may require more N than the grower initially thought, translating into a yield benefit. ***AmaizeN Lite*** will also produce a nutrient report to satisfy local regulatory requirements.

AmaizeN Lite was developed by Crop & Food Research and funded by FAR, Fert Research, MAF Sustainable Farming Fund and Environment Waikato.

CD-ROM copies of AmaizeN Lite and weather station update files are available from the FAR office, phone 03 325 6353.

MANAGING SOIL FERTILITY ON CROPPING FARMS
First printed 1998
Revised June 2009
Reprinted 2012

Fert Research