

**Soil Fertility Testing Workshop
Handouts
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When we hear the term soil fertility farmers and consultants often immediately think in terms of what is the Olsen P soil test result for available phosphorus. There are two drawbacks to this narrow association. One is that a particular soil test like Olsen P is always going to have inherent variability and often some pitfalls in its analysis and usefulness. The other is that there are many more facets to soil fertility.

Standard laboratory soil tests mainly address the chemical fertility of a soil though some measurements give indications of how to improve biological and physical fertility of that soil. In organic systems there is an even greater importance in looking at the biological fertility of a soil and this also makes sense for sustainable production of any crop. Good biological fertility will provide a more resilient farming system with more efficient nutrient utilisation, less nutritional issues in the crop and less susceptibility to pests and diseases (especially soil borne ones).

In this workshop we look at how to assess the fertility of soil and then how to improve it. One of the important lessons for organic farmers is to realise the interactions and interdependent nature of physical, chemical and biological soil fertility.

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1. What is Physical Soil Fertility?

The physical soil fertility of the soil includes aspects of just how well structured the soil is. Soil structure will influence the drainage of the soil and the aeration available in the soil. It also influences the ease with which roots can penetrate the soil and go wide and deep in search of nutrients and moisture.

The ideal soil for most crops will have a good aggregate or crumb structure. This provides the best of both worlds as within the crumbs there will be good moisture holding capacity whereas around the crumbs, there is good drainage and good aeration allowing healthy root function (the roots do literally need to breathe) without the increased risk of root rot that goes with poorly drained conditions. Other soil life including earthworms will also benefit from good soil structure as oxygen is available while moisture is able to be held and movement through the soil is easier.

Plant roots are able to come in close to soil crumbs and even penetrate them with fine feeder roots and thereby access the high nutrient availability and stored water within.

Physical soil fertility is affected by the original soil type and by soil management and soil organic matter levels. A heavy clay soil will typically have issues with poor drainage but have a naturally high level of many minerals. A light sandy soil will have excellent ability to drain but poor water holding capacity and naturally low levels of most minerals.

Soil organic matter helps bind soil particles together in crumbs and also directly improves the moisture holding capacity of soil.

A fundamental aspect of physical soil fertility will also be soil depth. This is especially important for tree crops and other deep rooting plants.

2. What is Chemical Fertility?

All too often, farmers and farm consultants concentrate on the chemical aspects of soil fertility. Although the organic approach places extra emphasis on the biological component it is important to not lose sight of the importance of chemical soil fertility. The pH of the soil for instance plays a large part in determining the plant availability of most minerals in the soil. And some of those minerals may be at naturally poor levels simply due to the soil parent materials in the first place. Ensuring adequate and balanced levels of many of the important minerals for plant and animal growth is part of enhancing plant and animal health and at the heart of natural pest and disease management. Thus a soil test for pH and nutrient availability still has an important place in organic agriculture.

The pH measures the acidity of the soil typically ranging from an acid soil as low as 4 through to what is desirable for most crops with a weakly acid soil of 6 to 6.4 and a neutral soil of 7. Few New Zealand soils have a naturally alkaline pH of higher than 7. Over-liming or build up of soluble salts can produce an alkaline soil.

At around soil pH 6 to 6.4, there is good potential for general mineral availability. There is also a reasonable balance between fungal activity (many favoured by more acidic conditions) and bacterial activity (many favoured by higher pH conditions). If the soil pH is too high especially at 6.6 or greater, there can be poor metal trace element availability (iron, manganese, copper and zinc). At low soil pH levels especially below 5.5, there can be poor phosphorus and molybdenum availability. Legumes are generally favoured by higher pH levels and will fix more nitrogen. With pasture the aim is usually closer to pH 6.0 to reduce the impact on metal trace element uptake as this is particularly significant for livestock.

The aforementioned pH values apply to most soil types but there are some changes in desirable levels in peat soils and sandy soils. In a true peat soil, the optimum soil pH is more around 5.8 and in a sandy soil, more around 6.4.

There are a number of major nutrient elements that are required for plant and animal growth. Carbon, hydrogen and oxygen are universally available and freely sourced from the air by plants. It is from the soil though that the major elements phosphorus, potassium and sulphur are primarily sourced. Nitrogen is often the most limiting nutrient in crop and pasture systems and it is also sourced from the soil although nitrogen fixing microorganisms in plants like legumes and to some extent free living in the soil source nitrogen from the atmosphere.

Elements required in lesser amounts include magnesium and a number of elements required in such small levels that they are termed trace elements including boron, cobalt, copper, iodine, iron, manganese, molybdenum, selenium and zinc.

Chemical soil fertility includes the extent to which these elements are sufficiently available and in balance for plant uptake and utilization.

The mineral elements in the soil are present as charged particles called ions. Ions are either positively charged (termed cations) or negatively charged (termed anions). Cations affect the pH of the soil. Some cations are acidic in effect, lowering pH and others are bases that lift pH. The elements calcium and magnesium (with double positive charges) and potassium and sodium (with single positive charges) are the base cations. The other two main cations in the soil are hydrogen (single positive charge) and aluminium (three positive charges and only present in acid soils); these are both acid cations.

The majority of available cations in the soil are held in cation exchange sites. These sites are created by negative charges on the surface of humus (well decomposed organic matter) and clay minerals. The varying proportions of cations present on sites affect not just the soil pH but also soil structure and the availability of each cation type.

A good proportion of calcium is important for good soil structure as this double charged cation has the effect of flocculating or drawing together soil particles to help form a nice crumb structure in soil (bringing good drainage and soil aeration). Magnesium although double charged is not as good at flocculating the particles.

3. What is Biological Fertility?

Biological soil fertility is related to the presence and activity of living organisms within the soil. These organisms are responsible for the breakdown of organic material to release nutrients that are then available for other soil organisms and the plants. Beneficial soil organisms also reduce the potential for root diseases and pests, and can generally improve the health and function of plants. Since it is not possible in organic agriculture to supply a range of readily available nutrients from chemical fertilizers or utilize a full range of chemical pesticides to control pests and diseases, biological soil fertility is more crucial to organics than to conventional agriculture.

“Food chain” is one term to describe the feeding relationship between the different types of organisms with e.g. protists grazing fungi, nematodes eating protists, larger animals eating the nematodes but in reality “web” is more accurate where there are also fungi preying on nematodes, nematodes parasitising earthworms. The term “soil food web” has become commonly used but I prefer the term “soil web” as there are more aspects and interactions occurring than just food.

Within this web of soil life there is constant release of nutrients (usually something like twice as much nutrient is lost through excretion or leaking than is actually utilised by the organism doing the eating. This makes resources available to the rest of the web, including plant life. The more complicated the web, the higher the rate of nutrient cycling. Just as the biodiversity of plants and animals is a feature of a well designed organic farm, the diversity below ground is what drives the entire system along.

Soil microorganisms include bacteria, thread forming actinomycete bacteria, and fungi. Fungi include a wide range of decomposers as well as a number of mycorrhizae (fungi that live in association with plant roots protecting them from disease and increasing the ability to access phosphorus other elements and moisture from the soil). Soil animals include the microscopic protists and nematodes as well as larger animals. Of particular importance are the earthworms that burrow through soil and digest organic matter while providing suitable conditions in their guts for increased activity of microorganisms in releasing nutrients from the organic matter.

4. Interactions between Physical, Chemical and Biological Fertility

The friable conditions that are the hallmark of good soil physical fertility are aided by good soil biological activity and in turn provide the right conditions for biological activity – the two should not be seen in isolation. Below is a list of the ways that soil organisms aid aggregate formation...

Sticky Polysaccharide Production (Bacteria, Cyanobacteria, Actinomycetes, Fungi, Some Protists)

Thread Formation (Actinomycetes, Fungi)

Mucus Production (Enchytraeids, Earthworms)

Physical Burrowing (Enchytraeids, Earthworms)

Humus Formation (All Saprophytes – aided by the full diversity of soil organisms)

5. Assessing Physical Soil Fertility

Visual Soil Assessment(VSA) has been developed internationally and in New Zealand to take advantage of the many visual clues of soil quality that are provided in looking at crops, pasture and soil itself. The majority of the visual characteristics are related to soil physical fertility. Landcare Research VSA guides are available electronically (<http://www.landcareresearch.co.nz/research/soil/vsa/fieldguide.asp>). For cropping and pastoral soils some basic descriptions have been set out for good moderate and poor condition in terms of soil aggregation, soil porosity, soil colour, soil mottling, tillage pans, clod development, erosion and interpreting the soil cover and crop production.

6. Assessing Chemical Soil Fertility

The typical method of assessing chemical soil fertility is to take a soil test which is then analysed at a laboratory. Soil tests are described later in this document as are plant tissue tests which can provide further information on availability of nutrient elements to plants and likely fertilizer responses.

7. Assessing Biological Soil Fertility

Many organic practitioners claim to be able to intrinsically tell a “good” soil. And there are certainly many field observations that can be made to confirm good soil biological activity. This section looks at some of the field observations as well as other “tests” of soil biology and how well they can be quantified, compared and justified.

7.1 Field Observations

Smell

The more fertile a soil, the higher the amount of actinomycetes and the stronger the musty/earthy smell. It is unclear how reliable this observation can be for comparing soils but may be useful in comparing two treatments. As yet, no gas chromatography work (or probably even panel assessment) has been carried out to quantitatively compare such samples. Another aspect of soil smell is to test that the soil is not too sour (low pH due to unbalanced organic acids), and this can be quantitatively assessed by soil pH measurement.

Friability

The friability of a soil is a good sign of (and cause for) of the level of soil biological activity. The soil should feel nice and crumbly due to good aggregate structure.

Colour

Generally as a soil improves under good management, its colour should darken due to the increased formation of dark brown to black soil humus. Earthworm activity in the subsoil can also be seen as the old worm burrows fill in with dark stable humus-soil particles.

Earthworm Counts and ID

An easily quantifiable method of assessing the health of soil ecology is to count and identify the earthworms present. It is mostly the case of the more the better and some species (e.g. *A. caliginosa*) are better indicators of good soil conditions than others. Care in interpretation would include the effect of time of sampling and temporary soil conditions as these will affect counts. Counts can be made of smaller soil animals but this becomes more of a laboratory job due to the size of the organisms. Pit traps are one method of assessing surface organisms like beetles and collembola.

Litter Decomposition

Perhaps the most direct assessment of a soil ecology's health is to test the rate at which litter is decomposed. This can be done by field observation of length of time for "aboveground" or incorporated crop residues to "vanish" or it can be done with a litter-bag containing a measured amount of a certain type of organic matter). An alternative being investigated for New Zealand soils by Lincoln University is the lamina bait probe which is a plastic strip with several holes that are filled with a mixture of bran, cellulose, charcoal and water. The probe is placed in the soil for a set amount of time and the level of microbial activity is determined by the number of holes created by the resident soil biological activity.

7.2 Laboratory Methods

Monitoring Organic Matter Levels

Organic matter levels can be assessed by a variety of means with the simplest being homogenising a soil solution in a blender and assessing the settled layer of organic matter or igniting the soil in a crucible over a hot flame. Commercial labs use flame and/or colorimetry (colour reaction of chemicals like potassium permanganate with organic matter). The main value in these lab methods is long term monitoring of changes to ensure that system management is maintaining or lifting organic matter levels.

Plate Counts

A classic microbiological approach is to isolate and quantify the organisms on media in petri dishes. This can be used to give concentrations of organisms and even, through the use of selective media, give specific information about certain organisms e.g. actinomycetes, sulphite reducing bacteria and single species of interest. Some of the disadvantages include that it underestimates the total number of such organisms present and some types of organisms do not grow well, or at all, on media.

Microscopy

Some commercial labs (see Soil Foodweb in Section 8.4.1) are offering a service that goes a few steps further than plate counts by using microscopy and providing comprehensive information. While this overcomes some of the disadvantages of plate counting, there may still be calibration required for good/useful interpretation.

Organism Activities

A less direct approach is to put the soil through its paces and in the case of Substrate Induced Respiration (SIR) put in a set substrate of organic matter (e.g. cellulose material) and measure the speed with which the soil metabolises it to carbon dioxide.

Fumigation

A further method is to fumigate a soil sample, killing the microbial biomass. The production of carbon dioxide is then measured and the amount of killed biomass is calculated from that. This gives no real information about the form of that microbial biomass and is probably more of value to general science studies than monitoring agricultural systems.

Organism Products

The levels of products from microorganisms can be measured e.g. certain enzymes, amino acids and nucleic acids. This has the advantage of showing functional differences between soils. It can be seen that the levels of enzymes for instance in a soil with regular organic matter addition have higher level of relevant enzymes for decomposition of the material as compared to a soil that has only just received the same organic matter addition.

Molecular Methods

A variety of methods are being developed that are able to take a “fingerprint” of the soil giving an idea of the types and overall variety and levels of soil microorganisms. Microbiological and molecular methods of assessing soil health are still in their infancy are probably at their best when comparing replicated treatments side by side and are probably difficult to use in comparing samples over time or over different areas. There may be some value in looking at the relative level of different organisms and good scope for using organisms higher up the food pyramid e.g. nematodes or at specific pathogens or beneficial organisms.

8. Soil Assessment

8.1 Soil Maps

In most cases, the soils on a farm will have been surveyed at least on a large scale and in some cases in great detail. Such soil survey information will be available on websites (e.g. through regional councils – contact them for details) and in soil map and soil survey literature in local libraries.

Find the farm location on a soil map using a detailed topographical map for assistance if necessary and note down the position and codes of each different soil type on the property. Associated text will give you a range of information about the soil type especially its physical characteristics and in many cases example soil test levels relevant to soil chemical fertility.

Land Use Inventories and similar documents on land use suitability will also often be available. With the use of these together with soil maps, it is possible to have a broad understanding of the natural suitability of the soils to the proposed land uses and what adjustments may need to be made to improve this suitability.

8.2 Soil Tests

Farmers may already have soil test information or the consultant may take a new one. In all cases it is wise to start instituting a programme of soil testing that will give a

good understanding of the soil's limitations and how well these are being addressed by the fertiliser programme and general management.

This involves selecting the paddock or paddocks that get tested, choosing the best time of year and deciding how often you're going to test. This is the time when soil tests are going to differ least from year to year and give you a better idea of any trends that might be occurring. Test taken in summer for instance can vary greatly depending on whether there is a dry summer or not or how good the growing season was (imagine December 2003 compared with December 2004 with fifty times more rainfall that month).

It is in seeing trends over several years that soil tests are at their most powerful. Taking soil tests every two or so years from the same area and at the same time of year will give you the information you require to help decide whether there are any reliable trends in your soil test values.

Soil sampling should pay particular attention to

- depth (higher nutrient availability closer to the soil surface – pastures generally sampled at 75mm, crops and fruit trees generally at 150mm, apples at 20 cm)
- sufficient numbers of samples (to avoid random effects of highly variable samples – should be at least 15 to 20)
- taking samples from a known transect or pattern (e.g. “W” shape) to allow accurate repeats – you can even mark posts to help repeat the same track next time
- covering the whole area selected
- selecting an area that is not too variable (e.g. separate sampling for hill and flat or for two different soil types)
- avoiding fence effects, shelterbelt effects, gateways, other high traffic areas and around troughs
- specific instructions for the crop e.g. “from drip zone” or “from rooting zone”
- time of year as recommended or the same as previous years to aid long term monitoring
- generally avoid times when the soil is overly dry or overly wet or frozen – preferably do not sample at a time of year like mid summer which will give high variation from one year to another making long term monitoring of changes more error prone (autumn to mid winter good)
- sufficient time since fertiliser application preferably greater than 3 months

The results will have a set of recommended or “normal” levels that should be treated as indications of where a good performing soil would often have a soil test level. It is still possible for a soil to be performing well and plants to not be deficient of that nutrient even when the soil test value is lower than the recommended levels. And it is rather sobering that even with a high soil test value, there may still be a response to a nutrient. Soil testing is not an exact science.

Fertiliser and or organic matter application should then be influenced but not completely dictated by the soil test result. The net removal of nutrients by a crop or by grazing should be replaced by application and if the soil test indicates room for improvement in a particular nutrient then there may be value in applying extra. A trend over the years of a soil test value dropping to a low level or rising is a good indicating that more or less respectively of that nutrient is required for maintenance.

Many soil test values will fluctuate due to soil conditions and plant growth. An Olsen P level will often be lower in a year of good pasture growth and higher in a dry year of poor growth. The soil pH can also fluctuate by as much as 0.4 in some cases simply due to soil moisture conditions and pasture vigour. All the more reason for soil tests at the same time of year in autumn to mid winter and repeated over several years to show reliable trends.

The basic soil tests recommended for organic properties

Soil Test	Variability	Interpretation
Organic Matter %	Stable	Would like to see it maintained or improved over years. Generally higher the better for mineral soils.
Cation Exchange Capacity (CEC)	Slightly variable	Indicative of soil texture combined with organic matter level. If low, “spoon feeding” of cations may be required and greater leaching could be expected. If high, larger amounts of cations (e.g. calcium from lime) may be required to shift nutrient availability and pH.
pH (Acidity)	Somewhat variable	Slightly acid but good calcium levels for soil biological activity (too high a pH causes metal trace element and other nutrient deficiencies and too low causes phosphorus and molybdenum deficiencies)
Available Nitrogen	Highly Variable	Only use for certain crops as required. Look for sufficient to provide good crop start.
Resin P (Phosphorus)	Variable	Olsen P better known but less reliable than Resin P in some soils and with the use of RPR fertiliser. High level means probably sufficient, low level means possibly deficient. Less history and calibration than Olsen P so worth getting both P tests
Exchangeable Potassium	Variable	Best interpreted in milli equivalents or Quick test units or kg/ha (not just as %

		of CEC). Medium to high level means probably sufficient.
Exchangeable Calcium	Variable	Best interpreted in % of CEC. Medium to high level means probably sufficient.
Exchangeable Magnesium	Variable	Best interpreted in % of CEC. Medium to high level means probably sufficient unless potassium % is high in which case magnesium may be limiting especially in spring and autumn times of high potassium.
Exchangeable Sodium	Variable	Not required for plants. Best interpreted in % of CEC. Very high level may mean problem with soil salinity and poor drainage. Medium to high level means probably sufficient unless potassium % is high in which case sodium may be limiting (to grazing animals) especially in spring and autumn times of high potassium.
Organic Sulphur (Easily Extractable Organic Sulphur)	Variable (less so than Sulphate Sulphur)	High value probably sufficient, low value possible deficient

8.2.1 Resin Phosphorus test

Special mention is deserved for the Resin P test. This utilises a strip of resin in the test suspension of soil to more closely mimic the root uptake of phosphorus as compared to a chemical based test like Olsen P. It has a number of advantages over the Olsen P test in that it does not overestimate available phosphorus in acid soils (Olsen P test is conducted at high pH releasing P normally precipitated with aluminium etc in some acid soils) and it is somewhat less prone to seasonal fluctuations. And, importantly for many organic farms, it gives a better idea of phosphorus availability when the main fertiliser type has been RPR (RPR is resistant to the sodium bicarbonate extraction used in the Olsen P test).

8.2.2 Trace Elements

There is still a disliking of soil testing for trace elements amongst New Zealand (and overseas) soil scientists. Part of this is a disappointment in not finding good correlations between trace element test levels and actual uptake by plants. Recently, however, good progress has been made allowing reasonable interpretation of cobalt, copper, zinc and total selenium. Boron soil testing is well established. Trace element testing can also be useful in monitoring the effect of a fertiliser or other management

programme on trace element levels and soil testing can also be useful in explaining the reasons for already identified trace element deficiencies.

The interpretation of these trace elements is improved by taking into account the other factors that affect plant uptake (such as pH, waterlogging, CEC and the relative levels of competing elements). Soil pH and waterlogging appear to largely outweigh (but not completely) the soil test value for iron and manganese (high availability in low pH and waterlogged soils) and molybdenum (high availability in high pH soils).

Many people prefer to use plant tissue tests or animal testing to determine trace element deficiencies as there is generally more information on the interpretation of results and they are a more direct assessment of likely problems.

8.3 Plant Tissue Testing

For most of the same reasons as for soil testing, sampling method is critical for proper interpretation. In the case of plant tissue testing, the type of leaves or area of shoot sampled can be important as can the time of year and crop growth stage. In this document, a number of useful testing methods that suit various situations will be discussed.

8.3.1 Pasture Herbage Testing

Use stainless steel scissors and try to avoid soil contamination (often difficult and indicated by high iron readings – soil also gives false high readings of cobalt, aluminium and to a lesser extent of copper and zinc).

There are two main strategic types of herbage test, mixed pasture and white clover only.

8.3.1.1 Mixed Pasture

An overall sample of what the livestock will be grazing for animal nutritional value assessment. For plant requirements the clover only test is recommended as this is the plant that will generally show nutritional deficiencies first. (If mixed pasture sample is desired for testing plant requirements then it is best to standardise the sampling to include 25% white clover as the levels of many elements are very different from white clover to grasses).

8.3.1.2 White Clover Only

A way of assessing what nutrients are limiting this plant that (through nitrogen fixation) pushes the whole pasture along. Sample during vegetative growth, not when flowering or when not growing. Sample poor performing plants rather than healthy plants to heighten chance of seeing limiting factors.

8.3.2 Plant Tissue Testing of Crops

A strategic method is to sample from poor performing plants or areas and from good performing ones and compare. This has the added advantage of not relying so much on recommended levels (which may not even have been established for some crops). With some crops (e.g. many tree crops), plant tissue testing may be more suitable than soil testing because the root system is deeper than the soil sampling depth (can be very significant for potassium and elements affected by potassium level).

8.4 Some Alternative Testing Methodologies

The organisers of this workshop requested information be included on some specific alternative testing methodologies which are increasingly available and utilised in New Zealand. These are the Soil Foodweb testing, the Reams Test, the use of a refractometer for Brix levels and the USA based Brookside Laboratories.

8.4.1 Soil Foodweb

The Soil Foodweb offers microbial testing of soil, plant roots, composts and compost teas. This can include estimation of the active component of soil and fungi in the soil as well as protest numbers and the numbers and community structure of nematodes. They can also provide an assessment of the level to which plant roots are colonised by beneficial mycorrhizal fungi.

The results of this testing need to be interpreted with caution and are perhaps more powerful when comparing two different treatments within the same crop to overcome the lack of calibration and the likely variability and seasonality present in such tests.

8.4.2 Reams Test

Proponents of the Reams Test point to the idea that the modified Morgan weak acid extraction method employed is a better indicator of truly plant available nutrients than stronger acid or alkaline extractions used in many other soil tests. The Reams Test includes a number of ratios that are claimed to be important for good functioning soil fertility and crop quality.

The Reams test should not really be relied on as a replacement of other soil testing methods but may have some value in providing more of a snapshot of what nutrients are available at a particular time and thus help diagnose issues occurring in the crop. There is no great proof around the ratios and some caution is warranted in overreliance on ideal ratios if this translates into questionable fertiliser practice and expenditure.

8.4.3 Refractometer (Brix) of pastures and other crops

Common amongst proponents of the Reams approach and other Biological Agriculture approaches is the use of a refractometer to measure the Brix level of plant sap. The refractometer is a standard device used in the horticultural and brewing industries typically to measure soluble sugar levels. In Biological Agriculture circles it is widely considered that high Brix levels indicate good sugar levels in plants which will mean high quality and pest/disease resistance. In plant sap, the Brix reading does give an indication of sugar levels but also other dissolved solids. Brix levels are changeable according to part of the plant sampled, crop cultivar, and time of day as well as general conditions. Caution is advised in interpretation and with the use of supposedly ideal or target levels.

8.4.4 Brookside Soil Test

This soil test is available through New Zealand agents with the analysis being performed in the USA. The export of soil samples to the USA is okay for analysis as long as the samples are dried appropriately first (drying under too high a heat will

exaggerate available nutrient levels). The Mehlich III extraction is used for most of the nutrients tested in a basic test there including trace elements. This probably provides a reasonable indication of plant availability of the elements but not much calibration work has been performed for New Zealand.

The Brookside soil test interpretation is partly based on the Base Cation Saturation Ratio (BCSR) Theory which considers that there are ideal ranges and balances for the base cations calcium, magnesium, potassium and sodium. While this makes some theoretical sense, the theory does not appear to hold up to experimental scrutiny and caution needs to be taken in making fertilizer recommendations on the basis of trying to achieve ideal ratios.

9. Ways of Achieving Good Soil Fertility

Soil organisms are affected by temperature, moisture, light, vegetation, food sources and many other factors. The general aim is to provide a system that has a minimum of shocks and fluctuations and ample opportunities for the organisms to carry out their function of decomposing organic matter. A more specific aim is to encourage the soil biology towards more of a mull soil (with the possible exception of some forestry operations).

The addition of organic matter increases microbial activity by providing both a mineral source and a food source for soil organisms. This is in line with the organic philosophy of feeding the soil to feed the plant. Management practice should also focus on...

Conservation of Soil Organic Matter

Adding organic matter (e.g. compost, mulch, suitable manure additions, feeding out to livestock in an area)

Limiting cultivation

Maintaining soil cover

Not removing crop or green manure or pasture residues where possible

Incorporating at least 2 years continuous restorative pasture in crop rotations

Preserving Soil Structure

Not cultivating when too wet or dry

Not over-cultivating

Growing some crop plants, green manures and pasture plants with deep or fibrous roots

Good calcium availability helps flocculation (binding aggregates through holding colloids, humus and clay particles, together)

Soil Nutrients

Maintaining optimum pH levels

Ensuring sufficient available calcium

Addressing other limiting nutrient requirements

Not over-cropping or over-stocking

Ensure Good Soil Cover

Not grazing pastures too low

Utilising cover crops

Undersowing crops where practical

Mulching where appropriate (benefits discussed further in Module 4 Plant Nutrition)

9.1 Fertiliser Inputs

9.1.1 Approved Fertiliser Materials

This section contains the names and attributes of fertilisers available for use in organics (approved by some or all certifying bodies). Some of these fertilisers are restricted by one or more of the certifying bodies and may be used only after permission has been obtained for a justified reason (e.g. low relevant soil test or plant test level and unavailability of other options).

Table 2.1. Elemental Symbols

Element	Elemental Symbol	Element	Elemental Symbol
Nitrogen	N	Boron	B
Phosphorus	P	Manganese	Mn
Potassium	K	Copper	Cu
Sulphur	S	Zinc	Zn
Calcium	Ca	Cobalt	Co
Magnesium	Mg	Selenium	Se
Sodium	Na	Molybdenum	Mo
Iron	Fe		

9.1.1.1 Phosphorus

Reactive Phosphate Rock (RPR) (12-13% P, 33% Ca)

Different sources of RPR can vary somewhat in their P content and ease of accessing that P. Some of the types available in New Zealand are shown in Table 2.2 below.

Table 2.2 Source and Composition of RPR

Source	% P	% S
Egyptian	12 to 14	~1
Gafsa	11 to 14	Negligible
Sechura	13 to 14	~1

The availability of P from weathering RPR in the soil is one of the main disadvantages of RPR compared to superphosphate. This can either be worked around (e.g. don't plant crops relying on fast P availability from the RPR or plant them after a pasture or covercrop phase that has utilised the RPR well and the decomposing incorporated residues can provide fast available P to the crop). Alternatively, the RPR can be finely ground (a process requiring the right heavy equipment, as the RPR is hard on machinery) to increase weathering speed or the RPR can be composted as below.

There are now voluntary limitations on cadmium (a heavy metal contaminant of phosphate rock) content in phosphate rock imported and sold in New Zealand. Cadmium availability is lower with the use of RPR rather than superphosphate (the residual acidity on granules of superphosphate increases cadmium release) but cadmium load in the soil is still a reason used for minimising the input of phosphate fertiliser.

Composted RPR (12-13% P and 32% Ca, variable S)

RPR can be composted in hot compost heaps or fermentations but is generally done at 1-5% of the heap by volume. Reasonably priced composted RPR can now be

purchased in New Zealand (so far in 2008, only as BioPhos in the North Island) and this has a P content of up to 12.3%. The availability of phosphorus from RPR is greatly increased by composting as found in trial results.

The composting process mostly acts on the citric soluble component of the RPR (just over 30% of total P) making this P more available by action of organic acids and enzymes (phosphatases).

9.1.1.2 Potassium

There is still much work to be done on efficient and sustainable application of potassium without the use of soluble salts.

Feldspar (9% K in high content Potassic Feldspar)

Feldspar has a disadvantage of very slow release of potassium and a relatively low potassium content in comparison to the potassium salts. There is limited commercial availability in New Zealand.

Potassium Sulphate (40-42% K, 17-18% S) (Restricted)

Up until 2003, this was an interesting situation where mined potassium chloride was not allowed by some New Zealand certifiers e.g. Bio-Gro whereas potassium sulphate produced from chemical processing of potassium chloride was sometimes allowed (albeit with restrictions). The main reason for this situation was the undesirability of chloride levels, for soil soluble salt build up and antagonism of chloride to some soil life and some plant roots. Now alternatives to chemically processed potassium sulphate have become more available, the use of non-mined potassium sulphate is no longer allowed. Over time it is expected that mined potassium sulphate will become more available in New Zealand but at this time, patentkali and potassium chloride are more commonly used.

Potassium Chloride (48% K) (Restricted)

Mined potassium chloride is now allowed by all New Zealand organic certifiers as a restricted input. Some organic practitioners are not happy with this seeing the chloride component as being potentially negative for soil life. Do not use potassium chloride on susceptible crops such as strawberries, raspberries and lettuce to avoid root damage. Also prevent close contact of potassium chloride and small seeds such as clover in the soil. This is the cheapest form of potassium and the potassium is highly available.

Patentkali (25% K, 6% Mg, 17% S) (Restricted)

This is available as a mined mineral rather than being chemically extracted or transformed. Potassium is mostly present as highly soluble potassium sulphate. Some magnesium is supplied also which can often be advantageous, aiding the base cation balance (balance between calcium, magnesium, potassium and sodium, which can compete with each other for uptake and utilisation), avoiding magnesium deficiency due to excess potassium. A variety of other mined minerals are available or being explored, though some of these contain a large proportion of chloride in them (see cautionary notes on potassium chloride).

9.1.1.3 Sulphur

Sulphur can be sourced from some of the fertilisers mentioned above and from gypsum detailed under calcium. Often the main fertiliser source is as elemental sulphur.

Elemental Sulphur (98-99% S)

Roughly three parts of limeflour are required to balance the soil acidification effect of applying one part of elemental sulphur.

9.1.1.4 Magnesium

As well as dolomite (discussed under calcium), there are other sources of applying magnesium.

Calcined Magnesite (52% Mg) (Restricted)

This is magnesium oxide and contains a high level of very available magnesium. The release is suitable for overcoming problems with excess potassium levels but use is restricted because of the fast release nature and the potential for creating temporary magnesium increases.

Magnesium Sulphate (20% Mg, 26% S) (Restricted)

Magnesium sulphate (Epsom salts) is mostly chemically derived and is only allowed with restrictions. It is suitable for foliar applications (soluble) to give a rapid response in magnesium deficient plants including tree crops where soil treatment with magnesium may have limited effect.

Kieserite (Restricted) (15% Mg, 20% S)

This is a naturally mined form of magnesium sulphate which is also a fast release product. Appears to work fast enough to overcome seasonal potassium excess problems.

9.1.1.5 Trace Elements

Where there use can be justified by e.g. plant test or animal blood/liver test, visual symptoms etc, trace element fertilisers may be utilised. Bio-Gro considers that this should only need to be a temporary measure until a system is improved (unless there is a distinct local trace element deficiency). In some cases there is a choice of trace element fertiliser types in which case, for example, a product like boronat (mined ulexite) should usually be the source of boron rather than boric acid or sodium borate.

9.1.1.6 Calcium

Calcium products are usually used for pH lifting and/or soil conditioning (structure and biology) rather than actual supply of calcium as a plant nutrient. The main form is as limestone, dolomitic limestone and gypsum.

Limestone (24-39% Ca)

Effective at lifting soil pH and supplying calcium requirements for soil biology and plants and improving soil structure through flocculation (aggregation). Lime varies from source to source in total calcium carbonate content but the biggest difference in effect is usually related to particle size. Agricultural lime (AgLime) has large particle

size and although crop fine lime is finer and much faster acting, it is not so suitable for aerial application.

The finest grade of limestone is limeflour with particle sizes as low as an average of less than 5 micron (usually around 20 micron). If limestone particles are 20 times as fine, they release calcium by weathering at around 20 times the rate. Limeflour also has an advantage of better incorporation into the soil further speeding up rate of release. The rate of release is so fast that soil solution pH is lifted despite the amount of buffering a soil might have so there can be a good temporary liming effect even in a very heavy acid soil. The effect though is one of priming a soil, stimulating soil biological activity, increasing release of minerals from organic matter and stimulating plant growth. The effect on pH in the long term is generally the same as a similar amount of coarser limestone. So limeflour is used as a stimulant rather than a means of permanently lifting soil pH (and sustainability must be watched – it should be used in conjunction with a programme of organic matter incorporation or legume presence).

Dolomite (20-25% Ca, 11-13% Mg)

This form of limestone (also called dolomitic limestone) contains a reasonable proportion of magnesium carbonate as well as calcium carbonate so as well as its liming effect, it provides magnesium. It is an effective magnesium fertiliser in many situations although the release of magnesium may be too slow in some circumstances to overcome seasonal high levels of potassium which induce magnesium deficiency. In such case, calcined magnesite or magnesium sulphate could be used if permission is granted.

Gypsum (18% Ca, 23% S)

Gypsum (calcium sulphate) is a source of readily available calcium and sulphur. It improves soil structure by adding calcium but has more or less no net effect on soil pH as the calcium is balanced by the sulphur. The sulphur component may cause some of the drawbacks of other soluble salt fertilisers in that it could lead to significant sulphate leaching, reduction in soil biological activity (balanced largely though by the calcium) and an imbalance with other elements.

9.1.1.7 Rockdusts

There are two main approaches with rockdust. The application of significant amounts for the actual provision of nutrient is possible although the amounts required may be large and the availability of elements could be questionable. The best rock dust sources are probably include basalt and serpentine. It would be advisable to have a chemical analysis and interpret this properly before deciding to purchase and apply. An on-farm trial might be warranted also.

The other approach with rock dusts that is mentioned is applying them for their paramagnetic or radionic quality. Often very small amounts are used and the basis for such use remains doubtful.

9.2 Compost and Farm Yard Manure

Artificial fertiliser didn't come around for no reason. Compost and Farm Yard Manure (FYM) is bulky for the amount of actual N, P, K and other elements it

contains. Furthermore, the concentrations of elements are variable and the sources may be limited. As resources become more limited and as people realize the value of compost that goes beyond the elements added, there will hopefully be more recycling of these “waste” materials and an improvement in the sustainability of our wider society (including the use of composted sewage on e.g. green manure areas or tree crops).

On a practical level, there are some basic considerations. The approximate amount of nutrients added in the compost or FYM should be taken into account in the nutrient budget for a crop. If material is coming from outside the farm the organic certification may require hot composting, residue test and documentation etc. In many cases, the hot composting or fermentation of FYM will be beneficial to control the loss of nitrogen and prevent too much nitrogen and disease-causing bacteria compromising crop quality or safety.

Attention should be paid to storage of materials before use or composting. Covering can reduce leaching problems and can keep some material dry and undecomposed before going into a hot compost.

Nutrient Composition of Organic Materials (N,P,K)

Material	N %	P %	K %	Dry Matter %
<u>Livestock Manure</u>				
Cow manure	0.5-0.8	0.15-0.2	0.6-0.8	25-30
Horse manure	0.6-0.8	0.1-0.2	0.3-0.5	50-60
Pig manure	0.6-1.0	0.2-0.4	0.4-0.7	25-30
Poultry Manure (broiler)	2.0-2.5	1.5-2.2	1.0-1.5	60-75
Poultry manure (cage)	1.5-2.0	1.4-1.8	1.0-1.3	40-50
Sheep manure	1.5-2.0	0.4-0.7	2.0-2.5	50-60
<u>Other Material</u>				
Seaweed (kelp)	0.2	0.05	0.5	70-80
Fish meal	5.0-10	1.0	<0.1	80-90
Garden compost	2.0-4.0	1.0-3.0	0.5-1.5	65-80
Grain straw	0.3-0.7	0.1-0.15	0.8-1.3	70-80
Mushroom compost	0.3-0.7	0.1-0.3	0.7-1.2	70-85
Wood ashes	-	1	5	95

The benefits of applying compost and farmyard manure include:

Provision of elements required by crop

Improvement in soil organic matter levels

and potentially:

Provision of beneficial microorganisms to the soil

Provision of active substances (acting as a biofertiliser)

9.3 Green Manures

In cropping rotations, there are many benefits from including in green manures. The varied benefits are listed below and from any single green manure species or combination of two or more species, it will be possible to achieve several of these at once. There are some alternative names for green manures that partly reflect the aims of the crop. “Green manure” perhaps implies an emphasis on providing readily

available nutrients (the nutrients gathered by and contained in the green manure will relatively quickly be released after incorporation to aid the establishment and growth of the next crop – perhaps mustard or a legume with the latter meaning another aim of nitrogen fixation). “Catch crop” might imply an emphasis on reducing leaching and capturing leached nutrients (e.g. the use of deep rooted chicory). “Cover crop” might mean a priority of protecting the soil surface (useful in extreme environments) or one of outcompeting or preventing establishment of weeds (perhaps choose a vigorous crop like mustard and buckwheat or very tall crops like ryecorn and triticale). “Restorative crop” places emphasis on soil structure (perhaps with a fibrous rooted grass component).

Table 5.1. The Benefits of Green Manure Crops

Benefit
Nitrogen fixation
Protect soil surface from rainfall and drying
Prevent erosion
Preserve soil surface organic matter and microorganisms from UV damage
Maintain or improve soil structure
Improve soil depth and drainage
Reduce susceptibility to leaching (N,S,Ca,K)
Return leached nutrients
Access nutrients from lower soil profile
Provide readily available nutrients to the next crop
Trap cropping of soil pests
Weed Control
Conservation Biological Control of Plant Pests

9.3.1 Green Manures and Organic Matter

Most green manures will have no significant direct effect on soil organic matter levels. They should be more considered as soil protectors and conditioners and as a source of relatively fast release nutrients to the following crop. Indeed some green manures may be so good at decomposing that more organic matter will decompose than was returned to the soil. In many cases such a green manure crop would be best mixed with another compatible species whose nutrients are slower to be released.

9.4 Mulching

The laying down of plant residues, compost and animal manure can have many benefits on soil condition and plant growth. Weed control with organic, paper/cardboard or plastic/weed mat mulching can also be a labour saver. Of the choice of mulches there are varying benefits as shown in the table below.

Benefits of Mulching Types.

	Straw	Clippings	Compost	Manure	Plastic
Lift Organic Matter	++	+	+++	++	
Add Nutrients	++	+++	+++	+++	
Control Weeds	++	++	+	+	+++
Conserve	+++	+++	+++	++	+++

Moisture					
Reduce Temperature Fluctuations	+++	+++	+++	++	+
Increase Temperature	++	++	+	+	+++
Improve Microbial Activity	++	++	+++	+++	
Aid Earthworms	+	++	+++	+++	
Erosion Control	++	++	++	++	++
Control Leaching	++	+	++	++	+++
Long Lasting	++	+	+	+	+++
Biodegradable	+++	+++	+++	+++	

Blank: No significant action (or negative), +: Okay, ++ Good, +++: Excellent

The amount of nutrients added as a mulch depend of course on the type and amount of mulch used.

Mulching is not right for every system. It can be very labour intensive though there are possibilities of machine laying of plastic or paper mulches. It may also get in the way of required operations on the soil e.g. controlling perennial weeds that will overcome or survive the mulch.

9.5 Liquid Fertilisers, Microbial Inoculants and Biostimulants

There is an increasing (even perplexing) choice of biological fertiliser options, seaweed extracts, microbial extracts, microbial inoculants and the like. There is also an increasing grower and researcher interest in these products. And there is also a high level of skepticism. Biofertilisers is a generic term given to fertiliser formulations which are biological in origin and claim (give?) to give benefit beyond the amount of elements contained in the product. It is worth noting that the amount of elements added are often very low indeed and even the trace elements may not really be added in significant quantity to make any difference to the system.

The claims of benefits usually include some of...

- increased plant growth
- higher Brix levels (more “energy” in the plant)
- better plant nutritional quality
- increased ability for nutrient uptake
- increased fine feeder root formation
- particular benefit for legumes (e.g. in pasture)
- increased nodulation in legumes
- increased chlorophyll content (for photosynthesis)
- lower free nitrogen content in plant tissue (higher quality)
- reduced pest and disease pressure

Most of these aspects lend themselves to testing and in the case of commercial products, manufacturers may or may not be able to provide research data of their own or from independent testing. It is possible to set up simple trials to go some way towards establishing whether the product is worthwhile in a particular system. Many organic practitioners will make their own products which saves money at the expense of taking time and energy. Such “home-made” products might utilize resources which are on-farm, nearby or relatively free.

Some of the techniques used by commercial companies might make a higher value product than home-made products (this could be tested) and the extra financial outlay may be worthwhile – a case by case pragmatic decision. This does not, however, sit well with the idealistic aim of reducing outside commercial inputs.

All of the above benefits have some basis in scientific literature but results from biofertilisers are characteristically variable perhaps due to product quality and probably also due to environmental fluctuations and the vagaries of not understanding the actual modes of action. Any use should be on a trial basis preferably with appropriate experimental controls to assess effect.

9.6 Biodynamic Preparations

(This section material supplied by Gill Bacchus, OANZ). The biodynamic preparations have been developed from recommendations made in 1924 by Rudolf Steiner (1993). Procter (Grasp the Nettle) has provided detailed descriptions of how they are made and applied. They consist of:

- The field-sprays, horn-manure (500) and horn-silica (501), are made by burying horns filled with cow manure during the winter, or with finely-ground quartz during the summer, respectively. Only small quantities are needed – about 25g/37L/ha (500) and 1g/37L/ha (501). A third preparation has recently been added: horn-clay, alluded to by Steiner (1993) to mediate between the 500 and 501. The horn-manure is sprayed on the soil or pasture in spring and/or autumn to activate soil life. The horn-silica is sprayed up in the air over plants to “increase light activity” in the plants.
- The compost preparations 502 – 507, which are each made by decomposing particular plant parts in specific animal parts buried in soil. About 1g of each of these is placed separately in a compost heap or liquid fertiliser to bring order to the decomposition processes.
- Equisetum (508), which is made up as a homeopathic solution to spray on plants for pest and disease control.

Some research into the effects of individual preparations (e.g. Remer et al., 1995) enables understanding of their function and how specific preparations can be used for specific purposes. However, it is generally recommended that all the preparations be applied each year to the land at appropriate times because they were developed to be used together bring about balance and harmony

References

- Remer, N. 1995. Laws of life in agriculture. Trans. Castellitz K., Davies B. Bio-Dynamic Farming and Gardening Association Inc. Kimberton, USA.
- Procter, P., Cole G.L., 1997. Grasp the Nettle. Random House, New Zealand.
- Steiner, R., 1993. Agriculture. A series of lectures given in 1924. Gardner, M. (Ed.). Translated by Creager, C.E., Gardner, M. Bio-Dynamic Farming and Gardening Association Inc., Kimberton, USA.

10. Nutrient Budgeting

The gains and losses to an agro-ecosystem should ideally be balanced for long term sustainability. Those losses that are not actual useful production should be minimised so that the requirement for brought in fertiliser and organic matter is diminished. The sources of gains and losses are discussed here.

Gains

- Brought in Fertiliser and Organic Matter
- Any brought in material adds nutrient elements to the farm system though the amounts contained in the organic matter will be very approximate.
- Brought in Feed
- Bringing in Feed for livestock also represents a gain for the system. The ideal organic system would normally grow its own livestock feed.
- Biological Nitrogen Fixation
- Not many elements have a large amount arriving into the system for free. Nitrogen from the atmosphere is, however, fixed biologically and in the ideal organic system usually represents the main nitrogen input.
- Brought in Seed/Plants/Livestock
- This category is usually reasonably small though in some systems that are either very low exogenous (outside) input or others that involve the bringing in of seedlings or the bringing in of weaned livestock, this category could be significant.
- Weathering/Soil Depth Increase
- Each year there is a bit more of the parent material accessed and weathered to release some of the important elements. Not so significant for nitrogen but important for potassium and phosphorus.
- Deposition
- Wind and rainfall carries in some net nutrients each year (although wind eroded sites may lose more than they gain). Deposition can take care of sulphur and sodium requirements in some coastal areas (excess sulphur in acid rain overseas). Small amounts of phosphorus and nitrogen are inputted in rain and dust (large amounts of nitrogen in industrialised countries). Deposition may also be significant in systems that gain nutrients from nearby wild areas, transferred by birds or free ranging stock.

Losses

- Removed in Produce/Livestock/Culls
- The removal of produce and livestock (e.g. for sale) represents a loss of nutrient elements. Where the amount of a nutrient removed is low, this allows for a quite efficient nutrient budget. In some cases, for instance potassium in

some crops, the amount of a nutrient removed in produce needs to be addressed with significant amounts of brought in material.

- Lost in Dung/Urine Transfer
- Transfer of nutrients to camping sites is an inefficiency that can be avoided to some extent by good fencing and adequate provision of shelter. On flat land it can usually be kept quite minimal. Loss of dung and urine nutrients in dairy races and sheds can become highly significant unless there is a good method for recycling wastes back on to pasture and preferably over as much of the farm as possible.
- Lost from Leaching
- Leaching can account for major losses of nitrogen (as nitrate) and sulphur (as sulphate). Most of these leach out taking calcium or sodium with them but there can also be loss of potassium and magnesium. A well designed system should seek to minimize leaching losses which pose not only a budget problem but also an environmental and health (nitrates in drinking water) issue. In most soils, phosphorus is highly immobile and does not leach much at all (e.g. <math><0.2 \text{ kg P/ha}</math>).
- Lost from Surface Run-Off
- Phosphorus may not leach much but significant losses can occur from surface run off. This can be reduced by not applying soluble phosphatic fertilisers, not leaving large granules on the surface, good soil structure (especially water infiltration) and avoiding excessive applications of phosphorus.
- Lost to the Air
- Some elements can be lost as gases. This happens after the denitrification of nitrate with nitrous oxide (a greenhouse gas problem) and elemental nitrogen being returned to the atmosphere. Nitrogen can also be lost to the atmosphere as ammonia (volatilisation). Sulphur and nitrogen are mostly lost to the atmosphere when organic material is burnt. In anaerobic conditions, some sulphur can be lost as hydrogen sulphide or within volatile organic substances.
- Amount Locked Up in Soil
- Elements locked up in the soil may be effectively lost from the system (timewise). There can be a net lock up of most of the elements in the soil organic matter if the soil organic matter levels are rising significantly. The main potential problem though is with phosphorus being chemically bound to soil minerals and then becoming occluded beneath aluminium or iron oxides. The net loss of phosphorus to occlusion can be kept to a minimum by not applying high rates of water-soluble phosphatic fertilisers, maintaining a good pH (especially not too acid) and having high soil biological activity.

11. Soil Fertility Programme

One of the first steps in developing a soil fertility programme is to analyse the intended system including budgeting for nutrient gains and losses. The choice and rates of fertiliser application are then based on the experiences of the farmer and others and make up for losses calculated in the budget and indications from any soil or plant testing are taken into account.

11.1 Healthy Soil – Healthy Plant

The aims of a fertiliser programme should go beyond creating the maximum dry matter production or yield of plants. In the organic system it becomes more important than ever to design a soil management and fertiliser programme that improves soil ecology and produces a healthy plant. This entails looking at the types of inputs and the overall balance of elements applied.

One of the greatest potential problems in plant quality that can impact feed value and susceptibility to pest and disease is the excess uptake of nitrogen and to some extent phosphorus.

11.2 The Desire for Rapid Nutrient Availability

A major premise of organic agriculture has been to avoid the excess availability of single nutrients such as nitrogen and phosphorus. This is often achieved by using compost or slowly weathering minerals, which will release a balance of nutrients over a period of time affected by soil conditions of moisture, temperature and biological activity. The organic system also relies on seasonal release of nutrients from the pool of soil organic matter.

The slow and seasonal release of nutrients in organic agriculture can cause a commercial setback. If a crop takes say two weeks longer than conventional crops the premium for early production could disappear before the organic crop is ready (a premium for organic production is often small compared to the premium for early or late production. Slow release of nutrients can also be a problem for some nutrient demanding crops that might require for example high phosphorus levels early in crop development. Many crops have also been shown in conventional growing to have increased from strategically timed nitrogen side dressings e.g. sweetcorn, maize, smaller grains, many fruiting vegetables.

11.2.1 Rapid Nutrient Supply in Organic Cropping Systems

One rather artificial way of increasing the rate of growth of plants is to use greenhouses (can be portable to allow market garden flexibility, maximisation of use and minimisation of soil build up of soluble salts). If organic growers adopt tunnel house use, significant commercial gains can be achieved. The risk remains that as other growers adopt the use of tunnelhouses, the commercial gains reduce (this is part of the sometimes vicious market forces which can mean that every advance simply means that commercial growers must work harder on a larger areas to make the same money). It is, however, organic farmers than stand to gain the most from portable tunnelhouses since they offer an improvement in natural soil mineralisation of nutrients and a cleaner crop.

The problem of slow nutrient availability can also be addressed by adjusting the fertiliser programme. One option is to use fast nitrogen releasing materials such as meat, blood or fish meal. The irony is that these materials can cause some of the same imbalance/excess nitrogen issues as soluble salt fertilisers including measurable increases in plant nitrate levels. They are partly for that reason restricted fertilisers in Bio-Gro regulations. It might be argued that they are less of an issue because they are also adding a range of other nutrients at the same time and they are still utilising/feeding the soil life. But such materials are probably best incorporated into a composting or fermentation system to reduce the potential for imbalances. Animal

manure should usually be treated in a similar manner or at least be well rotted (thus also avoiding potential harmful organism issues).

A less harsh method of releasing nutrients in sufficient quantity for grass feeding plants is to grow or carry in green manure that is incorporated a short time before crop planting (usually at least two weeks before hand – to avoid affecting the crop with initial nitrogen robbing decomposition or harmful decomposition products). Some green manures such as lupin can be efficient at accessing mineral forms of phosphorus.

Other fertiliser options for fast nutrient release include using a finer particle size of mineral fertilisers. Halving the average diameter of particle doubles the surface area and the rate of weathering increases accordingly. Applying very fine particles can be a problem for machinery in which case it could be mixed with material such as agricultural lime or compost. Applying in suspension is an ideal method though costing money in bringing in an applicator or setting up for application.

Finely ground limestone, limeflour, can have an indirect effect on nutrient availability by stimulating soil biological activity and increasing the rate of mineralisation. This can provide the extra speed of nutrient release required for early crops, nutrient demanding crop establishment and replace the need for nitrogen applications at strategic times in crop growth (probably best to time applications one to two weeks before the stage at which nitrogen fertiliser would be recommended). The use of limeflour in this manner is only sustainable if there is a programme of organic matter addition or legume led fertility build up (and is limited in how many times it will be effective without such a build up).

Liquid fertilisers are popular for providing strategic boost to plant growth. Any effect will usually be related to either the nitrogen content or a biofertiliser aspect to the product (and any limiting trace elements). One advantage of liquid fertilisers is fast response. Attention should be paid to the rest of the fertiliser/input programme to ensure that overall sufficient nutrients are being added to meet losses (liquid fertilisers contain low quantities of the major nutrients). Liquid fertilisers allowable in an organic situation can be even more nutrient limited as they cannot include soluble salt derived nitrogen, or phosphorus.

In pasture, the setbacks of slow release are usually less or even non-existent but there may be scope for using finer particle size of minerals especially when converting the pasture into the use of RPR and when relying on elemental sulphur for addressing a sulphur requirement. These fine particles may need to be supplied in suspension if such a service exists in the area or a slurry machine is suitable enough. The main challenge in pasture fertiliser programmes is to grow the legumes well (clovers especially have a poor root system for nutrient uptake in comparison to grass). It should be noted that a purist approach to organics could encourage working within seasonal limitations such that produce is available strictly when in season. The economic feasibility of this is dependent partly on the marketing system and how much the grower needs a high yield or a premium for early produce.

11.3 Pastoral Fertiliser Strategies

Although the aim with cropping fertiliser includes producing food of good quality, this is much more of an economic and system performance requirement for pasture

fertiliser programmes. Grazing livestock have limited choice of what they eat. The pasture needs to be presented with as balanced a mineral nutrition as possible. This includes no shortages of essential elements, and no excesses of potentially troublesome elements. The level of highly available nitrogen is particularly important as is the balance of the base cations (calcium, magnesium, potassium and sodium).

The aim of a pasture fertiliser then is to grow reasonable quantity of as high a quality of grass as possible. The success of a fertiliser is often simply judged in terms of dry matter of pasture grown but the aim of most livestock systems is livestock performance not just pasture bulk.

Clover and other legumes are a key focus of a good fertiliser strategy – they drive the pasture along with biological nitrogen fixation and clover is a poor competitor with grass. The requirements of clover should be analysed as discussed in Section 8.3. If phosphorus, sulphur or trace elements are limiting they are more likely to be affecting the performance of clover and beneficial forbs than grass species. It is these species too that appear to respond better to foliar fertilisers, biofertilisers and improved soil biological activity.

Improving the quality of feed with fertiliser strategy can include encouraging good pasture composition and simply not applying highly available nutrients. If there is scope for foliar application of nutrients (by spray or suspension) then this can provide an efficient means of applying elements which are not taken up very well by some or all plants from the soil e.g. salt to improve palatability and stock health in the face of naturally high potassium levels or ranks grass and trace elements for plant performance and animal health.

Further strategies in a pasture fertiliser programme are to address seasonal feed deficits (these feed pinches are either a hassle/costly in terms of supplementary feed or they lead to depressed growth rates and conditions). In an organic situation, seasonal deficits should ideally be addressed system based strategies such as a variety of pasture and fodder plants supplying year round feed. The options for a fertiliser approach are reasonably limited mostly relying on stimulating soil biological activity at the times of need e.g. with limeflour or biofertilisers. The success of this may be variable and is affected by how cold the soil temperatures are.

11.4 Integrated Strategies

In mixed cropping, a good strategy is to focus any added mineral fertiliser on the pasture phase to grow good clover levels and general pasture production. The pasture grasses will be particularly efficient at accessing resources such as phosphorus and sulphur from the applied fertiliser and convert them to an organic form (the grass itself) and release some to the surroundings. Many mixed cropping systems will be largely reliant on nitrogen provision from the clover so it makes good sense to support this.

A variation on this strategy is to apply mineral fertiliser onto large areas that are used for providing green manure, pasture clippings or mulching/composting material (including the straw from arable cropping). This material can then be transferred to a smaller area of intensive cropping.

The presence of livestock can be taken advantage of by feeding them with otherwise potentially troublesome wastes e.g. orchard or processing wastes for pigs. This provides produce and animal manure. The animal manure can be used in composting operations and the strategic supply of readily available nutrients.

11.5 Foliar Fertiliser

A major organic philosophy is to feed the soil to feed the plant. There may, however, be scope for using foliar fertilisers in certain situations. The uptake of certain elements is dramatically higher by foliar means than through the soil. This is the case with most trace elements as well as magnesium and, for many plants, sodium (which may be desired for livestock). Iodine, for example, has practically no measurable effect on plant tissue levels when applied to the soil. Selenium, however, is taken up efficiently from the soil. The other trace elements fit in between these extremes. Foliar applications are effective regardless of soil pH and other conditions that might prevent uptake from the soil.

Foliar fertilisers also give an opportunity to apply biofertilisers to the foliage, which may increase further the efficiency of nutrient uptake and give a strategic increase in growth. As mentioned above, liquid fertilisers contain very small levels of nutrients which although sometimes (though each product need checking) this might be sufficient for trace elements, the requirement for major elements should be addressed to aid sustainability.

12. Certification Standards and soil management

This section is taken from the Smart Start Template.

12.1 General Principle

Organic farming returns microbial plant or animal material to the soil to increase or at least maintain its fertility and biological activity.

12.2 Recommendations

- Biodegradable material of microbial, plant or animal origin produced from organic practices should form the basis of the fertility program.
- Nutrient resources should be used in a sustainable and responsible manner. Nutrient losses from the farm to the natural environment should be minimized. Nutrients should be used in such a way and at appropriate times and places to optimize their effect.
- Accumulation of heavy metals and other pollutants should be prevented.
- Naturally occurring mineral fertilizers and brought-in fertilizers of biological origin permitted under these standards should be regarded as only one component of the nutrient system, and as a supplement to, and not a replacement for, nutrient recycling.