CHAPTER 3

NUTRIENT MANAGEMENT

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3.0 NUTRIENT MANAGEMENT

Sustainable dairy farming is based on optimising soil fertility to grow high quality feed, and then using that feed efficiently in the production of saleable products. Nutrient management is a fundamental pillar of the farm system.

To achieve efficient production, soil fertility must be monitored and the results of that monitoring correctly interpreted. This information forms the basis of sound fertiliser decisions.

Nitrogen is the nutrient required in greatest quantities by pastoral systems, and the size of the N pool drives the growth of high quality forage for animal production.

Clover is an important source of N, as the bacteria in clover roots 'fix' atmospheric N and make it available to plants. On most New Zealand dairy farms, clover supplies a large part of the N requirement – between 50 and 250kg N/ha/yr. The precise amount depends on soil fertility, soil moisture, temperature, the proportion of clover in the sward, shading of the clover, and presence of clover pests.

Nitrogen fixed by clover is returned to the soil after grazing (in dung and urine) or as the clover dies and decays. This N boosts the grasses in the pasture and activates microbial activity in the soil. Applied fertiliser should aim to encourage this fixation of N and its transfer to grasses, to maximise pasture production at least cost. While nitrogen fixation by clover is an important basis for soil fertility, N fertiliser can be used strategically to boost feed production directly in anticipation of a future deficit. However, as applied N increases, clover content and N fixation declines.

Many New Zealand soils are naturally low in P, S and to a lesser extent K, and sometimes in trace elements. Deficiencies can be addressed using appropriate fertiliser.

Over time, removal of product and the nitrification cycle in the soil will create soil acidity. Lime is used to counteract this effect and maintain soil pH at an appropriate level for pasture and clover growth.

Nutrient losses should be minimised as they represent inefficient use of resources, and can have environmental impacts. Emphasis is being placed on nutrient management by both regulatory bodies and the dairy and fertiliser industries as a key to responsible farming.

Nutrient budgeting as part of a nutrient management plan, provides a means of comparing nutrient inputs and outputs from the farm system and thereby achieving the correct level of fertiliser and selecting management techniques for best nutrient use.

The Dairy Industry Strategy for Sustainable Environmental Management identifies nutrient losses to waterways as a key priority issue, and incorporates the Dairying and Clean Streams Accord target to have systems to manage nutrient inputs and outputs in place on 100% of dairy farms by 2007.

An overall nutrient management plan will help bring together all of the necessary information and plan appropriate actions for the farm, based on an analysis of property goals and risks. This will include:

- Core property details (area, stocking, etc)
- Targets for production and nutrient management objectives
- Specific industry and regional requirements (e.g. nitrogen loading for effluent areas)
- Farm resource factors (e.g. soil types, mole and tile drains)
- Farm nutrient status and fertiliser history
- Nutrient budget and analysis
- Recommended fertiliser programme
- Management practices

These steps are described in the Dexcel publication "Making Dollars and Sense Out of Nutrient Management" and the Fert Research publication "Code of Practice for Nutrient Management (With Special Emphasis on Fertiliser Use)" (an updated version of the Code of Practice for Fertiliser Use).

Both of these publications provide detailed information on all aspects of nutrient management planning.

3.1 NUTRIENT EFFICIENCY

The goal of nutrient use should be to maximise the efficiency with which applied and available nutrients are converted to product.

This means keeping nutrients where possible within the farm system (avoiding transfer to unproductive areas, waterways or the air) and within the rooting zone where they can be used by plants. Where nutrients become concentrated such as in the farm dairy, stand-off areas and feed pads, efficient use is achieved by collecting the effluent and spreading it back onto productive land.

Nutrients brought into the system as fertiliser or supplement should be well matched to the needs of the soil, pasture and animals to ensure efficient use.

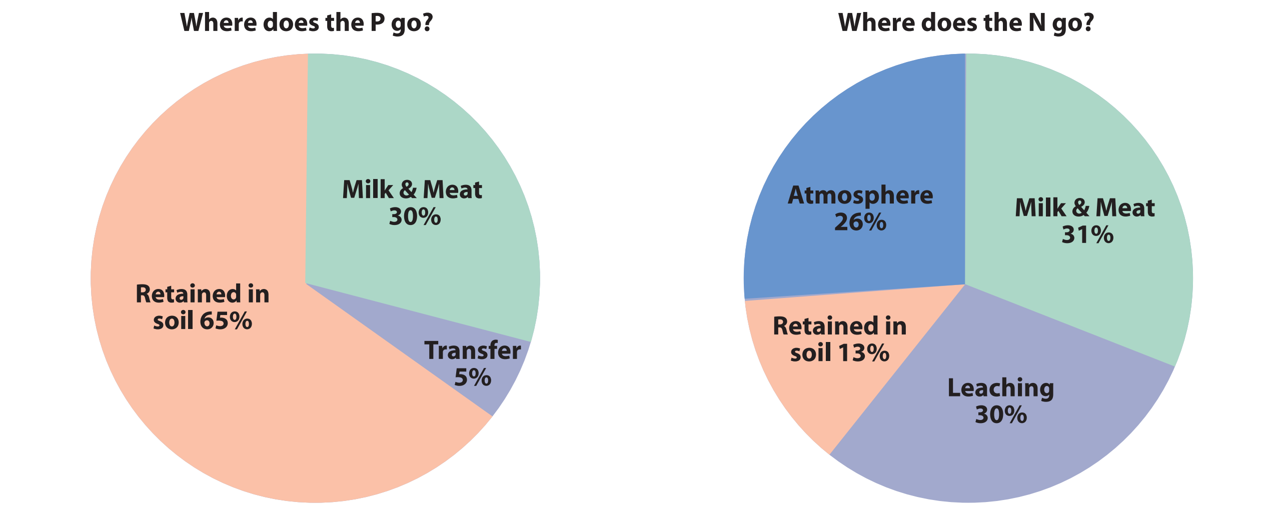
Efficiency of nutrient use not only makes economic sense, but it avoids polluting surface waterways and groundwater, and releasing greenhouse gases.

3.1.1 Nutrient pathways

Nutrients behave differently in the soil and farm system. Some (e.g. P) are less mobile and will be retained in the soil. Loss of P is most likely to occur bound to eroded soil particles or dung in overland runoff. N has varying forms. As nitrate, N is soluble and likely to be lost if soil water drains below the plant root zone (leaching). In its ammonia form, N is volatile and is lost as gas to the atmosphere. As nitrous oxide released from urine patches and fertiliser, N will be lost to the atmosphere where it contributes to the greenhouse effect. Figure 3.1-1 shows where N and P in the farm system end up.

FIGURE 3.1-1

FATE OF N AND P IN A TYPICAL FARM SYSTEM



Adapted from Getting Smart with Nutrients (NZ Farm Environment Award Trust)

3.1.2 Avoiding losses

P loss to waterways is mainly through overland runoff of sediment and dung, subsurface drainage flow (e.g. mole or tile drains), and streambank erosion. Table 3.1-1 shows some strategies to minimise this.

TABLE 3.1-1

REDUCING P LOSSES FROM THE FARM SYSTEM

Farm focus	Strategies	Refer to
Soil and run-off management	Reduce pugging, bare soil, and erosion, especially near waterways	Chapter 2
Soil fertility management	Do not exceed optimum levels of Olsen P for your farm – the higher the soil P, the more P is lost attached to soil	3.4.2.1 Increasing soil P
Fertiliser application	Avoid application to water and to steep soils near water, or when heavy rainfall is expected	3.5.3 Fertiliser spreading
Effluent and silage management	Apply effluent in dry conditions over sufficient area, at low application rates Collect effluent from feed pads/ stand-off areas and treat appropriately Site silage pits away from water, collect runoff	Managing Farm Dairy Effluent (DEC Manual)
Races and bridges	Use borders, berms and cut-offs to channel runoff away from waterways	6.5 Waterway crossings
Waterways and drains	Keep stock out of waterways Leave an ungrazed filter near waterways and in seeps and wet areas to trap runoff Plant up stream banks to reduce slumping Keep drains vegetated where feasible and spread material from drains onto paddocks	4.1 Managing waterways

Adapted from Making Dollars and Sense Out of Nutrient Management (Dexcel 2006) and Getting Smart with Nutrients (NZ Farm Environment Award Trust)

To reduce the concentration of P lost when soil particles are washed off paddocks, soil P should not be raised above optimum levels. Increasing Olsen P above 30 on ash and sedimentary soils, or above 45 on pumice and peat soils, is not generally economic. However a small economic response can be achieved on farms with exceptional pasture management. These farms generally have a comparative stocking rate above 80 kg/Lwt/tDM (refer to 2.5.1.2 Comparative stocking rate), excellent surplus mangement and good wet weather mangement to achieve pasture utilisation of around 80%. They will generally be in the top 25% of their area for pasture eaten per ha.

Research on farms in the Waikato with soil Olsen P tests that were above 30 showed P fertiliser being applied at a range of rates, including up to 150 kg P/ha/yr. When compared with maintenance requirements averaging 40-60 kg/ha/yr, this clearly represents an inefficient use of resources on some farms.

N loss is mostly through leaching from urine patches. This makes it hard to manage N in a grazing system. However, if it is leached through the soil profile and resurfaces at a seep or wetland, microbes can effectively remove high proportions of N from this water (upwards of 90%), releasing it back to the atmosphere through denitrification. This requires healthy wetland vegetation and adequate wetland area to maximise the residence time of water in the wetland system.

Another option is to slow the nitrification process in the soil and retain N as ammonia, a less mobile form than nitrate (refer to 3.3.3 Nitrification and urease inhibitors). This has the advantages of retaining N in the soil for later pasture uptake and avoiding the loss of nitrous oxide (a greenhouse gas).

N loss can also be manipulated through different feed – for example, maize contains about one third of the N of an N-boosted pasture and the N in maize is more efficiently utilised by cows.

Table 3.1-2 shows some changes to the farm system that can potentially reduce leaching, along with important considerations for each of these options.

TABLE 3.1-2

REDUCING N LOSSES THROUGH LEACHING		
Farm focus	**Strategies and considerations**	**Refer to**
Winter grazing management	On-off grazing or wintering off reduce N deposits in paddocks Off-farm grazing may reduce leaching on the home block but increase it on the run-off block	2.1.1.1 Winter grazing management
Supplements with lower N content (e.g. maize)	Supplements are energy-intensive and costly to produce and transport. High rates of supplements may result in more cows per hectare and/or increase the overall amount of N in the system	5.2 Energy efficiency; 6.6 Stand-off pads and feed pads
Nitrification inhibitors	N conversion to nitrate is slowed and N is instead retained in forms that do not readily leach More pasture can potentially be produced from N retained in soil N effectively recycled through the system	3.3.3 Nitrification and urease inhibitors
Wetlands and drains to process N in soil water	Retain and fence natural wetlands and seeps Open drains act as wetlands for N removal if vegetation is left in the drain Consider constructing wetlands at drain discharge points to remove N before it reaches waterways	4.2.2 Retaining and managing wetlands; 4.1.4 Drain management
Effluent and leachate management	Apply farm dairy effluent in line with best practice Collect and properly treat all effluent from pads/ stand-off areas/ silage pits so they do not become leaching 'hotspots'	Managing Farm Dairy Effluent (DEC manual)
N fertiliser use	Plan the timing and rates of application to minimise the risk of leaching	3.3 Nitrogen fertiliser
Cropping practices	Retain crop stubble or residues and/or plant cover crops after harvest for nitrogen uptake Practice direct drilling rather than cultivating soils Feed crop on a pad rather than grazing in-situ	2.3.3 Cropping; 2.1.1.3 On-off grazing

Adapted from Making Dollars and Sense Out of Nutrient Management (Dexcel 2006) and Getting Smart with Nutrients (NZ Farm Environment Award Trust)

3.1.3 Nutrient budgeting

A nutrient budget compares nutrient inputs and outputs on a farm, or part of a farm. While the soil test results are like a 'bank balance' of available nutrients, nutrient budgets, like financial budgets, give an estimation of what is coming in and what is coming out over a certain period. This indicates how the 'bank balance' is likely to change and what action may be needed to achieve the right balance. A surplus in the balance may represent the potential for unnecessarily high soil fertility levels, or nutrients available to be lost in the form of runoff from the pasture or leaching through the soil. Your fertiliser recommendation from a sales representative should take into account both the soil test results and the nutrient budget.

Current soil reserves may have added inputs (i.e. fertilisers, effluent or N fixation by clover). Feed supplements brought onto the farm are another form of nutrient input – for example, 1 tonne of maize silage contains about 12 kg N, 2 kg P, 10 kg K and 2 kg S. Nutrient outputs from the soil reserves leave in the form of milk and supplements cut and transported off the farm.

The purpose of nutrient budgeting is to identify excessive inputs of particular nutrients (i.e. over and above plant requirements) that may cause environmental impacts or inefficiencies in the farm system. It also helps assess different options to increase efficiency and avoid losses, by predicting the results of different nutrient scenarios (e.g. reducing N fertiliser, using a stand-off pad, etc).

Nutrient budgeting is supported by the Dairy Industry as a useful practice for dairy farmers. New Zealand researchers have developed a programme called OVERSEER® that can be used to produce nutrient budgets for individual farms. This, and other computer modelling based packages (including NPLAS, SPASMO etc), are inevitably based on a large number of assumptions. Accurate information must be fed into these models to reduce the margin of error in the results. However, as a voluntary farm management tool, they can provide useful guidance to farmers, when interpreted with good expert advice. A very simple nutrient budget model is also available in the New Zealand Farm Environment Award Trust publication "Getting Smart with Nutrients" available from the MAF website www.maf.govt.nz or from the Trust at info@nzfeatrust.org.nz .

The OVERSEER® programme is available from fertiliser representatives, or it can be downloaded directly from the internet at www.agresearch.co.nz/overseerweb

The relevant inputs and outputs that the model works with are in Table 3.1-3

TABLE 3.1-3

NUTRIENT INPUTS AND OUTPUTS IN THE OVERSEER® MODEL

Nutrient Inputs	Description
Fertiliser	Nutrients in fertiliser applied
Effluent added	Nutrients in effluent added to paddock as spray or as slurry
Atmosphere	Nutrients added in rainfall and N fixed by clover in pasture
Irrigation	Nutrients added in irrigation water
Slow release	Nutrients released from soil minerals into the plant-available nutrient pool
Supplements brought in	Nutrients in supplements brought onto the farm
Nutrient Outputs	**Description**
Product	Net amount of nutrients removed in meat, milk and fibre
Transfer	Movement of nutrients from productive to unproductive parts of the farm (e.g. races, stock camps)
Supplements removed	Nutrients in supplements removed from the block or sold off the farm
Atmospheric loss	Loss of N to the atmosphere by ammonia volatilisation and denitrification
Leaching and runoff	Nutrients lost to ground (below rooting zone) or surface water
Immobilisation/ absorption	Net immobilisation of N, P or S in soil organic matter, or absorption of P into slowly available forms in the soil
Change in inorganic soil pool	Change in inorganic soil pools is reflected in changes in soil test values

The soil information used by the programme includes:

- Soil test results: Olsen P, QT cations, Organic S, TBK reserve test, Anion Storage Capacity (ASC), pH, Carbon %
- Soil characteristics: clay % and field bulk density.

Default values can be used where farm-specific information is not required, based on soil type or a related value (e.g. organic-S may be estimated from sulphate-S).

Other data is entered related to:

- farm or block area, location, topography and rainfall
- soil type, drainage and development status
- stocking rates and breed
- fertiliser and effluent application method
- supplements brought in
- winter grazing management
- production exported as milk, meat or supplement sold off the farm or fed off the block in question.

From this information, the model produces a series of reports that help interpret the nutrient budget results. These can include reports for N, P, greenhouse gases, and energy.

3.1.3.1 Interpreting nutrient budget results

Nutrient budget results are best interpreted with expert advice. Data should be considered on a case-by-case basis. The commonly used nutrient budgeting models provide estimates of actual losses of N and P to waterways and provide links for interpretation and information on a range of management and irrigation practices.

As a key tool to help maximise efficiency of applied nutrients, the nutrient budget should be discussed with a specialist to identify the best actions to take within a given farm system.

3.2 MONITORING NUTRIENT STATUS

Soil fertility should be monitored regularly. Soils in a development phase receiving capital fertiliser or in a sub-maintenance phase where fertility is being mined, should be tested annually. Once maintenance status is reached, the soil should be analysed every 2-3 years.

Results should be recorded and graphed to establish trends and fertiliser inputs adjusted accordingly. Figure 3.2-1 shows a record keeping sheet where records can be kept of soil nutrient tests, plant or tissue analysis and fertiliser application.

FIGURE 3.2-1

SAMPLE RECORD KEEPING SHEET FOR FERTILITY MONITORING

Soil nutrient tests

Nutrient	Date	Location	Result	Comment
N				
P				
K				
S				
Mg				
Ca				
Trace lements				
Other				(CEC, AEC...)

Plant / tissue analysis

Nutrient	Date sampled	Location	Crop & stage of growth	Result

Fertiliser application

Fertiliser type (HPK S... Plus trace elements)	Date applied	Location and area (ha)	Rate / ha	Comment (Crop, application method, environmental CV%...)

Source: Code of Practice for Fertiliser Use, 2002

It is useful to calibrate soil tests against pasture growth to gain an understanding of the relationship between soil fertility and pasture production.

The following soil tests are available from most commercial laboratories:

- pH, a measure of soil acidity and therefore lime requirements
- Olsen P, a measure of plant-available P
- Ca, Mg, K and Na, a measure of plant-available cations
- Sulphate-S, a measure of plant-available S
- Organic-S, a measure of the long-term supply of S
- Anion Storage Capacity (ASC), a measure of the capacity of a soil to store negatively-charged nutrients such as P and S (also known as Phosphate Retention)
- Cation Exchange Capacity (CEC), a measure of the capacity of the soil to store positively-charged nutrients such as Ca, Mg, K and Na
- Tetraphenyl boron K (TBK), a measure of the K supply used for sedimentary soils.

While soil testing determines available soil nutrient status, pasture analysis assesses the nutrients taken up from the soil. Pasture analysis, and in particular clover analysis, is most useful to assess trace element status.

3.2.1 Taking soil samples for testing

Inherent variability in soil tests can be managed through a number of strategies:

- Take soil samples in the same month each year as nutrient levels differ seasonally
- Avoid sampling during, or immediately after, very wet or very dry conditions, or grazing
- Soil test paddocks at least 3 months after applying fertiliser or lime
- Stay at least 10m away from troughs, gates, stock camps, drains, fences, and hedges where dung and urine build up
- Take soil plugs at least 1 m away from dung and urine patches along the sampling line. As these are hard to see looking straight down, look 5 m ahead when sampling.

Take separate soil samples from areas with different:

- Soil types (i.e. peat, clay or sand)
- Contour (i.e. flat or rolling)
- Management (i.e. effluent paddocks, day or night paddocks, hay or silage paddocks, or paddocks with new grass).

Mark a sample line in each area with pegs or painted fence posts at each end, or use GPS. Record the sampling lines on a farm map.

Use a clean soil sampler, also known as an auger. Fertiliser companies or soil testing laboratories have these for loan. Wash the sampler before starting. Do not use a spade or trowel - it is difficult to get good samples with them.

Check that the soil sampler is set up to take a plug of soil from the right depth – 75 mm for pasture, 150 mm for paddocks to be cultivated.

Tip the auger sideways as it comes out of the ground to ensure no soil falls out. It does not matter if the plugs break up once in the bag.

The soil sample from each area of the farm should consist of at least 15 soil cores placed in a clean, labelled plastic bag.

Send samples away the same day for testing. If this is not possible, keep the samples out of the sun, and store them in the refrigerator overnight.

3.2.2 Taking pasture samples for testing

Use mixed herbage (clover and ryegrass) analyses to assess the nutritive value of pasture to the grazing animal. Use white clover-only analyses to determine nutrient status for pasture growth and trace element deficiency in soils.

Pasture samples should be taken along the same sampling lines as the soil samples.

Pastures should be sampled at grazing height, using clippers. The pasture should be mainly young and in a vegetative state. All pasture samples should be clean, or otherwise washed thoroughly under running water. Remove excess water.

Pasture samples should be loosely packed in paper bags and dispatched to the analytical laboratories with a minimum of delay. Avoid dispatch before weekends and holidays.

3.2.3 Sampling errors

If test results are higher or lower than expected, these should be discussed with an appropriate advisor, fertiliser consultant or the laboratory manager. There are various sources of variation including temporal (time of year), spatial (within paddock) and laboratory. It is often possible to explain such variations.

3.2.4 Sampling animal blood or tissue

Sampling the animal directly can determine the trace element status of the animal. Blood, serum or liver biopsy can be used to test for concentrations of Vitamin B12, selenium and copper. These tests should be discussed with your veterinarian.

3.2.5 Testing water for nutrient

While few farmers will be regularly testing waterways or wells for nutrient status, Regional Councils have nutrient monitoring programmes and publish the results. Farmers may also choose to periodically monitor water where the impacts of their own property might be significant. e.g. a stream originating on the farm or shallow groundwater beneath the property. Contact your Regional Council for advice.

3.3 NITROGEN FERTILISER

Nitrogen is continually cycling through soil and farm systems. Addition of N fertilisers can be used to increase the yield of hay and silage crops, and to build up feed cover ahead of the herd. Used strategically, they can provide an economic form of supplement. However, in nitrate form, N is a mobile element that can have environmental impacts if lost to groundwater or surface water.

Where soils are enriched with N fertiliser, clover will absorb N from the soil and fix less atmospheric N. On average, for every kg of fertiliser N used, clover N fixation is reduced in the short term by 0.3 to 0.5 kg N. When N fertiliser is withheld, clovers revert to normal N-fixation patterns. Vigorous grass growth following N fertiliser may also detract from clover growth if there is too much shading. Trials in Southland have shown that at rates of 200 kg N, clover yield was 35% less than in pasture with no applied N. At 400 kg N, clover mass was down 50%. Where clover is affected by pests (e.g. clover root weevil) this can also seriously impact on N-fixation.

Pasture responds well to N fertiliser, however as rates of fertiliser applied increase, the response in dry matter production per kg N applied decreases. Therefore getting maximum growth may not give the greatest economic benefit. Additional growth when grass is growing actively anyway may not be the most strategic use of N.

With any response, the key to profiting from N fertiliser use is high utilisation of the resulting pasture growth. This requires early identification of feed deficits and conservation of extra feed as standing pasture, silage or hay. Extra feed may be used to lengthen rotations in order that an appropriate feed wedge is created in front of the grazing animals.

Stocking rate may also be increased to utilise the surplus. The profitability of using N fertiliser to increase stocking rate depends on how farm costs change with additional cows, and how additional feed is utilised to maintain or increase per cow performance.

3.3.1 Environmental issues with N fertiliser (leaching)

Leaching refers to the movement of dissolved substances down through the soil profile, where they may eventually encounter groundwater. Several important farm nutrients are soluble and prone to leaching, including N in its nitrate form, and S in its sulphate form, (which can also induce leaching of the cations Ca, Mg, N and K). However, it is the effects of N leaching that are of most concern.

Nitrate contamination, particularly of groundwater, is considered to be a human health risk. High levels of nitrate are also poisonous to stock. Nitrate can also flow from groundwater into surface waterways where it may cause excessive algae and weed growth.

In New Zealand, the principle source of nitrate leaching through soil to groundwater is animal urine. When a cow urinates, it deposits nitrogen at an effective rate of up to 1000 kg N/ha (equivalent to spreading urea at 2.2 t/ha). This is well in excess of the uptake capacity of pasture plants, especially if the pasture is not actively growing (i.e. in cold, wet conditions). Similarly, soil cultivation for cropping induces mineralisation of N, which cannot be utilised if no plant uptake is occurring. As a result, excess N moves down through the soil profile and into the groundwater below.

Dairy farms have higher N losses than sheep farms since cow urine has a higher concentration of N than sheep urine, and the volume of urine is higher in each patch. Also, dairy farms are more intensively farmed, with higher stocking rates than most sheep and beef farms.

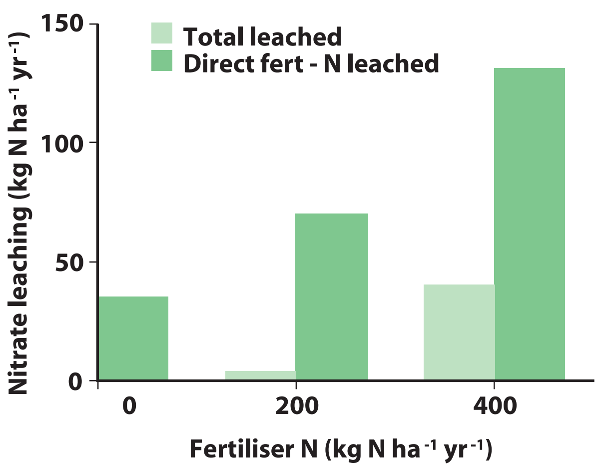
Soils most prone to leaching of N are the high permeability soils including pumices, sands and ash soils.

The following points regarding the leaching of N should be noted:

- In a pasture situation, leaching occurs mainly under urine patches. Direct leaching of N fertiliser is much less significant (refer to Figure 3.3-1)
- Direct leaching of N fertiliser is most likely in wet conditions

FIGURE 3.3-1

EFFECT OF N FERTILISER APPLICATION ON NITRATE LEACHING IN DAIRY PASTURE STOCKED AT 3.3 COWS PER HECTARE



Ledgard et al, 1999, 2000

- Leaching losses are high over mole and tile drains. Careful grazing of these areas is required, especially if wet weather is expected
- Leaching is least likely where vigorous pasture or crop growth results in rapid uptake of N from the soil (e.g. when conditions are not too cold or wet for active growth)
- Leaching losses can be high if soils are ploughed and then left fallow over an extended period of high rainfall. Cover crops will help take up this N and prevent leaching losses
- Losses are high if stock are wintered on a crop rather than using feed pads where effluent can be captured and treated
- Leaching losses are generally low on paddocks used for hay and silage
- Leaching can be slowed through using products that delay the conversion of N to nitrate in the soil (nitrification inhibitors).

3.3.1.1 N fertiliser management to avoid leaching

Urine patches on pasture are the main source of leaching. For strategies to avoid leaching from pasture, refer to 3.1.2 Avoiding losses.

N fertiliser management may also influence leaching. To keep the amount of nitrate leaching to a minimum:

- Apply N fertilisers at rates that can be utilised by the pasture or crop. Carefully work out the amount of N fertiliser needed to achieve the extra dry matter required. Do a nutrient budget. Take into account the type of soil and the use of animal effluent. Be aware of Regional Council regulations on N limits.
- Do not apply more N fertiliser than a total of 150-200 kg/ha/year. Application at higher rates risks leaching losses and nitrate contamination of groundwater. Also, the N fixed by clover will reduce by one third to one half.
- Apply N in small amounts (20-40 kg), with no single application exceeding 50 kg N/ha and with applications in cooler months kept down to 25 kg N/ha.
- Apply the fertiliser when the pasture is actively growing and can make best use of it e.g. not in a summer dry period, or when soil is cold.
- Do not apply N fertiliser to saturated soil or when heavy rain is expected.
- Use soil tests to ensure that soil pH and levels of other nutrients are adequate for high pasture growth rates so that the N can be utilised.

3.3.2 N application timing

N can be used to grow extra feed as long as grass growth is not being limited by other factors such as a moisture deficit or low soil temperatures (i.e. below 5ºC).

Plan ahead - anticipate a feed shortage, and apply N fertiliser 4-6 weeks in advance to fill the deficit with high quality feed. A feed budget and regular pasture cover monitoring can be used to plan the rates and timing of N-fertiliser for maximum gains and minimum losses or wastage. Figure 3.3-2 shows the expected response from N at different times of the year.

The best response to N fertiliser occurs on fast growing pasture that has been recently grazed but has had some regrowth (i.e. 3 to 7 days after grazing, depending on temperature and regrowth rates).

Calving dates on many farms precede the onset of spring pasture growth. There is often a feed deficit as herd requirements exceed pasture growth rates. Good pasture responses for milk production can be achieved from late winter/ early spring applications of 30-50 kg N/ha to winter grazed pastures, as they reach a herbage mass of 1600-2000 kg DM/ha.

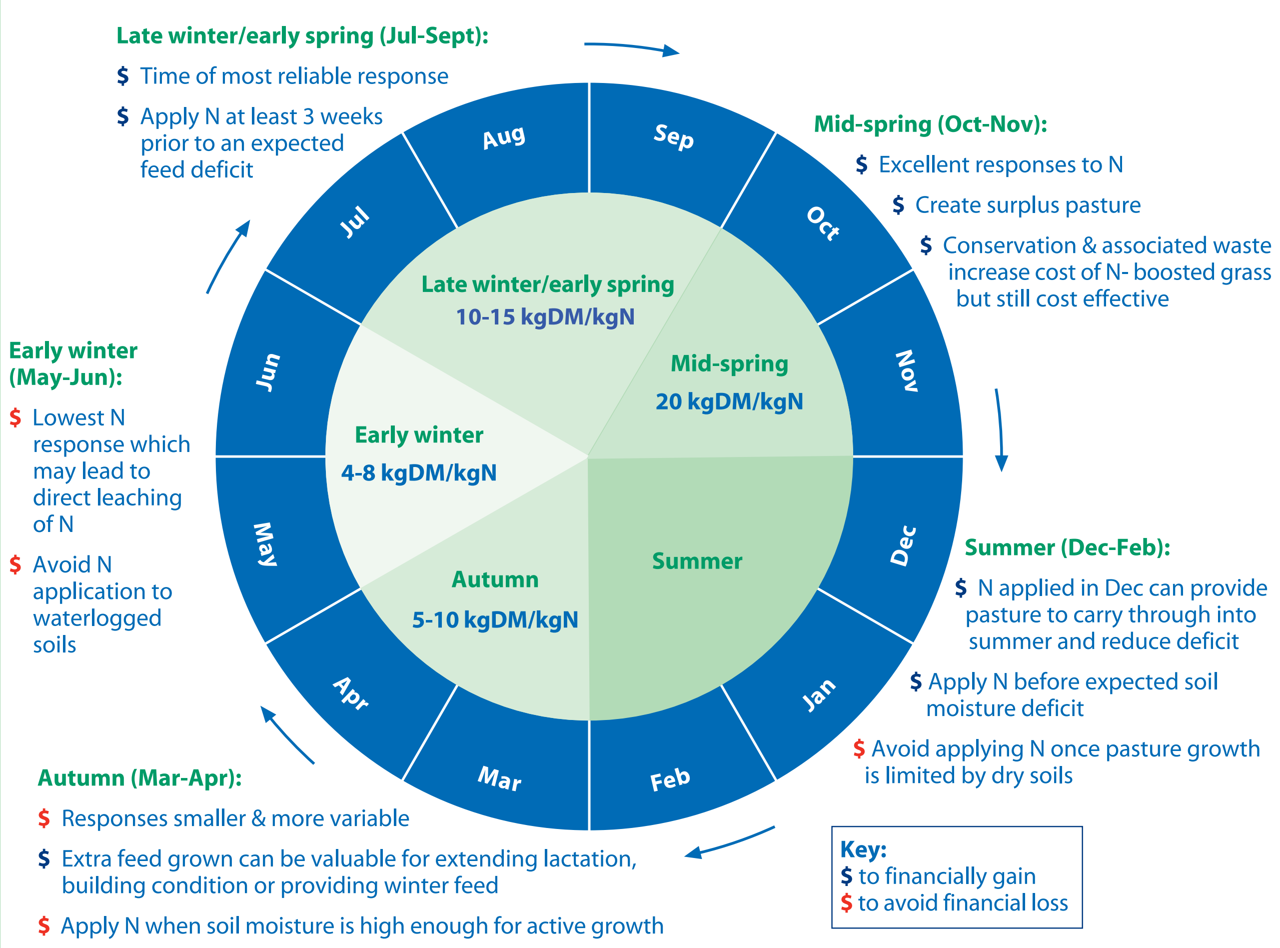
Spring applications of 40-60 kg N/ha to rapidly growing pastures will allow full feeding of lactating animals, lifting cow condition and increasing milk production. Silage production can also be boosted, and fed back to cows in dry summers (as long as good-quality silage is produced). Or, spring applications may be used to build up feed in front of the herd to assist with summer feeding. However, while responses are greatest at this time, the need to conserve extra feed creates additional cost in utilising the production from N applied in this period.

Autumn applications of 20-40 kg N/ha can be used to extend milking, build condition and lengthen the rotation as drying off approaches, creating a feed wedge for winter grazing.

Winter applications are least effective and most prone to leaching.

FIGURE 3.3-2

NITROGEN RESPONSES ACCORDING TO SEASON*



* Adjustment to response times may be required to take account of regional climatic conditions. eg. In late winter it may still be too cold in southern regions to get a reliable response from N application.

Making Dollars and Sense Out of Nutrient Management (Dexcel 2006)

3.3.3 Nitrification and urease inhibitors

Inhibitors have been developed to reduce the loss of soil N to groundwater via leaching as nitrate (NO_3) or to the atmosphere as gases (ammonia (NH_3), nitrogen (N_2) and nitrous oxide (N_2O)). These losses of N not only decrease N-use efficiency, and hence have economic implications, but also impact on groundwater quality (nitrate) and contribute to greenhouse gas emissions (nitrous oxide).

Losses of N via leaching and gaseous emissions generally increase with farming intensity. While these losses are extremely variable, Table 3.3-1 shows the typical N inputs and losses from an 'average' dairy farm.

TABLE 3.3-1

INPUTS AND LOSSES OF NITROGEN FROM AN AVERAGE DAIRY FARM		
N Inputs	**Amount from an average dairy farm (kg/ha/yr)**	
Fertiliser	122	
Clover	101	
N Outputs	**Amount from an average dairy farm (kg/ha/yr)**	**As percentage of total N input**
Product	69	31
Atmosphere	56	25
Leaching	37	17
Immobilisation	61	27

(Input data used to generate these scenarios are from Dexcel Economic Survey of New Zealand Dairy Farms. Output data is from OVERSEER 5)

This indicates that the combined losses of N to the environment are about 40% of the total N entering pastoral systems. At the individual farm level these losses represent about $93/ha (based on a cost of N at $1/kg N) or $8370 per average farm of 90 ha.

Nitrification inhibitors restrict the microbial conversion of ammonium (NH_4) to nitrate (NO_3) and hence to the gases, nitrogen (N_2) and nitrous oxide (N_2O) in soil. Urease inhibitors restrict the conversion of urea and urine to ammonium in soils. Thus, nitrification and urease inhibitors act to delay N losses and retain N in the soil. As a consequence N-use efficiency increases, since more N remains available in the soil for plant uptake.

3.3.3.1 Nitrification inhibitors

Three different formulations of dicyandiamide DCD currently exist in New Zealand: N-Care is a granulated urea-based product, which contains DCD and is applied as a normal fertiliser. Eco-N is a suspension preparation, which is sprayed onto soils. Taurine uses a special animal-mounted mechanism to deliver liquid DCD directly onto the urine patch. This product is not yet on the market.

3.3.3.2 Urease inhibitors

Only one has been developed through to registration – nBTPT (chemical name, N-(n-butyl) thiophosphoric triamide; trade name Agrotain). Agrotain is available in New Zealand as an active ingredient in the product SustaiN - a urea-based fertiliser treated with Agrotain.

3.3.3.3 Research into effectiveness

Peer-reviewed results have been published from trials over a number of years on the effects of spraying 'eco-n' to grazed dairy pastures. Field research has also been done with 'N-care', the pellet form of nitrification inhibitor. Both these sets of studies show similar beneficial effects – nitrification inhibitors can significantly reduce nitrate leaching and nitrous oxide emissions and also give an increase in pasture yields. There is less evidence on the effectiveness of urease-inhibitors in reducing N-leaching. The research into nitrification inhibitors shows that short-term nitrate leaching losses can be reduced by between 30 to 80% and nitrous oxide emissions are regularly reduced by between 50 to 75% and in some cases up to 90%. Pasture yield results have showed that increases in pasture production of 5 – 15% can be achieved with nitrification inhibitors on grazed dairy pasture, signifying a return on the initial investment of up to 180% if the extra pasture grown is well utilised.

Repeat applications may be required to cover the main period of leaching risk. Canterbury trials have found the most effective results from eco-N applications in May and again in August, while at Scott farm in the Waikato, three applications were required for the greatest benefit. In colder climates, where decompostion is slower, repeat treatment may not be needed. N that is held in the soil is then available for use by pasture in spring and summer, periods with lower leaching risk. While the N retained in the soil is not removed from the system, and is recycled back into pasture and re-deposited onto paddocks after subsequent grazings, by reducing leaching over the critical winter period, less N is lost from the system and more is retained for future uptake. Results may vary from region to region.

The available evidence suggests that the commercial nitrification and urease inhibitors are environmentally benign and biodegradable.

3.3.4 N product selection

To buy the fertiliser which is cheapest per kilogram of N calculate the cost of N in the fertiliser as follows:

$ per kg N = $/tonne of fertiliser / 10 x N in fertiliser

Cost for N in urea = $550 per tonne (Urea costs $550 per tonne applied) / 10 x 46 (Urea contains 46% N)

= $1.20 per kg N applied

To calculate the cost of feed from N fertilisers:

$ per kg DM = $ per kg N / Response rate X Utilisation rate

Cost of feed from applying urea = $1.20/kg N applied (Urea costs $1.20 per kg of N) / 10 X 0.85 (assuming: 10 : 1 response and 85% utilisation)

= $0.14 per kg of DM

If pasture is 11 MJ ME/kg DM, = $0.14 per kg of DM is 0.13¢ per MJ ME.

If other nutrients are required with N, then it may be more economical to buy a fertiliser with both N and other required nutrients (e.g. for supplying N and P, DAP may be more cost-effective than urea + superphosphate).

Volatilisation (loss as gas) is a greater risk with urea than other fertilisers but if applied at recommended rates with adequate plant cover and soil moisture, this loss is low (average 12% loss, minimal if rain falls within 12 hours). Nitrate-N is more mobile and easily leached than ammonium.

Table 3.3-2 gives the proportions of N in various fertilisers.

TABLE 3.3-2

PROPORTION OF N IN VARIOUS FERTILISERS

Fertiliser	N content	Rate of fertiliser needed for	
		30 kg N/ha	50 kg N/ha
Urea	46%	65 kg/ha	110 kg/ha
CAN - Calcium ammonium nitrate	27%	110 kg/ha	185 kg/ha
SOA - Sulphate of ammonia (24% S) (also know as ammonium sulphate)	21%	140 kg/ha	240 kg/ha
DAP - Diammonium phosphate (20% P)	18%	170 kg/ha	280 kg/ha
ASN - Ammonium sulphate nitrate (14% S)	26%	115 kg/ha	195 kg/ha

Adapted from Dexcel Farm Fact, 2001

3.3.5 Pasture management following N use

Grazing within 4 days after application will have no effect on pasture response, but grazing between 4 and 14 days post-application can reduce the response because N uptake by pasture has been rapid but insufficient time has lapsed to convert it to protein. The response in terms of dry matter production per kg N can double if pasture is spelled for six weeks rather than two.

However, if pastures grow too long clovers will be shaded out and the clover content of pasture will decline. More frequent grazing or mowing may be required.

Other effects of fertiliser N on clover include decreased nitrogen fixation and nodulation, fewer stolons per plant, and smaller plants.

3.3.6 Correcting acidification from N fertilisers

Lime may be needed to correct the acidifying effect of N fertilisers and animal urine (refer to 3.4.2.5 Increasing soil pH using lime).

Table 3.3-3 shows how much lime is required for various fertiliser applications to counter acidification.

TABLE 3.3-3

LIME REQUIRED FOR VARIOUS FERTILISER APPLICATIONS TO COUNTER ACIDIFICATION

Fertiliser	Extra lime needed for each 100 kgN/ha applied	Amount of N applied before an extra 1t/ha of lime is needed
Urea	180 kg/ha	550 kg/ha
SOA - Sulphate of ammonia (24% S) (also know as ammonium sulphate)	540 kg/ha	175 kg/ha
DAP - Diammonium phosphate (20% P)	360 kg/ha	275 kg/ha

3.4 FERTILISER USE (NON-NITROGEN)

Soil nutrient status and fertility has impacts on:

- Pasture growth or crop production
- Pasture quality
- Animal health
- Nutrient losses
- Fertiliser requirements and expenditure.

In addition to N, pasture and crops need consistent supplies of the major nutrients: phosphorus (P), potassium (K), sulphur (S), calcium (Ca), and magnesium (Mg), with additional minor and trace elements: iron, manganese, copper, zinc, molybdenum, boron and chlorine. Cobalt is also required by the N-fixing bacteria in clover nodules. Animals have requirements for cobalt, as well as sodium and selenium.

As long as the soil pH and the organic matter content are maintained, most nutrient requirements can be met by applying fertilisers to supplement the natural release of nutrients from soil and N fixation by clover. Trace elements will generally be supplied by the soil, but they may need to be supplemented by fertilisers or animal supplements.

The availability of some nutrients is affected by the levels of other nutrients. For example, high levels of K can affect Mg uptake in animals, leading to grass staggers when the dietary requirement of cows for Mg is high (during pregnancy and lactation). Because Mg reserves are not stored in the animal's body, cows need a constant dietary intake of Mg. Deficiency can be remedied by animal supplements or by fertiliser.

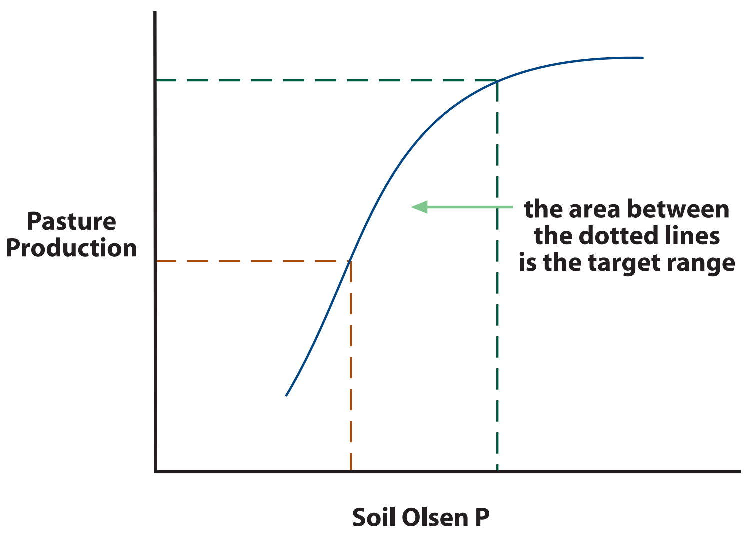
3.4.1 Determining fertiliser rates

When deciding on appropriate fertiliser applications, consider the following:

- Soil tests
- Herbage analysis
- Animal tissue or blood tests
- Specific crop or pasture requirements
- Current soil and weather conditions
- Additional nutrient inputs such as supplements and effluent
- Nutrient budget results.

FIGURE 3.4-1

PASTURE PRODUCTION AND OLSEN P RELATIONSHIP



The property may be in the capital development, maintenance or sub-maintenance (reducing fertility levels) phase.

Capital fertiliser is the fertiliser required to bring the nutrient content of the soil up to target soil test ranges (refer to Table 3.4-1).

Maintenance fertiliser is the fertiliser required to replace the nutrients removed from the soil each year - therefore maintaining the nutrient content of the soil within the target soil test ranges. Sub-maintenance levels are required when the soil nutrient status has become elevated to undesirable levels, and fertility must be 'mined' to lower nutrient status.

Table 3.4-1 gives the target soil test ranges for various soil types common to dairying regions.

Achieving these targets will ensure that pasture production is not limited by nutrient deficiency (refer to Figure 3.4-1). The pasture produced can then be converted to milk solids with good management.

If these targets are exceeded, the small increment of extra production is not usually economic given the cost of raising nutrients to these levels. Also, animal health imbalances can result from exceeding target levels of, for example, K.

TABLE 3.4-1

TARGET SOIL TEST RANGES

Soil Test	Ash	Sedimentary	Pumice	Peat	Environmental (E) or Animal (A) Health Risk
Olsen P*	20-30	20-30	35-45	35-45	More than 40 for ash, 30 for sedimentary, 45 for pumice or 55 for peat (E)
Soil test K	7-10	6-8	7-10	5-7	More than 10 for ash or pumice, 8 for sedimentary, 7 for peat (A)
Sulphate-S	10-12	10-12	10-12	10-12	
Organic-S	15-20	15-20	15-20	15-20	
Soil test Mg**	For pasture 8-10 For animal health 25-30	For pasture 8-10 For animal health 25-30	For pasture 8-10 For animal health 25-30	For pasture 8-10 For animal health 25-30	Less than 30 for all soils (A)
pH	5.8-6	5.8-6	5.8-6	5.0-5.5 (0-75 mm) 4.5-5.0 (75-150 mm)	More than 6.4 for all soils (A)

* Where management ensures that pasture is well utilised, it may be profitable to exceed these Olsen P targets – see 3.1 Nutrient efficiency

** Even where soil Mg levels are high, animal supplementation is necessary at critical times

Adapted from Dairying Research Corporation, AgResearch and Fert Research 1999 and deKlein et al. 2004

For the capital and maintenance fertiliser requirement to achieve the targets, refer to Table 3.4-4 through to Table 3.4-6.

Table 3.4-2 defines the trace element levels. Nutrient levels vary over time depending on pasture composition, time of year, stage of growth and soil moisture conditions. Due to the numerous interactions between nutrients, combined with pasture/ supplement feed rations, interpretation of results should be done in conjunction with a competent advisor or veterinarian.

In general, ash and pumice soils are often low in cobalt and selenium. Pumice soils may also be low in sodium. Boron may be deficient for legume growth or brassicas. Peat soil may be deficient in copper, selenium and molybdenum although some peats are high in molybdenum and low in sodium.

TABLE 3.4-2

GUIDELINES FOR INTERPRETING MIXED PASTURE ANALYSIS FOR PASTURE GROWTH

Nutrient (% of DM)	Deficient	Low	Optimum	High
N	<4.0	4.0-4.4	4.5-5.0	>5.0
P	<0.30	0.30-0.34	0.35-0.40	>0.40
K	<2.0	2.0-2.4	2.5-3.0	>3.0
S	<0.25	0.25-0.27	0.28-0.35	>0.35
Mg	<0.15	0.15-0.17	0.18-0.22	>0.22
Ca	<0.25	0.25-0.29	0.30-0.50	>0.50
Nutrient (ppm)				
Fe	<45	45-49	50-65	>65
Mn	<20	20-24	25-30	>30
Zn	<12	12-15	16-19	>19
Cu	<5	5	6-7	>7
B*	<13	13-14	15-16	>16
Mo*	<0.10	0.10-0.14	0.15-0.20	>0.20

* Clover only, NOT mixed pasture samples. For a Mo deficiency, clover N must also be low (<4.5%)

Dairying Research Corporation, AgResearch and Fert Research 1999

Pasture containing the above elements in the quantities designated as optimum in this table will also generally meet animal requirements if the animals are fully fed. However, for sodium (Na), copper (Cu), cobalt (Co), selenium (Se) and iodine (I), the concentrations required to meet animal needs are greater than those required by the plant.

The pasture concentrations shown in Table 3.4-3 below are those required to meet animal requirements.

TABLE 3.4-3

GUIDELINES FOR MINIMAL MINERAL CONCENTRATIONS IN PASTURE FOR ADEQUATE NUTRITION OF A LACTATING COW

Nutrients	Pasture Concentration
Na	0.11%
Cu*	8-10 ppm
Co	0.04 ppm
Se	0.03 ppm
I**	0.15-0.5 ppm

* Depends on Mo and Fe concentrations
** 2 ppm recommended if feed contains goitrogens (e.g. forage kales, other brassicas)

Dairying Research Corporation, AgResearch and Fert Research 1999

3.4.2 Capital and maintenance nutrient requirements

Maintenance fertiliser rates can be calculated from a nutrient budget, taking into account production levels, as well as nutrient inputs such as applied effluent and imported feed. Soil fertility should be regularly monitored and adjustments made accordingly.

3.4.2.1 Increasing Olsen P

Research suggests that the following rates of P, over and above the maintenance levels that replace annual losses from the farm, are required to raise Olsen P by 1 unit.

The following fertiliser recommendations relate to various common soil types.

TABLE 3.4-4

AMOUNT OF P (KG/HA) REQUIRED TO RAISE OLSEN P BY 1 UNIT

Soil	Average	Range
Ash	11 (122)*	7-18
Pumice	7 (85)	4-15
Sedimentary	5 (57)	4-7
Peat	Figures not available.	

* Superphosphate equivalent in brackets

Dairying Research Corporation, AgResearch and Fert Research 1999; Dexcel 2005

With ash soils there may be a delay before Olsen P levels increase from capital P applications. Peat soils should be treated like pumice soils until further research is available.

3.4.2.2 Increasing soil test K

Research suggests that the following applications of potassium (K) are required to increase the K soil test by 1 unit.

TABLE 3.4-5

AMOUNT OF K (KG/HA) TO RAISE THE SOIL TEST K BY 1 UNIT

Soil	Average	Range
Ash	60 (120)*	45-80
Pumice	45 (90)	35-60
Yellow-Grey Earths	125 (250)	100-250
Other sedimentary	Not available	
Peat	Not available	

* Potassium chloride equivalent figures in brackets

Dairying Research Corporation, AgResearch and Fert Research 1999

Yellow-Grey Earths and recent alluvial soils are unlikely to require capital application of K. Check K reserves using the TBK test.

3.4.2.3 Correcting sulphur (S) deficiency

While research is not available on the rates of sulphur required to raise soil S test levels, trials show that S deficiencies can be overcome with moderate inputs, even in a severe deficiency. Therefore, where soil S levels are below optimum, maximum production can be obtained by providing inputs of S as follows:

TABLE 3.4-6

AMOUNT OF S (KG S/HA) TO OVERCOME DEFICIENCY		
Soil	**Average**	**Range**
Ash	25 (210)*	20-30
Pumice	45 (375)	40-50
Sedimentary	35 (290)	30-40
Peat	Figures not available	

* Superphosphate equivalent in brackets

Dairying Research Corporation, AgResearch and Fert Research 1999

Peat soils probably behave similarly to pumice soils with respect to sulphate-S. On irrigated soils, in high rainfall areas, and on peat and pumice soils elemental sulphur rather than the sulphate form should be used if applied in autumn.

3.4.2.4 Correcting soil magnesium deficiency

Soils which are initially low in Mg will require around 25kg Mg/ha (45 kg Magnesium oxide/ha) to eliminate pasture Mg deficiency. Satisfying animal Mg requirements will require higher inputs (100 kg Mg/ha) followed by maintenance applications of 20-30 kg Mg/ha/yr). Direct supplementation to the animals may still be required in early lactation.

3.4.2.5 Increasing soil pH using lime

On ash, pumice and sedimentary soils, the following guide applies: 1 tonne/ha of good quality limestone will raise soil pH by 0.1 unit.

Good quality limestone contains greater than 80% calcium carbonate and has been ground so that 50% of the particles have a diameter < 0.5 mm.

Peat soils require 9 tonnes/ha of lime, surface-applied, to raise the soil pH by 1 unit in the top 75 mm of soil. Surface-applied lime does not move down into peat soil. If the pH of the soil at 75-150 mm is less than 4.5, it will be necessary to incorporate lime during cultivation.

Lime requirements increase as more nitrogen is cycled through the soil, so increasing N fertiliser use will raise the requirement for lime (refer to 3.3.6 Correcting acidification from N fertilisers).

3.4.2.6 Trace elements

Trace elements may be required for correct pasture/clover growth, or for animal health.

Trace element deficiences in plants will reduce vigour and may limit N-fixation in clover. Responses to boron application may occur in brassicas, lucerne and clover seed crops.

Trace nutrient deficiencies in stock affect their general health, production, growth rates and fertility.

Deficiencies are influenced by soil type, level of production, stocking rate, feeding levels, type of feed, age of animal, worm burdens and the ingestion of antagonistic elements.

Good information is required before recommending trace elements, including:

- Blood and liver tests
- Herbage analysis
- Knowledge of soil types, and fertiliser and lime history.

Table 3.4-7 gives guidelines on applications for trace element deficiencies. Some trace elements can be directly administered to animals, and this may be the only way to provide sufficient copper when high molybdenum or iron levels occur.

TABLE 3.4-7

TRACE ELEMENT APPLICATIONS SUFFICIENT TO OVERCOME CLINICAL DEFICIENCIES			
Element	**Additive**	**Application rate of additive**	**Frequency**
Co	Cobalt sulphate (21% Co)	350 g/ha	Annually for 5-10 years, then 60-100 g/ha annually
Cu	Copper sulphate (25% Cu)	10 kg/ha	Initially, then 5-6 kg/ha Every 3-4 years
Mo	Sodium molybdate (40% Mo)	50 g/ha	Every 4 years
Se	Ag Sel prills (1% Se) Selcote Ultra prills (1% Se)	1 kg/ha 0.5 kg/ha	Annually Annually
Na	Sodium chloride (39% Na)	100 kg/ha	Annually
B	Sodium borate (15% B)	10 kg/ha	Annually

Dairying Research Corporation, AgResearch and Fert Research 1999

Remember to include young stock when testing for and treating trace nutrient deficiencies.

3.4.3 Fertiliser application timing

It is important to time fertiliser application so that plant uptake is maximised. This minimises the potential for nutrient loss through leaching and/or run-off.

The factors that determine appropriate timing of fertiliser application, and the need for single or split applications include:

- Weather conditions - do not apply nutrients when surface runoff or leaching is likely to occur
- Mobility of the nutrients being applied
- Stage and state of growth of the crop or pasture (i.e. nutrient demand)
- Nutrient fixing capability of the soil
- Texture of the soil.

For information on N application timing, refer to 3.3 Nitrogen Fertiliser.

3.4.3.1 Phosphorus (P)

Soil phosphate moves relatively slowly through most New Zealand soils because it is readily bound to soil minerals or organic matter (phosphate retention). While sedimentary soils have a lower P retention than volcanic soils, there is still little leaching loss of P (though P may be lost in overland runoff during heavy rain).

Phosphorus runoff to waterways (from P fertiliser, or more likely attached to soil and dung) can cause algal growth in waterways. This can result in choking weed growth, less clarity due to green algae in the water column, and lower oxygen levels in the water as plant material breaks down. The response of water plants to extra P in the water depends on the existing N and P status of the water, and flow rates.

P can generally be applied at any time of the year, and while timing does not affect pasture responses it can affect P runoff, with potential losses being greater from application in late autumn/winter than in spring.

If application rates are over 100 kg P per ha it is better to split the application.

Where border dyke irrigation is used with the potential for runoff to waterways, it is wise to delay application of P fertiliser until after the last irrigation event in autumn.

3.4.3.2 Potassium (K)

K is weakly held by soil and is susceptible to leaching from the root zone.

Single annual applications of 30 to 60 kg K/ha are acceptable; consider 100 kg K/ha a maximum for K-deficient soils (e.g. pumice). Where effluent is being applied to the same area, the amount of K in the effluent must be accounted for and in most cases no extra K will be required. Additional K may be detrimental and cause animal health problems.

Split applications are recommended:

- For applications over 100 kg K/ha, to avoid plants taking up luxury K and K being lost through animal urine or causing metabolic problems
- On coarse-textured soils in high rainfall zones (i.e. above 1500 mm rainfall per year).

Avoid K application late in autumn and at or near calving, and on paddocks where effluent has been applied. K reduces Mg and Ca uptake and can induce grass staggers and milk fever in spring.

3.4.3.3 Sulphur (S)

Sulphate-S (i.e. the form of S in superphosphate) is readily available to the plant and is fast moving through soils. Elemental-S is less susceptible to leaching but must first be oxidised by soil micro-organisms to sulphate-S before it is plant available.

Timing of S fertiliser is unimportant on ash soils but more important on sedimentary peat and pumice soils, where S should be applied in spring. Using a mixture of sulphate and elemental-S on these soils reduces the requirement for split applications.

3.5 PRODUCT SELECTION, HANDLING AND APPLICATION

Different products can be used to achieve the same soil fertility effects. Handling and storage, fertiliser mixing and application may also be adjusted for local conditions. Protecting waterways from contamination is a key consideration.

3.5.1 Fertiliser product selection

Fertiliser product selection may depend on:

- Product cost
- Supply and availability
- Transport and spreading costs
- Environmental issues.

In cold, wet conditions soil micro-organisms are less able to convert nutrients to plant available forms. If there is a feed shortage during this cold, wet period it is important to apply nutrients in a plant available form.

Soluble forms of P are most frequently used for capital improvement programmes, but slow release forms are suitable as maintenance fertiliser or where there is significant risk of runoff (e.g. from border dyke systems that discharge to a waterway).

Sulphur is usually applied in soluble form (e.g. in superphosphate), but elemental sulphur is preferred under high rainfall or irrigation situations.

Use "Fertmark" certified products. Fertmark is an independently assessed fertiliser quality assurance programme. This label guarantees the proportions of nutrients in the fertiliser mix.

3.5.2 Calculating product application rates

The N-P-K-S ratings indicate the percentage amount of nutrients in a particular fertiliser. For example, diammonium phosphate is rated 18-20-0-2 and so contains:

- 18% N
- 20% P
- No K
- 2% S.

Table 3.5-1 lists the ratings for common fertilisers. Local suppliers are able to supply ratings for specific products not listed here.

TABLE 3.5-1

% RATINGS FOR COMMON FERTILISERS

Fertiliser	N	P	K	S
Superphosphate	0	9	0	11
Muriate of potash (postassium chloride)	0	0	50	0
Sulphur prills (elemental sulphur)	0	0	0	99
RPR* (reactive phosphate rock)	0	13	0	1
Urea	46	0	0	0
Diammonium phosphate	18	20	0	2
Sulphate of ammonia (ammonium sulphate)	21	0	0	24
Triple super phosphate	0	20	0	2

* Rating varies. Slow release fertiliser, therefore a direct comparison of P content may not be appropriate

To calculate the quantity of fertiliser needed to apply a given rate of nutrient:

$$\text{Fertiliser to apply (kg product /ha)} = \frac{\text{Rate of nutrient desired (kg/ha) x 100}}{\text{Nutrient in fertiliser (\%)}}$$

For example, if you want to apply 30 kg/ha of phosphorus, how much DAP is needed?

$$\text{Amount of DAP to apply} = \text{30 kg/ha P desired x } \frac{100}{20} = \text{150 kg/ha}$$

To calculate how much of a nutrient is applied at a given rate of product used:

$$\text{Nutrient applied (kg nutrient /ha)} = \frac{\text{Fertiliser applied (kg/ha) x Nutrient in fertiliser (\%)}}{100}$$

For example, to find out how much phosphorus will be applied with 150 kg/ha of DAP:

$$\text{Phosphorus applied (kg P/ha)} = \frac{\text{150 kg/ha DAP x 20}}{100} = \text{30 kg P/ha}$$

3.5.3 Fertiliser spreading

Key considerations when spreading fertiliser are the uniformity of distribution, and containment to the target application area.

Avoid applying fertiliser directly into a waterway. Under the RMA it is illegal to discharge a contaminant to water or to land where it may enter water unless allowed by a regional plan. Check your regional plan to see whether your Regional Council has any specific rules regarding setback distances to a waterway for fertiliser spreading.

Uniformity of application is important, especially for rapid response/ highly concentrated fertilisers, which have a greater risk of production loss and adverse environmental effects. The ability to achieve this depends on the equipment used, operator skill, product used, and site conditions (especially wind).

A coefficient of variation (CV) is used to describe the evenness of fertiliser application (e.g. a CV of 0% means that there is no variation in the actual application rate (kg/ha) over the entire application area).

Table 3.5-2 gives the rating from the Code of Practice for Fertiliser Use in terms of the CV (indicating evenness of application).

TABLE 3.5-2

RATING USING COEFFICIENT OF VARIATION STANDARDS

Standard	CV (%)
Low (poor)	25+
Acceptable	10-25
Excellent	<10

Fert Research: Code of Practice for Fertiliser Use

With aerial application it is more difficult to achieve uniformity, but a CV% of less than 15 can be readily achieved.

Application equipment with a swath or spreading width greater than the machine width has a greater potential for fertiliser drift outside the intended area. Unless headland discs have been fitted or the tractor linkage has been tilted operate the machine so that a strip of land beside the water is left without application.

Fertiliser particle or droplet size is the single most important factor in determining even spreading. Larger particles are less influenced by wind and can be placed more precisely. The application of small particles as a slurry/ suspension may reduce off-site losses.

If aerial spreading, avoid spreading in windy conditions making application to the target zone difficult.

3.5.3.1 Selecting spreading contractors

Use 'Spreadmark' certified operators. Spreadmark is the quality assurance scheme for the groundspread and aerial placement of fertiliser on farmland and increases confidence in the uniform spreading and accurate placement of fertiliser. The Spreadmark scheme maintains an audit trail from the manufacturer to the product spread on the land.
The scheme offers:

- **Training courses** – for spreader operators
- **Testing of fertiliser spreaders** – for accuracy and evenness
- **Technical parameters** – of reliability and repeatability for models of spreader
- **Spreadmark auditors** – independent and responsible for standards being met.

The fertiliser distribution pattern of spreading machines is tested and performance certificates are issued if the machine meets criteria set for 'good practice' (see Table 3.5-2). Each Spreadmark-registered company is audited within a two-year period.

Spreadmark certification costs between 4 and 8 cents per hectare per machine over the life of the certificate.

3.5.3.2 Consideration of others

The application of fertiliser to land can affect people outside the immediate target zone and so consideration is required.

Often arguments about fertiliser can be resolved or avoided by discussion with the people concerned and by observing good practice:

- Advise affected neighbours of your intentions. Explain what might be involved. This allows people to plan around this (e.g. not put the washing on the line that day).
- If practical, use the least dusty form of fertiliser (e.g. granulated Mg rather than standard Mg fertiliser).
- Consider noise factors and particular needs of staff and neighbours (e.g. new babies, shift workers).

3.5.4 Fertiliser storage

Fertiliser should not be stored or loaded near waterways. Check with your Regional Council for specific rules about setback distances; otherwise use the general rule of locating fertiliser storage/ loading and handling sites at least 50 m from open water. Fertiliser should not be stored or mixed within 20 m of the farm dairy.

Fertiliser should be kept dry and free from contamination. Absorbed moisture leads to poor flow, setting in storage, and wasted material through formation of lumps.

Storage areas should have an impervious floor (e.g. concrete, including a damp-proof course), designed to withstand vehicle traffic. Stored fertiliser should be covered with impermeable plastic sheeting to prevent contact with moist air.

Bagged fertiliser should be stored in bags with impermeable liners. If stored on wood floors, plastic sheeting should be placed under the bags and wrapped around the whole stock. Handle bags carefully to avoid damage and clear up any spilt material.

Take special care with liquid fertilisers to avoid spillage and water pollution. Most liquid fertilisers come in suitable plastic drums. If an alternative storage tank is used it should be made from a corrosion resistant material, there should be a hard area so that delivery vehicles can get to the tank and tanks should not be overfilled - allow space for the contents to expand.

Organic fertilisers such as chicken manure or effluent scrapings will lose N to the atmosphere when stored for long periods. Leaching may also occur from these materials, so they should be stored on an impervious surface and covered.

3.5.5 Mixing fertilisers - issues of compatibility

Mixing fertilisers, or mixing agrichemicals with fertilisers prior to application may result in hazardous chemical reactions. Also, topdressing pilots are at risk when applying a mixture of products that may solidify after mixing or solidify because of water absorption and there is a danger that the load will not fall out of the hopper freely.

Read the label and check with suppliers as to what can be mixed and what cannot, if there is any doubt.

Not all fertilisers can be safely mixed together. Some mixes are potentially explosive, others absorb water very quickly. Control of moisture during storage is more important when fertilisers are mixed together.

- Do not mix ammonium nitrate and urea.
- Mix the following only immediately before use: urea with triple or single superphosphate, and diammonium phosphate with triple or single superphosphate.
- The mixing of products containing N with other fertilisers can lead to chemical reactions and the fertiliser going hard. This especially applies where mixed products are to be stored on farms. Ideally products containing N should be applied separately.
- The mixing of fine trace elements with high analysis products like DAP is not recommended. The uneven sized granules can lead to mixes segregating and incorrect trace element application programmes. For best results, there should be no more than 10% difference in particle size between component fertilisers in a mixture.

3.6 ORGANIC AND BIODYNAMIC FERTILISER PRACTICES

Organic and biodynamic farming involves holistic production systems, emphasising management practices and enhancing natural cycles in preference to the use of off-farm inputs. The emphasis of organic systems is on increasing soil life and activity by:

- Encouraging and enhancing biological activity and nutrient release in the soil
- Maintaining and improving soil structure and long-term productivity
- Cycling organic matter and nutrients within a productive system.

There are a wide variety of fertilisers used in organic and biodynamic farming systems, ranging from solid fertilisers such as compost, reactive phosphate rock and elemental sulphur to liquid fertilisers (e.g. seaweed or fish). The aim of using these fertilisers is not only to supply nutrients but also to make the soil healthier and more functional as a growing medium.

Emphasis is placed on the build-up of organic matter. Soils high in organic matter have more biological activity, cycling nutrients within the soil. They also retain nutrients and reduce the risk of leaching, and retain water for release in dry conditions. Such soils are less susceptible to, and recover better from, pugging damage.

Various certification schemes are now available which specify the types of fertilisers that can be used (e.g. BioGro, Demeter, Agriquality and OrganicFarmNZ for smaller properties). Dairy companies accepting organic products can inform which standards need to be met. There is also an "Organic Pastoral Resource Guide" available from Soil and Health Association's book club (go to www.organicnz.org).

3.7 EFFLUENT AS A FERTILISER

Dairy effluent, when recycled back on to the land, offers a source of N, P, K and S and trace elements to enhance pasture or crop production.

Effluent correctly applied can substitute for solid fertiliser use, provide a minor irrigation benefit, and assist in maintaining water quality.

Successful use of effluent requires assessment of its value in fertiliser terms for both pasture and crop production. Effluent is extremely variable in nutrient content. As well as seasonal variation, the nutrient content of effluent will differ from property to property. Effluent stored in ponds changes in nutrient composition. The surface liquid is more dilute than the concentrated sludge at the bottom of the pond.

Table 3.7-1 gives the equivalent fertiliser value of effluent collected from the farm dairy and applied to land. The nutrient values assume a 270-day lactation, and that each cow will deposit 10 to 20% of its total daily discharge in the farm dairy. Both can vary according to milking practices.

The following fertilisers are used for the solid fertiliser comparison:

- Urea N-P-K-S-Mg rating 46-0-0-0-0
- 50% Potash super 0-5-25-6-0
- Magnesium oxide (i.e. MgO) 0-0-0-0-52

TABLE 3.7-1

FERTILISER VALUE OF FARM DAIRY EFFLUENT FROM 100 COWS

Nutrient (kg/year)					Approximate solid fertiliser Equivalent value (tonnes/year)	Value ($/year)
N	P	K	S	Mg		
590					1.3 of Urea	700
	70	540	80		1.3 - 2.2 of 50% Potash super	400-700
				100	0.2 of Mg Oxide	100
Total value per annum						**1200 - 1500**

Note 1: These are 'typical values'. A nutrient analysis will give the most accurate picture of the fertiliser potential of effluent from an individual property. Nutrient budget programmes such as OVERSEER® provide an estimate of nutrients returned in farm dairy effluent.

Note 2: Not all of the nutrients are available to plants in the first year. Some will be released over time.

3.7.1 Effluent application

When animal effluent (e.g. farm dairy effluent) is applied to soil, soluble N is turned into nitrate within a few weeks. The remaining N takes longer to break down and convert to nitrate.

If the effluent treatment area is undersized or soil characteristics are unsuitable, there is a risk of N leaching through drainage into groundwater. Particular care must be taken on land that is mole or tile drained.

When determining solid N fertiliser requirements in addition to animal effluent, total N loading must be considered. Excessive rates of N should be avoided, as large losses are likely, wasting the value of the N and degrading water quality. Some Regional Councils have rules limiting the use of fertiliser N on land receiving applications of effluent.

For details about effluent management, refer to the Dairy and Environment Committee manual "Managing Farm Dairy Effluent".

3.8 MANAGING ACIDIFICATION

Acidification is a natural process that occurs in most soils but can be increased by pastoral farming. The natural process of nitrification in soils causes the soil to become more acidic. The main factors that lead to acidification are the release of acidic hydrogen ions from soil organic matter, soil minerals, and during the natural process of nitrate production in the soil. Unless the soil is well supplied with calcium or magnesium carbonate (i.e. regular applications of lime or dolomite) the pH of the soil will decrease until the land becomes unproductive.

Optimum pH levels of soils are as follows:

- 5.8 to 6.0 for ash, sedimentary and pumice soils. As clovers are sensitive to acid conditions, this pH range should be maintained. Liming to pH greater than 6.4 may cause deficiencies of zinc, copper and boron.
- 5.0 to 5.5 for peat soil to a depth of 75 mm. Peat soils may be maintained at a lower pH than most other soils. Natural peat soils have a very low pH (i.e. pH 3.5 to 3.8). A subsoil pH of at least 4.5 (i.e. from 75 to 150 mm soil depth) should be aimed for.

On peat soils, lime needs to be worked into the subsoil as broadcast lime does not penetrate very deeply on peat soils. Liming into the subsoil encourages plant roots to grow deeper, making them better able to tolerate moisture stress.

Some soils of low pH support natural habitats for particular species or plant communities. Take care that the liming of pastoral soils does not raise the pH of nearby acid soils, wetlands or aquatic habitats, which could reduce their conservation value.

The application of ammonium-N fertilisers, such as urea or ammonium sulphate, can increase the rate of soil acidification (refer to 3.3.6 Correcting acidification from N fertilisers). Application of superphosphate fertiliser has little direct effect on soil pH. However, it may indirectly increase soil acidification because it stimulates the growth of pasture plants, including clovers, which adds to the nitrogen in the soil, lowering its pH.

3.8.1 Lime

The major effect of lime is to increase soil pH, countering acidification. Liming leads to decreased aluminium toxicity, better water absorption by soil, increased earthworm and micro-organism activity, improved nutrient cycling and increased availability of Ca, Mg, P and molybdenum (Mo).

New Zealand limestones range between 65% and 95% pure. In general they contain low levels of useful nutrients other than calcium.

The speed of reaction of lime in soil is influenced by the following:

- The fineness of the lime particles. A range of particle size is desirable, but very coarse lime (i.e. > 8 mesh) will not be effective
- Soil acidity (pH). High acidity increases the rate of dissolution of lime but the rate of change of soil pH depends on the 'buffer capacity' (i.e. CEC) of the soil. Sandy soils have a lower buffer capacity than clay soils and, therefore, the same amount of lime will produce a larger and more rapid increase in pH in sandy soils than in clay soils
- Application rate. A high rate increases the rate of change in soil pH because there is more lime to react with the soil
- Soil moisture. The presence of moisture increases the rate that the lime dissolves and reacts with the soil and thus increases the rate of change in pH
- The degree of calcium saturation in the soil. A high concentration of calcium will reduce the apparent rate of pH change in the soil because the soil is likely to be near neutral with a high calcium or base saturation. There will be a slightly slower rate of lime dissolution.

For rates of lime required to raise the soil pH, refer to 3.4.2.5 Increasing soil pH using lime.

3.9 HEAVY METALS AND OTHER CONTAMINANTS

Elements that can kill plants or reduce yields if they are present in high concentrations include zinc, copper, nickel, cadmium and arsenic.

Elements which can be harmful to stock or humans include lead, arsenic, cadmium, mercury, copper, fluorine, selenium and molybdenum.

In the low concentrations usually found in New Zealand soils, many of these elements are essential trace elements for plants or stock.

Residues may also be present from previous pesticide use (e.g. DDT). Refer to 7.1.1.5 Soil contamination for information on these residues.

3.9.1 Cadmium

Cadmium is present at low levels in the soil and in phosphate fertilisers. It is naturally present in the rock deposits from which these fertilisers are made. Cadmium in the fertiliser does not break down, so levels in the soil increase over time. Soils that have received a high level of phosphate fertilisers have higher levels of cadmium.

The cadmium content of milk is generally very low. Not only do ruminants absorb only a small percentage of the cadmium ingested, but very little of the absorbed cadmium enters the milk.

Levels of cadmium in New Zealand are low in comparison with those in areas of Europe, the UK and the USA.

However, cadmium does accumulate in the kidneys of animals and approximately one-third of kidneys from cows exceed maximum residue levels. Kidneys from cattle over 2.5 years old are automatically excluded by the meat industry from human consumption.

In people, cadmium can damage the kidneys and liver and may increase the risk of some cancers. Standard guidelines for soil cadmium levels have become stricter and significant areas of dairying regions are expected to exceed cadmium standards within 10-20 years if current fertiliser use continues.

The New Zealand fertiliser industry has made significant attempts to reduce the cadmium in its products. A cadmium working group convened by MAF is undertaking an assessment of cadmium accumulation in New Zealand. Farmers can also take care not to over-apply phosphate fertilisers, for example by carrying out a nutrient budget and not raising Olsen-P levels above optimum (refer to 3.1 Nutrient efficiency).

3.9.2 Zinc

Zinc is another metal that can accumulate in soil. Zinc may be applied to pasture as a fertiliser, but is more widely used in facial eczema treatments, either in water, with feed or as an oral remedy. Animals require high levels of zinc to resist facial eczema, but much of this zinc is then excreted by the animal and builds up in the soil.

Zinc is less damaging to human health than cadmium, but it can have impacts on the environment. If it reaches waterways it can harm aquatic life and build up in sediments and the beds of waterways. High levels of zinc can affect plant growth.

3.9.3 Fluorine

Fluorine is present in phosphate rock and therefore is in all fertilisers made from phosphate rock. If excessive quantities are ingested, fluorosis can occur, causing unsteadiness, a drop in milk production and bloating or even death.

This is best avoided by not grazing fertilised paddocks until after a rainfall has washed fertiliser from the pasture. Fluoride applied via fertiliser may also accumulate in the soil, causing a health risk to animals ingesting soil as they graze.

3.10 TOP TIPS TO AVOID TROUBLE WITH FERTILISER USE

- **Signs of fertility problems can be seen in the presence of low-fertility species (e.g. browntop, Yorkshire fog), poor pasture growth even in the spring flush, and dung and urine patches that stand out markedly.**
- **Soil and plant test regularly - every two to three years - and use the correct fertilisers as recommended based on soil and plant testing, milk yields and your nutrient budget.**
- **Keep test records as these help build up an accurate picture of a farm's fertility.**
- **Avoid over-application of fertilisers as it wastes money and may cause fertility runoff or leaching. Set realistic growth targets and match application to requirements.**
- **For most farms, it is appropriate to maintain soil Olsen P levels in the target range (20-30 for ash and sedimentary soils, 35-45 for pumice and peat soils) to get the best economic return.**
- **Time fertiliser application so that plant uptake is maximised. Do not apply fertilisers to cold or waterlogged soils or when heavy rain is likely.**
- **Ensure pasture is left for 3 - 7 days after grazing for regrowth to occur before applying N fertiliser.**
- **Make efforts to achieve the most accurate application possible. Use Spreadmark certified operators.**
- **On steep slopes or where natural drainage runs towards open water, establish grassy filter strips and leave a buffer zone where no fertiliser is applied.**
- **Avoid applying fertiliser when wind is blowing towards open water.**
- **Use fertiliser with larger particle sizes (greater than 1 mm).**
- **Inform neighbours of your plans.**
- **Follow the Code of Practice for Nutrient Management (with Special Emphasis on Fertiliser Use) (previously the Code of Practice for Fertiliser Use).**

3.11 FURTHER READING

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