Organic Pastoral

Resource Guide

Second edition: Project Manager Esther Dijkstra, EcoAgriLogic Ltd

Soil & Health Assn • Organic Dairy & Pastoral Group • BioGro NZ • Bio Dynamic Assn

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Organic Pastoral Resource Guide

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Organic Pastoral Resource Guide

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Preface to first edition

In the first half of 2001 a successful application to the Sustainable Farming Fund was made on behalf of the Bio Dynamic and Soil and Health Associations. The project aim was to draw on the knowledge and experience of established organic and biodynamic producers and make it more widely available. The first step was to identify key sectors where we felt the project would make a difference and involve experienced organic people, associated with those sectors, who were keen to contribute. As a result we focussed the project on: dairy/pastoral farming; and avocado, citrus and summerfruit production. Successful organic producers are pioneers, as they acknowledge that there are always more questions than answers and thus are continually taking on new challenges. That capacity has been very evident in this project. Individuals have taken on multiple roles: they have acted as workshop facilitators, field day organisers and presenters, and have written and collated material for a series of resource guides. Many others have contributed through their participation at workshops and field days, by acting as reviewers and giving their time to make written contributions. This resource guide is a result of that work.

It is important to be clear as to what this resource guide isn't and what it is. It isn't a detailed technical "how to" document, as there is no simple prescribed pathway towards successful organic production and there are still many more questions than answers. It is a number of things. First and foremost it is a multi-authored collation of existing knowledge, presented from a practical perspective. Second, there has been a deliberate weaving together of organic and biodynamic information. The purpose of weaving together a range of views is to provide you with choice – take what is relevant to you at any given time and ignore what you don't consider to be relevant. Third, it is intended to be a practical "living resource". We've drawn together what is known to help you avoid making the mistakes that others have, to achieve success more quickly, and to allow for clearer identification of gaps in knowledge so that these can be addressed. In summary, this document won't make you a good organic producer. It is meant to guide, not to prescribe.

Gavin Kenny, Earthwise Consulting Ltd

Project Manager

August 2003

Preface to second edition

A further grant from Sustainable Farming Fund in 2008 made it possible to update the contents of the Organic Pastoral Resource Guide. The concept of this guide, being a multi-authored collation of existing knowledge, has remained unchanged from the first edition.

We regrouped information in the various chapters of the first edition to give the resource guide a better flow.

New in this manual is an addition to the chapter Pasture Management and Cropping. It is a section on crop production written by Charles Merfield.

While the animal health section in the first edition of the guide was mainly based on organic dairy, this time we extended the information on organic sheep, goat and beef management to make this resource a more all-round pastoral guide. The information on goats was compiled by Julia Geljons.

The internal parasite section has been adapted from a publication on that subject by Organic Aotearoa New Zealand (OANZ) and included with permission.

Material from the Grow Organic Dairy project (MAF/SFF 08/017) about organic animal health management and organic pasture and weed management has also been included in this manual.

The information in this manual was as much as possible checked against the references and current, but ever changing, organic standards.

Esther Dijkstra, EcoAgriLogic Ltd

Project Manager

December 2010

Chapter One: Introduction

What does one see on an ideal organic pastoral farm?

When one first walks onto the farm, it has a feel of its own, of strength and balance.

The animals are healthy and contented. There are shade and shelter trees at various stages of growth scattered over the farm to protect the animals. There may even be herbal leys under the trees so the animals can graze them.

The pasture of clover and rye plus mixed herbage, includes species such as plantain, subterranean clover, cocksfoot, chicory and timothy. It is deep green and holds its own longer during a drought, and comes away again quickly when the rains come again. There may even be crops and silage when and where it is needed. The grass, at times, may not appear to be long or bulky; however the energy levels tend to be more concentrated and balanced in nutrients, and the animals seem content.

Of course all this strength is coming from the soil beneath. If you put your spade in the soil, dig up a soil profile, and begin to look carefully, many small but important aspects begin to appear. Firstly you can see and sense a jam-packed mass of life in a world of its own, with enzymes, microbes, fungi, algae, arthropods, bacteria all interacting to produce the necessary elements for a healthy soil. There will be evidence of earthworm activity throughout the profile. The soil will show a deep humus layer at the top, roots that reach right down into the subsoil and no clearly defined line separating the humus and subsoil. It will show a mixing of colours and soils instead. We, as farmers, can add elements such as liquid fertiliser, lime and RPR (reactive phosphate rock), to help this process. The topsoil is a healthy depth and growing each year, the soil is breathing, and there is no litter on the top of the ground thanks to those worms and enzymes. The number of worms will keep increasing each year.

Because the soil is healthy, alive and balanced, the grass in turn is balanced and healthy, which makes for healthy animals and in turn a healthy, life-giving product for the consumer.

How is this achieved?

Over the last few decades all farmers have become more aware of the need to become more sustainable on the farm. This has led to greater efficiency, through better use of chemicals and other management tools. In so doing, many have taken the first step toward organic farming. This can be called the efficiency step.

The next step is substitution. The basics are a commitment to not relying on pesticides, chemical fertilisers or drugs for the animals. Underlying the whole procedure is the aim of getting the soil active and balanced and creating an interactive ecosystem. The rest then tends to follow. Basic requirements are lateral thinking plus the ability to make good observations. A good conventional farmer will make a good organic farmer. Many farmers begin slowly and take one aspect at a time, for example using fish fertiliser or homeopathy, trying other things once they are comfortable to do so. They join a discussion group, or find a mentor, or an email network to keep in touch with others. There are many methods around and many farmers use a combination as to what suits them. The reality is that things are never perfect and we are always learning.

You then begin to redesign your operation. You resolve the problems not through efficiency or substitution but by looking at why they are there and how you can work with nature. You may begin to look at your farm as a dynamic organism made up of interrelated processes and activities. The closer one can come to this organism being self contained the better. This approach capitalises on the efficiencies of nature and enables significant reductions in inputs.

A simple but far reaching example is the establishment of a well sited and effective shelter belt. This could well serve a range of purposes over time:

- To provide shelter from the cold and a place to feed out, where stock are able to use more of the feed energy in development and less on merely staying warm.
- To provide shelter at birthing, which will reduce stress on both dam and offspring and probably reduce mortality and the need for other support measures.
- To provide shelter for pasture, reducing evaporation and wind stress.
- To provide stress reducing summer shade for stock.
- To stabilise soil in possibly erosion prone sites.
- To provide a source of future timber and possibly fencing materials if ground durable trees are judiciously incorporated and sustainable harvest is considered in the shelter design.

These benefits have been clearly shown on many farms to outweigh any losses to pasture growth from shading, a reason given over many years for not planting trees on pastoral properties.

Another example is the use of mixed herbal leys mentioned above, instead of a typical dual species of ryegrass and clover. Having a range of different plants in the sward provides more nutrition and a balanced diet to stock. The inclusion of deeper rooting species enables a cycling of nutrients from a greater depth in the soil, a reduction in soil compaction from the soil structuring effect of roots and an increase in drought tolerance.

A re-consideration of animal numbers and species composition on mixed and cropping farms can also help in a range of ways to further the closed system. Cross-grazing of stock has been shown to be very effective in parasite and general pasture management; the benefits and limitations of different soil types and topography can be worked with more effectively. Crop residues may well be utilised by cattle.

You look to create a healthy environment and you look at your farm in the context of the whole ecosystem. If you thought it was a big step to become organic when you get to the redesign stage you will find it is an even bigger step (or leap) to develop a whole farm system approach. Some people find that substitution is as far as they wish to proceed. They can still be certified organic producers and are happy to remain at that stage. There are models and support networks available for those interested in moving to the redesign stage. Two of these include biodynamics and farm forestry.

A warning however, it is not possible to eradicate all animal health problems on a farm due to simply pushing nature outside its boundaries a bit. Some also believe it is unavoidable to lose some production under this regime, but not necessarily lose profitability. This concept will be challenged in the future. Regardless of which stage you are at crises will occur from time to time; these are there to challenge us. The important thing to remember is makegood observations and attend to detail to ensure immediate action. Once committed to organics, there are no crutches to fall on, so building a resilient system is the key.

About this resource guide

This resource guide will give you some answers to the many questions you may have, and will no doubt lead you to asking many more questions.

The design and content of this resource guide has been shaped by the experiences of practicing organic farmers. It has four main sections: soil and soil fertility, pasture and cropping, livestock (animal health) and the environment of organic farms. These four sections relate to the progression experienced by many who have converted to organic farming but it is not a recipe for organic farming. Rather it provides a range of options and ideas for you to choose from.

There are two key ingredients to being a successful organic pastoral farmer:

1) Access to information and looking at your options – this resource guides provides you with a start and will give references to additional information. What works for others may not work for you. If you can't find the answers to the questions that you have this is where support networks become important.
2) Support from others. You can achieve this by:

- Joining an organic discussion and support group. This can be a big help. It enables you to have support, especially through the transition period. Once you have some experience you will in turn help support others in the group;
- If there is no discussion group in your area, try and get one going, even if it is only two or three people; and,
- If this is not possible, find yourself a mentor that you can phone and visit when you need to (www.ruralmentor.co.nz).

The distinction between organic and biodynamic agriculture

Organic farming (sometimes called biological or ecological farming) is defined as a system whereby a fertile soil is maintained by applying Nature's own law of replenishing it through the addition and preservation of humus, the use of organic matter instead of chemical fertilisers and the making of compost and mulching (J.I. Rodale; *Encyclopaedia of Organic Farming*, 1959).

Organic farming started in New Zealand in the 1940s as an alternative to using synthetic chemicals in farming and food production. The skills and techniques which had been developed in home vegetable gardens and orchards began to be applied to larger commercial enterprises. Organic farming is based on a philosophy, key principles, and defined practices that create and maintain fertile soils sustainably, which is the foundation for healthy food and healthy people. It is based on the pioneering work of the likes of Sir Albert Howard and Lady Eve Balfour in the UK and J.I. Rodale in the USA.

Biodynamic agriculture is founded on the work of Rudolf Steiner who gave a series of lectures to farmers in 1924. It encompasses the basic principles of organics but also works with interactions between the cosmos and earth.

The grower needs organic methods that work, and to know that changing to organics is practically and financially sustainable. Biodynamic methods as an approach to organics, give advantages to the grower. Firstly, they are practical tools for soil management, such as the biodynamic preparations and the planting calendar, utilising resources and helping the farmer to practice organics more efficiently. Secondly they give some guidelines to help growers with their decision on changing to organics. It enables them to observe effective changes in soil properties, plant growth and animal health.

Organic growers often say that they needed to change the way they think, and that's the challenge. They have to develop new ways of thinking about their enterprise and this is where the biodynamic approach is a great help. In organic farming the holistic approach means that the grower needs to take a broad and often a long- term view – for example anticipating soil fertility issues well ahead, and managing them before they become problems. Biodynamics gives guidelines to work with and enhances the soil fertility from the start.

Something important to always keep in mind, it is optimal to use all the Biodynamic practices and integrate them as they work in together; however, you do not have to be a Biodynamic or Demeter farmer to use these methods. Each one is a tool in its own right to be used to enhance all forms of organic farming. There are many BioGro certified farmers using biodynamics as well.

Milestones of the Organic Sector in New Zealand

Late nineteenth century - Pre World War II European Roots

- The population in Europe was moving off the land, population numbers were exploding and the new working class in Britain were spending their wages on food, rather than self-provisioning as they had done before
- At the same time technological development was providing machinery and chemical farm inputs. Often these chemical inputs were by-products of the heavy (steel) industry
- In this light people like Rudolf Steiner, Sir Albert Howard and Lady Eve Balfour started questioning the nutritive value of the industrially fertilised food and the effects of chemical inputs on the soil
- In New Zealand a small group of growers rejected the new farming methods based on unnatural chemical fertilisers. This was supported by a large group of urban dwellers, such as dentist G.B. Chapman. He helped found the Food Reform Society
- Bio Dynamic Farming and Gardening Association was formed in 1939
- In 1941, the Humic Compost Club was formed, which later became the Soil & Health Association of New Zealand. The Humic Compost Club peaked during the 1950s with 6000 members

Post War - Declining Interest in Alternative Food Production

- After World War II food demands from Britain soared and New Zealand farmers prospered by meeting this demand
- The tendency started to emerge for agricultural success to be measured in terms of productivity per acre
- New Zealand took pride in being internationally perceived as a nation leading the world in understanding and carrying out technology based agriculture
- This was supported by state policies and state agricultural research, extension and education agencies expanded
- Superphosphate and organophosphates and organochlorides (DDT family) were promoted

Late 1960s - 1970s - Emerging Organic Agricultural Movement

- In 1968 USA refused entry to New Zealand meat containing DDT residues
- World prices for agricultural products were falling, the wool crisis of 1967/68 the oil shock of 1973 occured and in the same year Britain joined the common market
- Agriculture was encouraged and financially subsidised to search for new and innovative agricultural products

- Smallfarmers Association was formed, which highlighted the changing land-use practices: the decline in commodity prices for traditional farmers combined with a desire to shift from urban to peri-urban residence encouraged considerable subdivision of farmland
- Peri-urban lifestyle development and growing environmental concern among middle class New Zealanders set the scene for the emerging organic agricultural movement
- Immigrants and WWOOFers (weekend workers on organic farms, in New Zealand adapted to willing workers on organic farms) added to the rise of the organic movement
- The Biological Husbandry Unit was established in 1977 and became an important resource for teaching
- By late 1970s consumer demand had reached levels high enough to support a cooperative and small retail outlets in Wellington (The Wellington Organic Consumers Cooperative), Christchurch (Piko Wholefoods) and Auckland (Ceres)

1980s - Today - Internationalisation of Organics

- The New Zealand Biological Producers and Consumers Society (NZPPCS), trading as BioGro NZ was formed in 1984 to promote the concept, study and disseminate techniques, set up and supervise standards, establish a registered trademark and issue the trademark to certified producers
- Large corporate entities like Wattie Frozen Foods, Fonterra and the Fruit boards (kiwifruit, apple) led to an internationalisation of the organic industry
- In the early 1990s, The Organic Products Exporters of New Zealand (OPENZ) was set up to develop the international market
- In 1994 the Ministry of Agriculture published a seminal paper, Towards Sustainable Agriculture: Organic Farming, which confirmed that organic farming was viable in New Zealand
- Organics Aotearoa New Zealand (OANZ), the organic sector's representative body was formed in 2005
- The export market grows from 32 million in 1997 to 170 million in 2009

Note: Adapted from H. Campbell (1996)

Principles & Recommendations for Organic Production

The International Federation of Organic Agricultural Movements (IFOAM) has established the following principles and recommendations in relation to organic conversion to an organic system (IFOAM, 2005).

Principle

Organic agriculture develops a viable and sustainable agro-ecosystem, by working compatibly with natural, living systems and cycles.

Recommendations

- For optimum sustainability of an agro-ecosystem, all activities including crop production, animal husbandry and general environmental maintenance should be organised such that all the elements of the farm activities interact positively.
- Practical farming skills, based on knowledge, observation and experience are therefore important for organic growers. Careful practice based on skill and knowledge often avoids the requirement for synthetic inputs, and reduces reliance on inputs.
- Conversion may be accomplished over a period of time. A farm may be converted by gradual introduction of organic practices over the whole farm, or by application of organic principles to only a portion of the operation at first.
- There should be a clear plan of how to proceed with the conversion. This plan should be updated as necessary and cover all aspects relevant to these standards.
- The plan should indicate that the totality of crop production and animal production in the operation will be converted to organic management.
- Standards should determine how organic and non-organic production and product can be clearly separated and distinguishable in production and documentation, to prevent unintentional mixing of inputs and products.
- Independent sections of the operation unit should be converted in such a way that these standards are completely met on each section before it is certified as organic.

NOTE: These Principles and Recommendations are guidelines only. You will need to familiarise yourself with the appropriate New Zealand organic standards, such as the BioGro Standards, Demeter Standards or AsureQuality Standards.

Organic certification

Organic certification is necessary if you would like to access markets. Organic certification might not be needed if you would like to sell your products to your local farmers' market, but it becomes crucial if you would like to sell your products to processors or if you would like to export your products. Organic certification is intended to assure product credibility, product quality, prevent fraud, and to promote commerce.

New Zealand has four main organic certification agencies each with their own set of production standards, certification systems and audits. BioGro and AsureQuality are able to certify against international standards and work as part of New Zealand's Official Organic Assurance Programme. The Bio Dynamic Farming and Gardening Association is the certifier for Demeter, an international certification system that assesses against biodynamic standards. OrganicFarmNZ is an organic certification system, tailored for small producers wishing to supply the New Zealand market.

The conversion process takes a minimum of 2 to 3 years depending on the level of certification and market access you are seeking. The first year is generally called Registration Year, Stand-down period or C0, The two subsequent years are called 'In Conversion' or C1 and C2. You will become fully organic certified after two or three years if you comply with the organic standards and stay fully certified if you continue to farm within the certification standards. You will be audited yearly. The time it actually takes to gain full organic certification depends on your previous farming practices and your approach to incorporating the organic principles into your farming practices during conversion.

Choosing the right certifier is one of the most important and significant decisions in the conversion process to organics. As a producer you want to make sure that your certifier is a good match for your type of production, the way you operate and your target markets. It is advisable to consult with the appropriate certifiers and find out who provides the best match. More information about certification and a checklist is available from the OANZ website: www.oanz.org.nz.

After registration with your preferred certifier you will have to complete a management plan and update this every year. Your management plan will form the starting point for an audit. A management plan provides details such as past, present and future developments on your property, on topics such as soil fertility and pasture management, livestock management, and animal health and environmental management. Your certifier will have examples or templates of management plans available.

Record keeping

You will have to start recording all inputs and outputs, including restricted input you wish to use.

1. Keep good records. Buy yourself a diary and fill it out everyday. Trivial details will become important, so keep a record of everything, how you used it, what for, how much, at what rate, where it came from.
2. Read and keep all labels. Ask questions before making purchases or using a product. Once you are registered with the certifier, you must have proof from them of their approval for all products you use. Don't accept salespeople's words; ask for written approval (certificates etc). Make sure that the actual batch or product you are buying is the one that's on the certificate. There have been cases of certification lost when the actual product purchased was not the one certified.
3. Gather up letters and certificates, especially for brought-in materials, animals and feed as you go. Giving details of the source, any treatments and if so, when, and ensuring that it is free from GE.

Important: Ensure you check the rules of your certifying agency to ensure it is allowed before you use any product. The rules can change quickly and at short notice and it is up to the individual farmer to keep up with them. If in doubt contact your certifying agency to make sure. A mistake can have costly consequences and your organic certification can be at stake.

Each standard has lists of permitted and restricted fertilisers and animal remedies. A permitted material, generally speaking, is one that may be used as of right.

A restricted material is one that the certifying agency wants eventually not to be used at all. However, different agencies have different procedures associated with such lists and such materials, and may have additional specific requirements.

Any product not listed in the rules are generally forbidden.

Minimise contamination

With organic certification it is very important to minimise contamination to your property and crop. It is best to identify the risks and deal with them before contamination happens. Possible sources of contamination, and a potential threat to your organic certification, are:

- Spray drift, runoff and drains from neighbouring properties
- Old spray tanks
- Seed
- Contractors

Conversion issues for livestock

Selecting breeds and livestock for organic farms

Many farmers feel that they do not have the option of buying in the most suitable livestock to start their organic farming enterprise, but have to work with what they have already.

Current breeding tends to focus on producing animals for quick return traits like high milk yields at first lactation, high weight gains at early maturing, and good early fleece growth. These characteristics have often been at the cost of other factors like longevity, fertility, and robustness. Some of our animals are culled from the system due to illness, poor performance or injury before they have reached peak performance.

What we are looking for under an organic system is a way to build on positive animal traits. We are aiming for a profitable system of farming with healthy, well-fed and contented animals. All animals need to have robust constitutions, high natural immunity and vigour to manage pests and disease, be thrifty to grow and reproduce with high fertility and few health problems.

While there is a shortage of organic stock available for rearing on, we may need to consider developing a system with a closed herd or flock. This means a herd or flock which is self-sustaining in terms of numbers and into which we do not normally introduce other animals except under occasional circumstances. Animals bred and reared on the property tend to be more adapted. By selecting the best animals for breeding, you will improve your stock and their genetic fitness in relation to your particular circumstances.

Occasionally we may want or need to bring in new herd/flock sires to introduce or improve particular traits or to prevent continued close in-breeding. Although the sire's contribution to the adaptedness of the offspring is certainly less than that of the dams, it still plays a significant part.

Longevity is encouraged in organic farming. Longevity is important in that, to a certain degree, the farm does become a closed system. Look after what you already have and raise all your own replacements. Feed and treat your entire herd well, especially your young stock.

Over the generations the breeds and individual animals adapted to particular environments and systems of management. There are breeds that have been developed for the New Zealand environment. There still conventional stud breeders around on harder country who have continued to breed a more moderate frame type of animal. You want to work with these breeds (unless you are keen to try something different), but towards the traits that are more suitable to an organic system. Talk to stock agents to help find out who has a reputation for hardy animals. You also need to like the type of animal you are handling. This is a motivator to make things work.

It is unlikely that the animals that you might source will have been reared and managed under an organic regime. It pays to think long-term when making livestock selection choices. Stock that is already managed organically, especially if they have been bred from organically-reared stock, will be able to cope with conversion to organics much better than conventional stock. It seems to be the second generation that makes the difference.

Animals adapt very rapidly to their local environmental conditions. They learn to adapt directly from their parents, particularly the dam. They learn how to forage and develop preferences for plants based on the environment in which they live. They also learn how to adapt to the physical environment in which they are living e.g. weather patterns, ground conditions and wind.

So when selecting stock we also need to choose animals which have come from conditions as close as possible to those on our own farm, that means farming and environmental conditions. Animals which have come from very harsh environmental conditions, will usually adapt fairly well to conditions that are easier. Animals raised in a fertile environment will not perhaps adapt very well to a harsher environment, certainly not for a few generations. If possible try to choose animals, which have been managed least intensively as possible, i.e. farms with a minimal drenching policy, and who use RPR rather than super phosphate, so that their natural immunity and constitution will be least compromised.

A hypothesis: It is preferable to keep the herd/flock sire with the breeding group if at all possible and to maintain mixed age groups rather than separating them out according to age cohorts. This reduces the psychological stress on the animals as they are much more content in this more natural grouping, and it also reduces the rate of re-infestation of the young stock from the environment of pathogens like intestinal parasites, since the older immune animals act as pasture cleaners.

Cross-breeding and grading-up

If you are farming at a commercial scale you may need a cross-breeding programme, utilising the traits of more than one breed and the hybrid vigour of your terminal sires for increased size and vigour in your calves and lambs. This approach can still work well in an organic system since different breeds provide access to other traits. Remember that hybrid vigour dilutes very rapidly after the first cross and then you are left with a highly variable gene pool. You will need to be regularly bringing in new purebred sires, and often replacement dams too, to maintain the genetic consistency and traits you want. In doing this you can lose some benefit of the stock adapting to their specific environment. An alternative is to run a commercial crossbred herd/flock and a small purebred group, specifically for replacements.

Due to the lack of availability of organic stock you will probably need to compromise and buy in some replacement stock for your organic conversion, but being left with the task of grading-up with your existing animals to achieve the livestock genetics you are looking for a little way down the track. Your carefully selected bought-in animals will make this task much easier, as they will bring in much of the genetics that you are aiming for, and then it is a matter of planning your breeding programme to make best use of this and spread it through the flock/herd. At the same time you will also be able to select the genetic traits in your existing stock that enables stock to thrive under the new organic system. This is obviously not a simple or quick task, it takes time and you will have set-backs and failures. However, that is to be expected and so don't let it put you off your overall goals.

Some of your existing animals won't be able to cope under the new regime. If they are ailing under an organic regime they may need to be culled depending on their ailments. However, if a dam is failing due to a lack of adaptation rather than to any predominantly congenital defects, then it pays to keep their offspring. The young animal will have full exposure to the new environment from birth and so will have a much better chance of doing well. A good example of this is intestinal parasites in sheep. While a dam may not be able to cope with exposure to a higher worm burden and start to ail, her offspring will have been getting antibodies passed to them through her milk as the mother's body has tried to respond to the threat. Natural immunity in our stock is one of our main allies. However, sometimes the opposite will occur and an ailing dam will produce ailing offspring. This tells us that there is something missing in the genetics of that line and we don't want it in our organic flock/herd. It is very much a matter of close observation, keeping an open mind, and acting accordingly.

Beef

Cattle have evolved over many thousands of years, and since having been domesticated, they have been bred especially for beef, dairy or draught. When keeping beef cattle a true beef breed to suit the conditions must be selected. These will be efficient converters of pasture to good tender beef. They must also be very quiet to handle. Dairy breeds produce more milk and draught breed develop coarse heavy muscling to pull implements etc, but these are not suitable for top quality beef production.

Suckler beef systems are probably the easiest of all livestock systems to convert to an organic regime as we are making use of the unrivalled abilities of the dam to look after her offspring. Mature cattle have a much higher resistance to parasites and disease than sheep on organic farms, as it is much closer to their natural environment of wet, lowland grasslands and woodland edge.

Cattle thrive best on fertile, wetter soils, with reasonable drainage. They like quite tall pastures, with a lot of roughage, so they can wrap their tongue around it when grazing. Beef cattle are quite hardy, and if given a bit of shelter and plenty of good organic grazing, will have very few health problems at all.

Beef systems also tend to be some of the least intensive systems in farming. The main requirements of the organic beef enterprise are that they are based mainly on natural pasture grazing. Calves should be left on their dam for a minimum of 3 months, preferably much longer, with natural weaning being the ideal. The time of weaning is the main danger time for organic beef as this is when the young calf is exposed for the first time to its environment without any support from its mother.

Beef cattle in some parts of the country have had little or no serious breeding for generations. If you want a robust, adaptable animal, it would be difficult to go past the Angus cattle of the steep North Island papa country, encompassing eastern Taranaki, Wanganui and southern King Country. These cows only get to see real grass for about 3 months of the year if they're lucky, the rest of the time their diet seems to consist largely of thistles, fern, rushes and pasture the sheep have left behind. Despite this, they maintain good condition and, as long as they get a bit of copper (papa is severely copper deficient), they get in calf easily. If yearlings are well fed after weaning, they can be calved as 2 year olds.

These cows are run in a virtually chemical-free system, many of the farms having had little or no fertiliser on the hills for 20 years. Economic circumstances mean that little in the way of animal remedies are used. Adult stock is only ever likely to receive a copper injection and the odd liver fluke drench. This means they have become well adapted to a harsh environment.

Dairy cattle

Forty years of artificial breeding with the emphasis on milk production has resulted in a very different dairy animal. The modern cow will lose an awful lot of body weight in order to continue milking if she is inadequately fed. Her udder is like a huge parasite in this respect.

This was largely not the case up until the 1970's where if starved beyond a certain point, cows would tend to dry off rather than lose too much condition. They were possibly more 'robust' (they certainly got in calf easier than today's cows) probably because of this self-preserving characteristic. However, these cows were not particularly efficient due to the relatively high proportion of feed they needed for maintenance.

Today's dairy cows are very efficient at converting grass to milk. It is possible to fully feed cows on a conventional farm but not sustainable. Organic farming has the opportunity to provide cows with a balanced diet in a sustainable fashion. It is a matter of adjusting stocking rates to ensure they can be fully-fed all year round. Having big, high producing cows and less of them is one way of maximising productive, economic and ecological efficiency, although there are aspects of management which need consideration with this approach (e.g. possible difficulties in controlling pasture quality in a good season and controlling pasture damage in a bad one).

Sheep

Sheep are native to dry habitats in Asia and so they are the most difficult to keep healthy and thriving under organic systems in our wet pastures here in New Zealand. Unlike mature cows, ewes do not act as pasture 'vacuum cleaners' for parasites all year round, as at lambing they become increasingly susceptible to internal parasites and act as infective agents on the pasture, causing a double-dose effect when the lambs are starting to graze. Preferably they need to be cross-grazed with cattle, particularly at this time and when the lambs are weaned, so that the cattle can help to clean the pasture.

Sheep can be kept organically successfully without cross-grazing with cattle but there needs to be plentiful range of clean grazing available to keep moving the sheep onto, and a good range of natural herbs in the pasture to allow the sheep to self-medicate. Preferably the lambs should be kept on the ewes as long as possible to get the best start as the larger more thrifty lambs are much less prone to problems from worms. If possible allow the lambs to self-wean, especially during the conversion period when your pastures won't yet be fully mineralised and balanced, and your stock's immunity will be being tested to the full in trying to adapt to the new regime.

The selection of the right breed of sheep for the conditions is very important. Like cattle, sheep have evolved over many thousands of years, and many different breeds have become established to suit different environments and conditions.

There is also a large variation of types or strains within the breeds. Some have the ability to withstand varied seasonal conditions, with good resistance to parasites and diseases, but some don't. Unfortunately a lot of the hardiness has been bred out of some sheep now, and these cannot be kept under an organic situation, but can survive quite well under a chemical farming situation, with drenches, dips, vaccines, antibiotics etc. Some hardy strains are still available so these are the ones to keep. Parasite and facial eczema resistant rams are now available in some common breeds.

Animal handling and intervention

We must ensure that our animals are stress-free and live as contented lives as we can possibly give them. It also means that our animals are likely to be healthier, do better and live longer, and that their meat, milk or fibre will taste better or be of better quality.

Most mutilations of stock are prohibited under organic certification. Even permitted mutilations should be reviewed in the context of your own operation to evaluate whether or not they are actually necessary. Tail docking of sheep is a good example. It tends to be carried out as a routine practice without regard to its implications for the animals. Anyone watching tailed sheep will soon realise that their tails have some important functions to perform, which is presumably why they were given them. During dunging sheep use their tails to disperse the droppings away from their back ends, to keep themselves clean. If the tail becomes soiled, it is attractive to flies, and is a nuisance to the shearer trying to cut away the soiled wool. The tail can be left on to perform its essential functions for the sheep, which also include acting as a fly swat and keeping the vulva warm and clean. Another part of the solution may be to use the Wiltshire Horn as a terminal sire to eliminate unwanted wool in the crutch area and on the tail.

All handling of livestock should be done with the minimum of stress for animals and humans. Animals should be moved quietly and calmly and in an unhurried manner, using an understanding of their natural behaviour to anticipate their reactions and working with them to achieve the desired result. They should be handled firmly but gently to avoid injury to either them or to the handler. All handling should be of minimal duration, and at all times there should be adequate shade and shelter, especially over yards or where animals are held for any length of time, and fresh water should always be available. It can get to the point on an organic stock rearing farm where the only handling that becomes necessary is annual tagging, with possibly also drenching and weighing at weaning time. Apart from that it's just a matter of standing and admiring them! It must be remembered though, the less you handle them the wilder and more stressed they will be when you do. Moving amongst them every day, talking to them, helps them to get used to you and they learn to trust you.

All stock transportation also needs to be done with minimum stress. Each certifier will have their own specific restrictions, but basically they are there to ensure consideration and high welfare for the livestock. For organic meat production it is certainly worthwhile trying to develop a good relationship with your nearest abattoir and persuading them to become certified to handle your slaughtering, as distance to slaughter is one of the important considerations in organic meat quality. Years of good handling and management on the farm can be undone by animals highly stressed by a long distance travel to slaughter and bad treatment prior to killing.

NOTE: At all times, the minimum standards of the Animal Welfare Act Code of Practice must be adhered to.

It is important to remember an animal is not allowed to suffer. If this means administering an allopathic remedy, then it must be done. The animal will no longer be organic and must be put into the quarantine paddock.

All animals treated must be held in the quarantine paddock and lose their organic status for a certain period. Check the standards of your certifying agency for details.

Quarantine paddocks

This is a designated area of the property (clearly identified on the farm map) where any treated stock and any incoming conventional stock can be run for the duration of the required quarantine period. No other organic animal can graze this area at any time and it cannot be used for the production of certified crops.

Be nice to your cows:

Do you talk quietly to your cows, pat them in the paddock and use the alkathene to guide them rather than hit them? If not, the results of a major six year study into human/animal interactions carried out in Australia suggest you should. Endearing yourself to your cows can improve production by up to 10% and the report also concluded that fear of humans accounted for up to 20% of the variation in milk yield between farms.

During the first stage of the study, farmers were asked to answer a questionnaire on their attitudes towards cows and how they handled their animals. This was combined with direct observation of stock handling and standard tests of avoidance used to assess fear. The researchers were able to establish that:

- Negative attitudes to patting or talking to cows correlated with more pushes, slaps and hits
- The more often slaps and hits were used, the more fearful the cows
- Fear of humans was associated with lower productivity

The second part of the study involved 94 Victoria dairy farms and set out to see if a change in farmer behaviour would result in a change in production. Half the farmers were put through a training course which emphasised that while slaps and hits may sometimes be necessary, they should be greatly outnumbered by positive behaviours - patting not hitting, talking not shouting. The course was followed up with booklets, newsletters and regular visits. By the end of the trial period most farmers reported a marked improvement in cow behaviour and a change in their own beliefs about how much force is needed. There was a significant production increase at zero cost to farmers which, it was pointed out, also fits neatly with the new industry emphasis on animal welfare and quality assurance.

A similar scheme is now being tried out on pig farms.

Source: *The Veterinarian*, 2001 (Australia).

Useful contacts

Organics Aotearoa New Zealand

Phone: 0800 FUTURE (0800 388 873)

Email: info@oanz.org.nz

Website: www.oanz.org.nz

BioGro

Phone: (04) 801 9241

Email: info@biogro.co.nz

Website: www.biogro.co.nz

AsureQuality

Phone: 0508 001122

Email: certificationservices@asurequality.com

Website: www.organiccertification.co.nz

Demeter - Bio Dynamic Farming and Gardening Association in NZ

Phone: (04) 589 5366

Email: demeter@biodynamic.org.nz

Website: www.biodynamic.org.nz

Organic Farm NZ

Phone: (09) 419 4536

Website www.organicfarm.org.nz

Soil & Health Association of New Zealand

Phone: (09) 419 4536

Website: www.organicnz.org

Standards New Zealand

www.standards.org.nz

International Federation of Organic Agriculture Movements (IFOAM)

www.ifoam.org

Organic Dairy and Pastoral Group (ODPG)

www.organicpastoral.co.nz

The Biodynamic Consultancy Society (Inc)

Phone: (06) 874 9064

Email: volkop@clear.net.nz

Website: www.biodynamic.org.nz/consultants

DairyNZ

Website: www.dairynz.co.nz

Rare Breeds

Have a browse through the following websites for information on different breeds to see what could be most suitable for your needs:

NZ Rare Breeds Society

www.rarebreeds.co.nz

Australian Rare Breeds Trust

www.rbta.org

British Rare Breeds Survival Trust

www.rare-breeds.com

Some examples of older breeds that are available in NZ:
Dairy: Guernsey, Ayrshire, Brown Swiss

Beef: Welsh Black, Galloway, Red Devon, Red Poll, Sussex

Wool sheep: Leicester and Lincoln Longwools, White-headed Marsh

Meat sheep: Wiltshire Horn (no wool), Ryeland, Dorset Horn

For a more in-depth background the following are recommended readings:

Fukuoka, Masanobu. 1978. "*The One Straw Revolution*". Rodale Press, Emmaus, Pennsylvania.

Howard, Sir Albert. 1943. "*An Agricultural Testament*". Oxford University Press, New York and London.

King, F.H. 1911. "*Farmers of Forty Centuries*". Rodale Press, Emmaus, Pennsylvania.

Mollison, Bill and Holmgren, David. 1982. "*Permaculture One: A perennial agriculture for human settlements*". Tagari Publications, Stanley, Tasmania.

Steiner, Rudolf. 1993. "*Agriculture*". Bio Dynamic Farming and Gardening Association Inc., Kimberton, Pennsylvania.

Chapter Two: The Soil

Soil. We walk on it every day. We drive over it. We dig in it but do we really know what it consists of? We will have to have a review of what 'soil' is so that we have some appreciation as to what we are farming with. Then we can begin to appreciate some of the profound effects that some of our day to day practices do to our soil.

Soil physical properties

The soil should consist of the following - minerals, organic matter, water and air in the approximate ratios listed below.

Minerals - 45%

Organic matter - 1 to 5%

Water - 25%

Air - 25%

Nearly all crops and pastures need all four components in a correct balance for optimum growth.

Minerals

Minerals form the matrix of the soil. The mineral portion has originally come from weathered rock (the 'parent material'). Rock is weathered by mechanical forces like water, wind and ice until the parent material is broken down into gravel, sand and silt (for more information see the Texture box).

Chemical reactions with substances from the air, water, and plant material break down the rock further into clay minerals and salts. Weathering is a very slow but consistent process.

The delivery of cations (calcium, magnesium, potassium and sodium) and micro nutrients largely depend on weathering. Weathering also maintains the cation exchange capacity (CEC).

Texture is the feel of the soil, reflecting the portion of sand, silt and clay sized particles as well as the amount of organic matter mixed with them.

Sandy soils feel gritty, silts smooth, and most clays are sticky and plastic (i.e. they can easily be moulded into shapes when moist). The textural differences among the soils of New Zealand reflect both the age of the soil (duration of weathering) and the parent material.

Since most of our landforms are youthful, and our climate is far from tropical, most soils are relatively young, with sand and silt dominating their textures.

The mix of sand, silt and clay is called a loam. Soil specialists use names for the various loams. The textural name of a soil can be determined from a mechanical analysis. The official composition of loam is a mixture of 40 parts sand, 40 parts silt and 20 parts clay (from "*Soils in the New Zealand landscape; the living mantle*". Les Molloy, 1988)

Soil organic matter and humus

Soil Organic Matter (SOM) is needed to bring the soil to life. Without organic matter, the soil is a dead environment consisting of only minerals. Organic matter plays an important role in the soil in many ways. Organic matter provides a habitat for soil organisms, stores and delivers water and nutrients to both soil organisms and plants, improves the soil structure and therefore the movement of water and air through the soil.

Soil organic matter includes the remains of plants and animals at various stages of decomposition. It can be divided into the follow classes, depending on the degree of decomposition:

- Fresh organic matter
- Dynamic organic matter
- Stable organic matter or humus

Fresh organic matter as in stubble, straw yard manure or incorporated green manure crop, will lose its specific characteristic during the first year due to soil life activity. Soil dwelling fauna (like insects and worms) chop the fresh organic matter into smaller pieces, and mix it with the mineral particles. Carbohydrates and proteins in organic matter are digested quickly by micro-organisms, mainly bacteria. The remainder of the organic matter is called dynamic organic matter.

Dynamic organic matter contains the more resistant organic molecules, such as lignin, waxes, fats and resins. These are broken down into smaller molecules by micro-organisms such as fungi. Dynamic organic matter breaks down at a rate of 5-50% a year.

The delivery of anions (carbon, nitrogen, phosphorus and sulphur, generally combined with oxygen) comes from the decomposition of fresh and dynamic organic matter. The nutrient release slows down at the end of the dynamic organic matter stage. Microbial activity joins small particles together into large and complex molecules called humus.

Lignin

Lignin is a structurally complex, highly diverse and therefore hard-to-breakdown compound that comes from the breakdown and condensation of decomposition of woody plant material. Fungi are just about the only soil organism group that can in fact use the carbon ring structures in lignin as food. As it decomposes, lignin contributes a major fraction of the material that becomes humus.

Humus is that part of the organic matter that has changed significantly both visually and in chemical structure, compared to the original plant and animal residues it originated from. Humus is highly recalcitrant organic matter, consisting of complex 3-dimentional organic structures that remain after many organisms have used, condensed and transformed the original organic material. This biological process is called humification. Humus molecules can still change in composition, and some forms of humus are water soluble; humus is sometimes described as a 'state of matter'.

Humus is a station in the cycle of a number of elements, in particular carbon, oxygen and hydrogen and to a lesser extent of nitrogen, phosphorus and sulphur. Humus is particularly important for the sequestering (storage) of carbon from the atmosphere. Carbon and the other elements will be released slowly from humus by micro-organisms. This process is called mineralisation.

The beneficial properties of humus:

- Humus creates a diverse living environment for soil organisms: a basis for colonising fresh and dynamic organic matter by soil (micro) organisms.
- Humus is the most important factor for good soil structure. This is due to its ability to glue mineral parts together and form soil aggregates. It adds to the tilth and friability of the soil.
- Humus, together with clay determines the cation exchange capacity (CEC) of a soil. Humus and clay are colloids, covered with negative charge, attracting positively charged nutrients (cations). Humus prevents major nutrient losses from the system and the nutrients stay near plant roots.
- Humus aids in making insoluble plant nutrients soluble through chelation reactions.
- Humus reduces toxicity of certain substances both man-made and natural.

Water and air

Water in the soil is very important because it dissolves and carries nutrients and other materials inside the plant and in the soil. Air is important as most of the beneficial soil organisms require oxygen (aerobic).

Water and air make up, on average, 50% of the space in the soil (the range can be 30 to 75%). These water and air filled spaces are called soil pores. In a well-drained soil of moderate moisture about half the pore space will be filled with water and half with air. The amount of water a soil can hold (amount available for plants) depends on the soil type. Sandy soils have relative large pores, and won't hold water well. Clay soils have much smaller pores that hold water well, but don't release it easily.

When the soil doesn't have enough larger, continuous pores to transport air, soil will become anaerobic and deprive soil micro-organisms and roots of oxygen. These larger pore spaces could be filled with water (in waterlogged soils) or been destroyed due to loss of soil structure and compaction (see soil structure). These soils also take a long time to warm up and microbes will be slower to act.

Under anaerobic conditions we can have undesirable bacteria dominating that can cause problems by releasing nitrogen and even toxic by-products such as hydrogen sulphide, methane and nitrous oxide into the air.

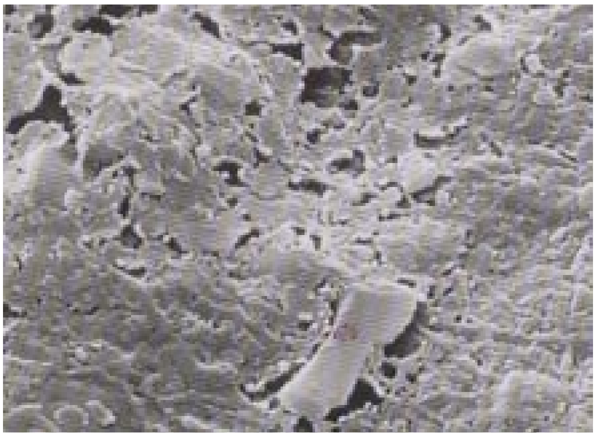
Soil structure

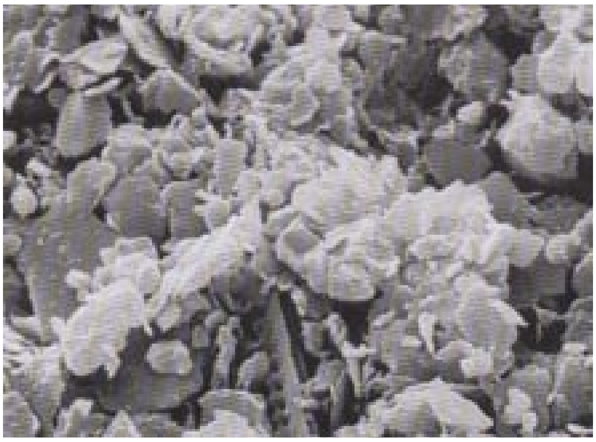
The soil structure is the way that particles clump together to form aggregates or crumbs. These aggregates are the building blocks of the soil.

The soil structure is affected by the original soil type (minerals) and the organic matter levels. Both clay particles and organic matter play an important role in forming soil aggregates, binding individual particles of sand and silt together. A well-structured soil has ample pore space between the aggregates for movement of water and air through the soil.

A good soil structure is vital for the fertility of a soil and will influence:

- Soil aeration
- Storage and transportation of water
- Soil microbial life
- Soil temperature
- Root penetration and development
- Nutrient delivery
- Resistance to soil degradation and erosion





Electron microscopic photo's of pasture soils, showing protective 'glue' (top) or organic matter forming stable aggregates by covering and bridging soil particles, and a soil without the glue (bottom).

Source: *Soil Management Guidelines for Sustainable cropping*. T.B. Shepherd, C.W. Ross, L.R. Basher and S. Saggar (2000) Manaaki Whenua Press.

Soil damage, such as compaction, erosion and loss of soil organic matter can happen very quickly and it can take considerable time and money to correct the damage. Preventing soil damage (or managing the soil structure) will require forward planning and sometimes investments. Any low lying or poorly drained paddocks should get preferential protection during wet periods to prevent pugging. Investing in a stand-off area or feed pad could be an option, if these paddocks make up most of the farm are grazed during high risk periods.

Soil organic matter levels will be maintained under permanent pasture. Cultivation increases aeration, which can increase the number of micro-organisms in the soil needing a food source, depleting the soil organic matter levels. The soil organic matter levels will decrease even quicker when cultivating under warm and moist conditions. Cultivation using minimum tillage will maintain the soil organic matter levels. This requires investment in new skills and machinery.

Cultivation at the correct moisture levels, using the correct tools and managing vehicle traffic all help to reduce soil compaction. Subsoiling, artificial drainage and restorative crops all improve aeration and drainage

Testing for soil physical characteristics

A good way to start understanding your soil better is by studying a soil map. Your regional council should be able to provide you with regional information about soil types. Maps can also be ordered on-line from Manaaki Whenua Press (www.mwpress.co.nz).

There are a number of (expensive) laboratory tests to measure the soils physical characteristics. Soil composition, bulk density, porosity, aggregate stability and distribution, total carbon and organic matter content are a few of these laboratory measurements. Soil density (compaction) can also be measured using a handheld device called a penetrometer.

A cost effective way of monitoring the soil's physical properties is by using a spade and your senses. You can develop your own technique or use the VSA (Visual Soil Assessment) tool developed for New Zealand farmers by Landcare Research (www.landcareresearch.co.nz/research/soil/vsa).

Soil biology

Without the activity of soil organisms, organic matter would accumulate on top of the mineral soil, and there would be no food for plants. In fact a farmer would have far more livestock in the soil than he would ever have in the four-legged variety walking upon it. As most of this underground 'livestock' is not readily visible to the naked eye, the farmer seldom realises the adverse effects some farming practices have on it.

When we appreciate what part each of these organisms play in the soil we can start to understand some of the negative impacts our everyday farming practices have on them. We can also begin to understand why organic accreditation agencies insist on some of these practices being banned, and why there is an increased interest in sustainable agriculture in general.

The soil food web

Information in this section is based, in part, on The Soil Biology Primer (Tugel et al).

The soil food web includes a group of organisms living all or part of their lives in or on the soil. There is a conversion of energy and nutrients, as one organism eats another.

All food webs are powered by the plants, photosynthetic bacteria, algae, moss and lichens, which harness the sun's energy to fix carbon dioxide from the air to make - amongst other things - sugar. Most of the rest of the soil organisms get their fill and energy by eating organic compounds found in plants and other organisms and from waste products. Nutrients end up cycling along the food pathways and get converted from one product to another and are then made available to other plants or other organisms.

The health of a soil is influenced by the variety of organisms. The greater the biodiversity in soil, the greater the food web complexity. Biodiversity is measured by the total number of species as well as the relative abundance of these species.

So in summary all plants - grass, trees, shrubs and crops depend on the soil food web for nutrition. The power of the organisms present in healthy soil should never be underestimated. They can never be replaced with interventions by farmers using solid fertilisers or by using chemicals in an attempt to 'fix' problems. Farmers must appreciate this critical interrelationship between soil organisms and successful or failing soil and crop management. Farmers should farm the soil organisms so that the pasture or crop is fed and so that the soil remains 'alive'. To become better farmers of soil organisms, lets learn a little more detail about each group of inhabitants that should be present in your soil and what each does.

Soil micro-organisms

Bacteria

Unfortunately bacteria are so tiny you need a microscope to see these organisms. They consist of a single cell and perform a remarkably broad set of functions in the soil.

Bacteria are the most abundant micro-organisms in the soil; there can be billions in one gram of soil. There are an estimated 60,000 different species each with their own function. Most bacteria are aerobic (those that need oxygen to live), and live in the top 10 cm of the soil where organic matter is present. Bacteria thrive in the 'rhizosphere', which is the narrow region in and around plant roots. There is evidence that plants produce certain types of root exudates (like sugars, proteins and carbohydrates) to encourage the growth of protective bacteria (and other soil micro-organisms).

Bacteria, like actinobacteria, are important in the decomposition of organic matter, and give healthy soil its characteristic smell. Others cycle nutrients or are disease suppressors.

Bacteria play an important role in the nitrogen cycle. Three important groups of bacteria are the nitrogen-fixing bacteria, nitrifying bacteria and denitrifying bacteria.

Nitrogen-fixing bacteria, can be free living, non-symbiotic bacteria such as azotobacter or azospirillum, or like rhizobia, form close (symbiotic) associations with the roots of legumes. The plant supplies simple carbon compounds (sugar) to the bacteria and the bacteria convert nitrogen (N_2) from air into a form the host plant can use. If you have unearthed a clover plant you will see visible nodules created where the bacteria have infected a growing root hair. If the nodule is cut in half, the interior colour gives an indication as to the state of these bacteria and whether they are fixing nitrogen - a pink colour indicates that they are. When the leaves or roots from the host plant decompose, soil nitrogen increases in the surrounding area.

Nitrifying bacteria change ammonium (NH_4+) to nitrite (NO_2-) and then to nitrate (NO3-), which is a preferred form of nitrogen for grasses and most row crops. Nitrate is the most easily leached form of nitrogen in soil.

Denitrifying bacteria convert nitrate (NO_3-) to nitrogen (N_2) or nitrous oxide (N_2O) gas. Denitrifers require anaerobic conditions so you will find these in waterlogged soils or inside soil aggregates where there is little oxygen.

It is difficult to manage and build bacteria populations by adding bacteria to the soil. Low populations of soil bacteria are most likely caused by unfavourable soil conditions, such as lack of soil organic matter, compaction, waterlogging, dry conditions, acidity or salinity. Any new additions will more likely than not suffer as well. If you want to increase the population of bacteria in your soil, you will first of all need to improve your soil health.

Some bacteria favour wet, poorly drained, anaerobic soil and can produce toxic compounds that can limit root growth and can cause root diseases. Reducing soil compaction and building soil organic matter has multiple benefits and will also support healthy populations of soil bacteria.

Fungi

Fungal cells form long chains called hyphae - a single hypha can range in length from many metres down to a few cells.

These hyphae are only a few micrometers in diameter. Some fungi, such as yeast, are single-celled.

Saprophytic fungi decompose dead organic matter and are commonly active around woody plant residue. Another group, mycorrhizal fungi, are a very important group as they form associations with plant roots. This enables the fungi to get energy from the plant (in the form of sugar) and to help supply nutrients (like calcium, sodium, phosphate etc.) to the plant as these fungi forage extensively. Their hyphae are like extremely fine threads that form a matrix within the soil, source minerals the plant needs at some distance away and transfer these to the root hairs.

Under dry conditions fungi can bridge gaps between pockets of moisture and continue to survive and grow, even when soil moisture is too low for most bacteria to be active. Fungal hyphae bind soil particles together thus building stable aggregates that improve water-holding capacity. This feature explains why biologically farmed land tends to hold on longer during a drought and rebound quickly when the drought breaks.

How to increase fungi in soils:

- Minimise tillage. Tillage disrupts the hyphal network and decreases the number of spores and hyphae to start the process again on the next crop. Some in-ocula of mycorrhizal fungi are commercially available and can be added to the soil at planting time but must come into contact with a root within 24 hours otherwise it will die.
- Use cover crops to maintain living roots for the fungi to colonise.
- Maintain adequate phosphorus level for crops, but do not over-apply soluble P because high levels de-press the activity of these fungi. There is evidence that soluble phosphate and nitrogen sources are not that friendly for mycorrhizal fungi and so their num-bers decline in the soil and with this goes the ability of the plant to have access to minerals that are at a distance from the root.
- Broad spectrum fungicides are also toxic to mycor-rhizal fungi.
- Fungi live in aerobic (need oxygen) conditions so it is important that the farmer attempts to keep the soil in a condition that allows it to breathe. If the soil is water logged or compacted (heavy machinery, pugging by cows, incorrect mineral balance - see the cation section later in the manual) for a significant period of time then generally the soil loses its fungal component.

Algae

Algae can be either unicellular or complex multicellular plants occurring in moist ground or in fresh or salt water. They have chlorophyll and other pigments so can harvest the energy of sunlight to build sugars (carbohydrates), proteins etc. but lack true stems, roots and leaves. This energy source is important for the soil system. This group of plants requires light, water and carbon dioxide for photosynthesis and they do not appreciate being sprayed with herbicides. If herbicides are not degraded in the soil (some of the modern ones cannot be broken down), they will continue to limit algae numbers. This can have serious repercussions for the rest of the food web as an important source of sugar (and other foods) has been lost or reduced.

Nematodes

This family of worms are tiny - usually you need a microscope to see these and they are non-segmented. Most of these live free in the soil.

There is a lot of bad press about nematodes as a few cause plant problems (root feeding nematodes graze on the roots of plants and are not free-living in the soil) but the vast numbers in the soil are in fact highly beneficial. We can have bacterial feeders, fungal feeders, predatory feeders, plant feeders and omnivores who eat a variety of organisms and may have a different diet at each life stage.

Nematodes have many duties in the soil but a key duty is to cycle nutrients. Other duties relate to their activity in the soil. They graze, they spread microbes, they also end up being a food source if they are caught and can be involved in disease suppression. It would appear that they are a pretty versatile member of the soil microbe group.

Whenever nematodes eat bacteria or fungi, plant available ammonium ends up being excreted back into the soil as more nitrogen is eaten than is required by the nematode. So you can immediately see that this group of soil micro-organisms is an important part of the nitrogen cycle.

Grazing activity by nematodes also influences the bacterial population numbers and can impact negatively on mycorrhizal fungi. Nematodes may be a key in controlling the balance between bacteria and fungi in the soil.

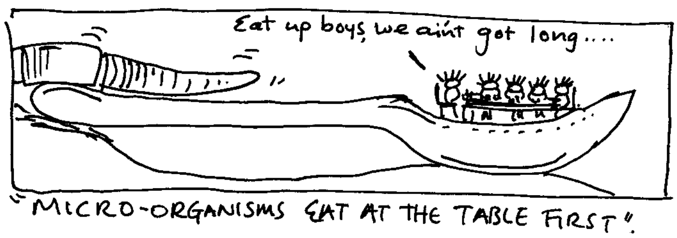
Nematodes can be described as 'taxi cabs'. Their movement helps to spread bacteria and fungi in the soil and along plant roots by carrying live and dormant microbes on their surfaces. When they excrete their waste from their digestive tracts, even more microbes are released.

Nematodes are a source of food for higher level of predators, e.g. predatory nematodes, soil micro-arthropods and soil insects. They are also parasitised by bacteria and caught by fungi.

Nematodes can consume disease-causing organisms or prevent their access to roots. So, in fact this family have the potential to become biological control agents.

Protozoa

These are tiny, single-celled animals and include amoebas, ciliates and flagellates. Their presence in the soil is important for the nitrogen cycle as they graze on bacteria. Excess nitrogen from this process is put back into the soil in the form of ammonium (NH4+). This occurs near the root system of a plant and either the plant absorbs the ammonium ion or other soil organisms use it. One group of amoeba eat fungi by drilling a hole in the hyphae by generating enzymes that eat through the fungal cell wall.



Protozoa also regulate bacterial populations so may influence the numbers of pathogenic (disease causing) bacteria and are themselves a source of food for other soil micro-organisms. Those farmers who do spore counting for monitoring facial eczema risk will have seen protozoa swimming across the microscope field.

Soil meso and macro fauna

Arthropods

Here is a family of soil organisms that can be seen by the naked eye. These are invertebrate animals with jointed legs but no backbone! They include insects, crustaceans, sowbugs, springtails, arachnids (spiders), ants, dung beetles, mites, centipedes, millipedes and others.

Most arthropods live on or in the upper 75 mm of the soil. They can be grouped as shredders, predators, herbivores and fungal feeders based on their functions in soil. Arthropods can be present in huge numbers in or on the soil. For each square meter there can be 700 to 250,000 individual arthropods depending upon the soil type, plant community and management system in place.

If you exclude the herbivore group, which feed on plants and can become pests (clover flea, clover weevil), most arthropods perform beneficial functions in the soil-plant system. Arthropods shred organic material so that the surface area is increased allowing bacteria and fungi to do their work. These organisms act like can openers and greatly increase the decomposition rate. Arthropods eat decaying plant material in order to eat the fungi and bacteria on the surface of the organic material. Arthropods stimulate microbial activity. They mix microbes with their food and, for bacteria who have limited mobility, being moved to a food source is a good idea. Bacteria are carried on the exoskeleton of the arthropod and through their digestive system.

Arthropods mineralise some of the nutrients in bacteria and fungi and excrete these in plant-available forms. Arthropods enhance soil aggregation by their deposits of faecal pellets. These contain a highly concentrated nutrient resource, which is a mixture of organic and inorganic substances required for growth of bacteria and fungi. Burrowing done by some of these arthropods exerts a huge influence on the composition of the total fauna by shaping the habitat.

The physical properties of the soil can change, including the porosity, water infiltration rate and bulk density. Arthropods stimulate the succession of species. Soil arthropods consume the dominant organisms and permit other species to take their place thus facilitating the progressive breakdown of soil organic matter.

Arthropods can also control pests. Where a healthy population of predators is present they will be able to be available to deal with a variety of pest outbreaks. To be able to do this there must still be a food source constantly available so it is important for there to be a diverse and healthy food web.

Earthworms

Earthworms dramatically alter soil structure, water movement, nutrient dynamics and plant growth! That should be enough reason to encourage them to stay!

There are over 190 different species of earthworm in New Zealand, but less then a dozen are most likely seen in farmed soils with mostly two or three dominant types. These worms under pasture are predominantly European species. They came with the early settlers in the ship's ballast or in potted plants. The most common worm in New Zealand is the 'grey worm' (Aporrectodea calignosa). Most native species of earthworms are mainly restricted to the native forest or dense scrubland.

The presence of the earthworm is a good indicator of the health of the soil. A count of 25 per cubic spade of soil indicates excellent soil while below 5 per cubic spade is poor during spring and autumn. Worm populations can be counted by digging out a cube and counting them or by counting their castings (vermicast) on the surface.

Note however that not all soils have earthworms yet they may be good, fertile soils. Earthworms are simply rare or absent in some geographical areas, such as Southland where earthworms were never introduced by early settlers. Sandy soils seldom have many. Also, if the soil is extremely dry the earthworms may be deeper in the soil profile and in a hibernation state – curled up in a tight ball.

Different species live differently and occupy different parts of the soil profile. Some worms live on the surface fragmenting organic matter and recycling the nutrients it contains. Some burrow shallowly or laterally, whilst others burrow deeper into the soil. They will drag fallen leaf material into their holes and shred this, which allows bacteria and fungi to grow on the torn leaves (so earthworms stimulate microbial activity). Earthworms then derive their nutrition from grazing on the fungi and bacteria and even possibly protozoa and nematodes. Worms have the ability to concentrate nutrients from the food they consume and excrete these in the casts (see table). Earthworm castings also have many more micro-organisms than in the organic matter they consume. This increased microbial activity facilitates the cycling of nutrients from organic matter and their conversion into forms readily taken up by plants.

Earthworms mix and aggregate the soil while they go about their business. They can move large amounts of solid matter from the lower strata to the surface and carry organic matter down into deeper layers. No doubt you have seen worm cast piles (vermicasts) on biologically active soil so you can appreciate the amount of soil moved around. They have the potential to turn over the top 15cm of soil in 10 to 20 years.

Earthworms enhance the porosity of the soil as they move. Some worms make permanent burrows deep into the soil. These burrows can persist long after the inhabitant has died and can be a major conduit for soil drainage particularly after heavy rain. At the same time the burrows can minimise surface water erosion. By fragmenting organic matter and increasing soil porosity and aggregation there can be a significant increase in the water holding capacity of soils.

Earthworms provide channels for roots to penetrate deep into the soil and these are already lined with readily available nutrients to feed the plant. Earthworms have few enemies in the soil apart from native flatworms (planaria) and a species of parasitic fly but birds and mammals prey upon them at the soil surface. There are quite a number of products applied to soils that can kill earthworms. Copper sulphate is not very soil microbe friendly and ideally foot-bath fluid should not go into the effluent system as the high concentration of copper will take out a lot of other soil organisms as well. Ammonium sulphate is also very unfriendly on the worm population.

Mineral content of the soil vs earthworm castings

Nutrient element	Soil (0-16cm)	Surface worm casts
Total exchange capacity	22	26
pH	6.5	7.0
Humus %	14	25
Nitrate ppm	4	77
Ammonium ppm	13	66
Total nitrogen ppm	17	143
Sulphur ppm	25	29
Phosphate (eas. extr) ppm	39	155
Phosphate (Bray) ppm	162	253
Calcium ppm	3320	4250
Magnesium ppm	250	420
Potassium ppm	170	253
Sodium ppm	38	39
Boron ppm	1	2
Iron ppm	49	64
Manganese ppm	35	66
Copper ppm	7	30
Zinc ppm	9	33

The above analysis from Brookside Laboratories.

We have now covered all the main soil organisms and you will now have an appreciation for the potential diversity the soil on a farm can achieve if we remove or limit some of the damaging practices that are routinely applied to the soil. Here are a few conventional farming practices to ponder:

- Consider what a fungicide such as that used for killing the facial eczema fungus does to the other fungi in the soil. If we consider the fungus whose spores cause facial eczema of cattle, sheep, alpaca and llama we could also wonder if the problem is exacerbated by the use of soluble phosphates and nitrogen which causes the loss of the highly beneficial mycorrhizal fungi.
- Consider what the effects of the regular anthelmintics (drenches) applied to dairy cattle which are then excreted in either urine or faeces are doing to the nematodes in the soil.
- Again, consider the ionophore called Rumensin (a rumen modifier which kills protozoa) that is used for bloat and ketosis control and production gains and its effects when passed through the cow and is deposited on to the soil (this is believed to be active for some weeks).
- Consider what insecticides do to all the beneficial arthropods. Spraying for a clover weevil or clover flea will kill off many other arthropods resulting in declining soil diversity. As this happens predator arthropod populations decline and the possibility for subsequent pest outbreaks increase.
- Consider what tillage does to soil life. Heavy machinery can cause a lot of damage to soil structure and especially if the soil is very water logged.
- Consider the damage that cultivating in general does to all the various soil inhabitants. Nothing really enjoys being sliced and diced. It is a myth that cutting earthworms in half creates two worms!

Testing for soil biology

Soil biology can be tested for number of species or activity.

Species or population analysis is based on microscopic counts (food web analysis), growing cultures on a variety of growth media (plate counts), or field counts such as earth worm counts.

Biological activity can be tested by measuring the carbon dioxide released (soil respiration), or measuring the nitrification rate (anaerobically mineralisable N).

Indirect measures are monitoring the soil organic matter levels, soil carbon levels or carbon to nitrogen levels, or monitoring the increase of humus in the soil profile. These are measures that indicate how well micro-organisms decompose soil organic matter.

Soil chemistry

While the importance of the soil biology can't be over-emphasised we shouldn't forget the important role of the soil chemistry. As we will discuss later, the role of the farmer is to ensure adequate and balanced levels of minerals necessary for plant and animal growth as part of enhancing plant and animal health. This is at the heart of natural pest and disease control.

One of the major factors influencing nutrient availability is the soil pH as it is the acidity or alkalinity, which determines whether an element is going to be plant available or not. The desirable range for most crops is a weak acid soil (pH 6. to pH 6.4), which will provide good potential for general mineral availability. In this pH range there will also be a reasonable balance between fungal activity (favouring more acidic conditions) and bacteria (favouring more alkaline conditions). True peat soils however will have an optimum more around pH 5.8 while sandy soils have their optimum more around pH 6.4.

The availability of trace elements, such as iron, manganese, copper and zinc can be poor in alkaline soils (pH>6.6). At low soil pH levels, especially <5.5, there can be poor phosphorus and molybdenum availability.

Plants need, apart from air, water and sunshine, the full array of elements in the available form. It is generally stated that 16 elements are required for life processes, to grow, to be healthy and to be able to reproduce. This number will probably be incorrect as there are plants that need other elements like silicon and nickel - but we will concentrate on the main 16 elements - oxygen, carbon, hydrogen, nitrogen, potassium, calcium, sulphur, phosphorus, magnesium, manganese, iron, zinc, chlorine, boron, copper and molybdenum.

Only 5% of the bulk of the plant comes via the soil from minerals, soil organic matter and fertilisers. The other 95% of the plant's needs is freely sourced from the air in the form of carbon dioxide, hydrogen and oxygen (see table below). In the presence of sunlight these elements convert into carbohydrates (sugars, cellulose and starch). This process is called photosynthesis.

Figures for a typical 16 element content of a plant

Oxygen (O)	45.0%
Carbon (C)	44.0%
Hydrogen (H)	6.0%
Nitrogen (N)	2.0%
Potassium (K)	1.3%
Calcium (Ca)	0.6%
Sulphur (S)	0.3%
Phosphorous (P)	0.4%
Magnesium (Mg)	0.25%
Manganese (Mn)	0.05%
Iron (I)	0.02%
Zinc (Zn)	0.01%
Chlorine (Cl)	0.01%
Boron (B)	0.005%
Copper (Cu)	0.001%
Molybdenum (Mo)	0.0001%

The balance of nutrients needed from the soil (the other 5% of the plant) is not just nitrogen, phosphate and potassium (N-P-K). Plants also require trace elements - copper, cobalt, zinc, manganese and molybdenum. Even though these are needed in tiny amounts, it does not mean that there is no point in supplying these. These trace elements are components of enzyme systems and are vital for not only the health of the plant but also for animals and humans that consume them. NPK fertiliser, or rather the phosphate content of this conventional fertiliser, does not supply nearly enough of these trace elements. Soil chemistry (i.e. soil testing) determines the extent to which these elements are sufficiently available and in balance for plant uptake and utilisation.

Crops or pasture need various amounts of each mineral throughout the growing season and the soil may not completely meet all the plant's needs all the time. The productivity of the soil can never be greater than the plant nutrient in the least supply. The element in least supply will be the plant's first limiting factor if you consider nutritional factors alone. Some of those minerals may be at naturally poor levels due to the type of parent material.

Also, an excess of one element can cause a deficiency of another element. This is another reason why it is necessary to try and get a balance in the soil so that there is no chance for an 'excessive element'. Scientists still probably don't know all of these interactions but here are some examples of ones that have become obvious:

- Excessive potassium, sodium and magnesium can cause a calcium deficiency
- Excessive potassium will depress sodium, iron and manganese
- Excessive nitrogen can depress magnesium and calcium levels
- Excessive nitrogen can tie up copper
- Excessive calcium can cause phosphorus and trace element deficiency (over limed soil is not easy to correct so it is best to never develop this situation)
- Excessive calcium can tie up potassium and manganese
- Excessive phosphorous can depresses zinc, iron, calcium, copper, manganese and magnesium
- Excessive iron will depress copper, potassium and phosphorous
- Excessive zinc will depress iron and copper

Nutrient requirements are small at the beginning of a plant's growth then increase dramatically during peak vegetative growth and then during seed production. For example;

Look at this soybean crop's mineral uptake of the following 5 minerals in kg per hectare:

Nutrient	DAYS				
	40	80	100	120	140
nitrogen	9	140	11	74	73
phosphate	1	24	4	14	14
potassium	7	119	8	46	44
calcium	3	35	8	13	0
magnesium	1	11	1	6	4

Adapted from Zimmer, Gary F. 2000. *The biological farmer*.

Under conventional fertilisation practices it is not uncommon to put most of the NPK and perhaps calcium in at the time of planting, or having another application at an early stage during the growth of the crop and hope that it is not leached out, if there is a lot a rain. As you can see from the above figures nutrient requirement for each element changes throughout the whole period of crop growth. That is why under the organic or biological system we need to manage the decay cycle and provide a balance of nutrients both soluble and slow release so that we can grow healthy and good quality plants. Management of the decay cycle means that the residues are digested by mid-summer so then their nutrients can become available for the next crop.

Soils do have huge amounts of nutrient elements - more than a crop will need. A lot of it is, however, unavailable to the plant or crop due to being held by soil particles or in the complexes of humus or in the bodies of soil micro-organisms like bacteria and fungi. Some of these nutrients can be made available through natural processes like weathering (temperature and precipitation), the release by the roots of mild acidic substances that can cleave off certain elements, the action of micro-organisms in the soil, excreting substances into the soil and there is the microbial decay of plant material or other litter.

In an organic system with a healthy soil food web the natural release of nutrient elements can often meet much of the plant's element needs. In some types of soil, however, like sands with low cation exchange capacity (CEC - see later section) or where very high plant densities per hectare are planted then there will still be shortfalls in crop needs. Biological/organic farmers will notice though with time that the amount of fertiliser inputs will reduce after several years as natural nutrient release will 'kick in'. It is thought that about 5% of a typical soil's total supply of nutrient elements can become available each year.

A crash course in chemistry!

We now have to get into a bit of chemistry to uncover the next bit of the soil system and how this affects the soil. It is not the goal to turn you into soil chemistry experts but there are some basics that, if grasped, will enable you to better understand what it is that you are trying to achieve in the soil.

The 16 nutrient elements - oxygen, carbon, hydrogen, nitrogen, potassium, calcium, sulphur, phosphorus, magnesium, manganese, iron, zinc, chlorine, boron, copper and molybdenum are often written down in the form of one or two letters e.g. Ca, N, P, K. Really this is just a code letter for each of these atoms. Plants have no knowledge of chemistry and don't deal much with atoms as such but are more interested in ions. Ions are electrically charged atoms or molecules (more than one atom). These can either be positive (+) charged cations or negative (-) charged anions.

Cations and CEC

The elements calcium and magnesium (Ca^{2+} and Mg^{2+}) and potassium and sodium (K^{+} and Na^{+}) are the base cations. The other two main cations in the soil are hydrogen (H^{+}) and aluminium (Al^{3+}).

Now if we remember the rule that opposite charges are attracted to each other you will be able to work out what will happen if you put calcium ions into the soil in the form of lime. The surfaces of clay and humus are negatively charged so this will tend to attract positively charged ions like calcium. These sites are called cation exchange sites, and cations can be exchanged from the soil to the soil solution in the pores. Cation exchange capacity or CEC of a soil is a measure of the negatively charged sites in a soil that have the potential to hold exchangeable cations. CEC is measured in milli-equivalents/100grams (me/100g). As a general rule, if your soil has a high CEC value this means that it has a high clay contend and/ or is high in organic matter.

pH

Cations affect the pH of the soil. If cations like calcium, magnesium or potassium are removed off a holding site in the soil, something always wants to balance this event. What happens is that a hydrogen cation slips into the spot. This is a sure way of making your soil acidic or making the pH of the soil low. pH measures the amount of hydrogen cations in the soil.

The hydrogen percent saturation is zero at a pH of 7. In an acid soil the hydrogen ion has replaced calcium, magnesium, potassium and sodium on the soil holding sites. pH becomes self adjusting when calcium, magnesium, potassium and sodium are in proper balance or equilibrium. Where a pH is low this means that there is a shortage of fertility elements, not necessarily only calcium. Magnesium could raise the pH up to 1.67 times as high as calcium. A soil high in magnesium and low in calcium could test pH of 6.5 and still be entirely inadequate for the growth of lucerne. Any one of the four major cations can in excess push the pH up and any one of them in lower amounts can push the pH down. Once a balance of the major cations has been found at around pH of 6.3 for farm crops you will find plants will be prompted to flourish.

There are a couple of ways to measure pH. Most used is the pH-water method.

A lot of emphasis is put on the pH of a soil and most farmers know that if you want to make the soil less acidic (or increase the pH reading) then you have to add lime to your soil. Some soil consultants only recommend lime to 'fix' pH but the real reason we want to add lime is to replace the store of cations on to the soil particles or increase depleted nutrients. If you need to increase the pH of a soil there are in fact a choice of cations that can be applied - calcium, magnesium and potassium and the choice will depend on what is needed to bring the cations back into balance.

Total base saturation

Total base saturation is the measure of the fraction of the negative holding sites (sometimes called the soil colloid) in the soil that is occupied by base cations.

Total base saturation is calculated by adding all the cations of calcium, magnesium, sodium and potassium together that were found in the soil and expressing this as a percentage of the CEC value. For example, a base saturation of 75% means that 3 out of 4 holding sites on the soil have bases attached and the remaining 25% must have acid attached. Range required depends on the soil but from 50 to 85% is usual.

The individual base saturation levels are used in organic and biological farming to gauge the balance of cations on the holding sites in the soil expressed as a percent: BS%.

The general cationic balance is (for a soil in the pH range 5.8 to 6.5):

Calcium	70 - 75%
Magnesium	10 - 12%
Potassium	2 - 5%
Sodium	1 - 2%

The optimum cation balance of potassium, calcium, magnesium and sodium has been determined by studying the animal's preference for grazing. Animals are incredibly good nutritional chemists if they are allowed to be.

If there is a choice between poor food and good food the animal will always be able to detect, without any laboratory reports, the difference and will devour the better food. Under current farming practices we often deny animals this choice.

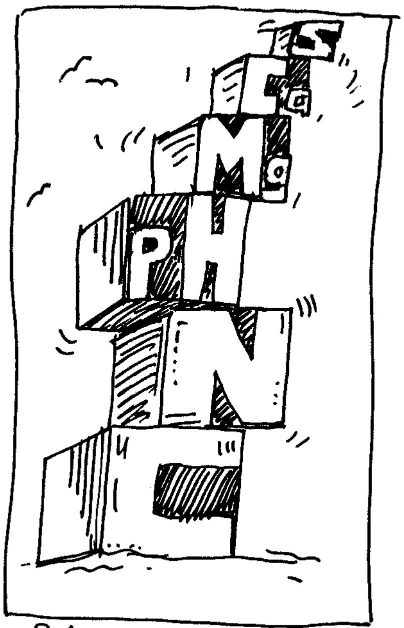
Albrecht (1975) has suggested that if we get the soil's exchange capacity saturated with around 70 to 75% of calcium, around 10% to 15% magnesium, 2 to 5% potassium and up to 1% sodium, we will then have the potential growth of forages rich in protein along with carbohydrates and also carrying many of the other inorganic elements, vitamins and enzymes. It was at these soil sites where animals preferred to forage and had the best of health. Thus we can alter the exchange capacity of the soil to grow more nutritious food.

There is potentially a lot to be gained by moving your soil's cation ratios to this range as finance allows. Soils widely out of cation balance, with a high CEC (cation exchange capacity) reading may be too expensive to correct quickly. The 'repair' in soils with a high CEC may take up to 5 to 15 years. Sandy soils or ones with a low CEC value may be corrected quickly, but will not be able to hold as many nutrients and will need more frequent top-ups.

Anions and anion storage capacity (ASC)

Negative charged ions are called anions, such as nitrate ion (NO_3^-), chloride (Cl^-) and sulphate (SO_4^{2-}). Because soil particles are also negatively charged, anions are mainly found free in the soil solution. A small amount can be held on soil particles and some taken up by the soil food web. Excess anions can be lost from the soil in the form of leaching with excessive rain.

The Anion storage capacity (ASC) is a measure for the amount of anions that can be held by the soil. This is also called P retention. See also phosphorus.



'Balancing' to set up soils with right foundations!

Chemical soil tests & interpretation

One of the major short falls of a soil test report is that it is difficult to know for sure in many cases how large the soil's total or available nutrient supply really is. There are many different types of soil tests that have been developed over the years to measure the soil nutrient levels. All these chemical tests involve mixing soil with water and an additional chemical that extracts or dissolves nutrients from the soil. This mixture of soil, water, and chemical extract is then filtered and tested to determine the level of nutrients in the soil.

The extract solutions can be divided into 3 basic classes:

1. Strong Acid used for Base Saturation and Cation Exchange Capacity (available and exchangeable nutrients). Sometimes called the 'Albrecht method'.
2. Weak Acids (Reams test) to measure the nutrients using a chemical extract that mimics the exudates that roots give off. This provides a snapshot of what nutrients are available at a particular time.
3. Water Extract to measure the amount of nutrients that is dissolved by water.

The analysis most commonly used by New Zealand laboratories to measure the available nutrients in the soil will be discussed when reviewing the individual nutrient elements.

A short fall of some nutrient elements cannot be measured in a soil report - yet - though it may be guessed at. You will have to assess the effect that previous crops, green manure crops and the addition of nutritional elements by roots and microbial activity will have. In addition there will be the influences of weather and soil structure and so on.

There is also the use of plant analysis to give you a snapshot on how the crop or pasture is coping and if there are any deficiencies in nutrient elements, which can be a useful check. An alternative is to develop skills in using a refractometer and taking Brix readings to monitor changes (see appendix).

One aspect of a soil test report that is useful is that it reports the level of cations in percentage terms. With organic farming there are very many benefits to be gained by altering your soil cation balance towards an 'ideal' ratio. The rest of a soil test report really indicates whether or not you have most elements present to grow grass or a crop (quantity). However, under organic or biological systems this is not enough and we actually want quality as well. The success of fertilisers is often judged in terms of dry matter of pasture grown, but the aim of most livestock systems is livestock performance and not pastures bulk.

As mentioned previously each soil testing laboratory will have its own way of reporting its findings so no two laboratory reports look the same or report all the same elements. It is a good idea to gather trends with regular soil testing and stay with the same testing agency so that you can monitor the trends that are occurring in your farm's soils. You would be encouraged to retest the same sites each time and log GPS readings so that true comparisons between years can be done.

How do you test the soil?

Get a soil kit - follow the directions in the kit. Most laboratories will provide information pamphlets on how to take soil samples. A better way is to employ a consultant and get them to take the soil sample as there are a few traps for those that are new to the game. The consultant will want to look at the soil profile, the smell of it, the type and health of the pasture and will also want to look at your animals. A pasture or crop sample taken at the same time is also a very valuable exercise.

When do you test the soil?

As soon as you decide that a more sustainable farming system is the path you want to take. Preferably done in spring but can be done in autumn. This is the time of year that the soil tests will differ the least from year to year (e.g. soil moisture, temperature) and will give you a better idea of reoccurring trends.

How often do you test?

Initially, it would be wise to do this annually. Some types of natural fertiliser are slow to show up in a soil test so it is good to have a trend and by doing an annual test you will tend to get more information which can help your consultant fine tune your system.

Some farmers and consultants prefer to send their soil samples to overseas laboratories. While this is perfectly acceptable for most analysis, caution must be taken with interpretations and fertiliser advice from overseas laboratories, as these are often not based on New Zealand soils and environment.

What do I do next?

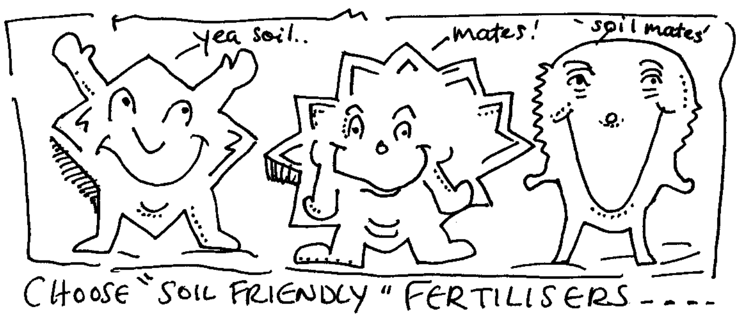
A nutrient budget will show the nutrient inputs (gains) and nutrient outputs (losses) to your farming system. Ideally these gains and losses should be balanced for long term sustainability and the requirements for brought in fertiliser and organic matter diminishing.

The bottom line on your nutrient budget tells you about the balance between nutrient inputs and outputs. It helps you determine whether nutrients are used efficiently and indicates the amount of avoidable nutrient leaching and runoff.

There are a number of nutrient budget programmes available. '*Overseer*' is one of them. Free to download from:

www.agresearch.co.nz/overseerweb/download.aspx.

A soil fertility programme can be developed from the outcomes of the nutrient budget. The aims of the fertiliser programme should go beyond creating the maximum dry matter production or crop yield. In organic systems it becomes more important to design a soil management and fertiliser programme that improves soil ecology and produces a healthy plant. This means considering the types of inputs and the overall balance of elements applied.



Balancing the mineral part of the programme may only take a year to do but on some farms it might be as long as 10 years - each farm will be different. Do as much as possible in the first years of conversion.

Water and nutrient uptake by roots

Plant tissue consists of up to 90% of water (H_2O) and only 10 to 20% of dry matter. Plants are constantly loosing water, so a constant supply must be supplied through root absorption from the soil. There is water loss through the leaves, which is called transpiration. On the underside of the leaf there are thousands of tiny pores (which are visible with a microscope) called stomata, which allow for the movement of water, gases and even uptake of other elements that might be present in the water. Plants can regulate the size of the stomata and can slow down losses of water in dry periods but there is a balance here as this transpiration is used to cool the leaves in hot weather. One element that is considered vital to correct stomata functioning is potassium but this is seldom deficient. Water can also be 'lost' in the plant exudates that leak out of the tips of the roots.

Nutrients from the soil are taken up by the roots, typically following the same pathway as water. The upward flow of water is able to carry nutrients through vascular tissue called xylem. The other vascular tissue is called phloem and carries food (energy in the form of sugar) downwards to other parts of the plant and to the roots.

What factors affect root uptake of water and nutrients?

The water content of the soil is important. As mentioned before there is water in pore spaces and some of this is plant available and some is too tightly held by the soil particles to be used and so is unavailable to the plant. Salt content of the soil has an affect. Roots growing in soils high in salt or where salt high applications of muriate of potash fertilisers have been used will find it harder to absorb water. Some crops can tolerate high salt soils and some soils are naturally high in salt but excessive use of salt fertiliser aggravates the condition.

Roots usually have thousands of tiny root hairs near their tips, which extend out into the soil. These are not seen by the naked eye and are broken off when a plant is pulled from the ground. These hairs increase the surface area of the root by up to 20 times and allow for more efficient absorption by having a greater access to the soil. This area of the roots should be considered the digestive system of the plant. A large healthy root system is vital for drought resistance for a crop and these roots do best in un-compacted soil. Those soils that are compacted with tight small pore spaces will hold little water and a plant on a hot day, with wind and low humidity will loose water so fast that eventually it will wilt. It may recover over night when transpiration is slower.

Moon rhythms

In biodynamic circles, these flows are summarised as earth and cosmic flows (Steiner 1924). Where both flows meet, life can exist. The development of life in the soil depends on both flows being connected.

The rhythms of the moon influence the downward and upward flow of the plant as they do high and low tide. Two different main rhythms are observed: the phases (waxing to full moon then waning to new moon) and the ascending and descending of the moon.

The ascending and waxing of the moon both influence/increase the upward low, root pressure is higher, growth impulse during pruning is higher and the mineralisation in the soil is higher.

Descending and waning have the opposite effect. The emphasis has sifted towards the downward flow, wounds heal better, the plants store more nutrients and the immobilisation in the soil is higher. This used to be well known and many farmers still use these principles.

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The way nutrients are taken up by the root involves some of the following mechanisms:

- Ions dissolved in water that simply flow into the root along with the water the plant root was absorbing
- Slow seep along concentration gradients
- Active transport where a pump in a root cell can pump ions inside against the normal flow or diffusion
- Base exchange can occur when the root releases hydrogen ions from its tip and this swaps places on the holding site of the soil with a base or cation like calcium or magnesium so the soil becomes more acidic and the plant gets a cation

The above-mentioned systems may indeed work but there are also soil micro-organisms functioning and the role of fungi in element transport cannot be overlooked. The hyphae of the fungi are often distant to a root and can source minerals at a distance and transport them to the plant. It is thought that the plant drives the mineral uptake of the fungus. When the plant registers a need for a particular element it organises the fungus to source it and in return gives it essential nutrients by leaking small quantities of carbohydrates, organic acids, vitamins and many other substances (root exudates) through the root tips. See also soil biology: fungi.

Putting theory into practice

This is the part you've been waiting for – how to actually use all of the information we've given you so far and put it into practice on your farm. Before the advent of certifying agencies like BioGro, Demeter and AsureQuality, farmers started to farm a little differently. They picked up ideas and tried them on a small scale, even just on part of the farm. When results were seen there was courage to make more changes. If we look at the process these people took we find a common pattern.

These farmers were not happy with some aspect of their farming ways. Perhaps they were doing a process every year and not seeing the desired response. Most had identified animal health problems that were becoming more prevalent and seemingly more difficult to cure or eliminate. What is more interesting to note is that all these individuals had decided in their own way that it was the way the soil was being treated that held the key to removing or reducing these problems. So what followed was a change in the way that these farmers farmed 'their soil'. Their next step was to remove some of these practices they perceived as being 'damaging to the soil'.

We will list them down as 'steps' but they are really just the sequence of events in common with all these farmers who have moved away from current farming practices. The five steps that have been identified from these experienced organic farmers are:

Step 1: Test and balance the key elements of your soil

Step 2: Choose fertilisers that are 'soil friendly' (refer Chapter 3)

Step 3: Eliminate pesticide and herbicide use

Step 4: Nourish the soil micro-organisms

Step 5: Increase the variety of plant species in the pasture and plant trees on the farm. This will be discussed in more detail in Chapter 4

Step 1: Test and balance the key elements of your soil

In the early stages there is often an appreciation by the farmer that the current nitrogen, potassium and phosphate fertilisation practices are not resulting in better animal health, plant health or a stronger bottom line in the accounts. The starting point, therefore, is a soil test, which often involves a different type of consultant - often one not tied to a particular fertiliser company. The soil test may be conducted in New Zealand or may be sent overseas.

Up to 10 to 16 elements are tested for and a programme to 'balance' these elements is embarked on. Excesses of elements are looked at as well as deficiencies. This is one of the most important steps to take if you are going to change to biological/organic farming. It is possible with 'balancing' to set the soil up with the correct foundations (like the piles for a house). When you introduce the plants to the soil (put the house on the piles) you can get the whole biological system to function better with micro-organisms (no good putting the wiring or plumbing in the house if you haven't got the house built on sturdy foundations).

Some notes on soil balance shared by experienced organic farmers:

- Soil that is neglected looses fertility, even organic land still needs to be fertilised.
- Do not aim to feed the plant initially. Feed the soil and let the soil feed the plant. Foliar spray to fine tune deficiencies identified by plant analysis.
- Excesses are just as restrictive as deficiencies. You cannot have a deficiency of one element without having an excess of another.
- In terms of nutrient balances, the same principles apply whether it is dairy farming, crop farming, vegetable gardening, vineyards, horticulture or whatever. And the ratios apply whether you are farming in NZ, USA, Ecuador or Timbuktu.
- If the soil minerals are not in balance work on rectifying it.
- Apply calcium (through lime, RPR, dolomite) before you start using liquid fertiliser.
- It is like tuning a violin – get the first four strings right first, by using solid fertiliser. The fifth string for fine-tuning is the liquid fertiliser.

Step 2: Choose fertilisers which are 'soil friendly'

There is a change in the type of fertiliser applied when a shortfall is found in a particular element. Sometimes the cheapest source of an element is not actually the best for the soil micro-organisms.

There is a move away from soluble phosphate to phosphate rock. Ensure the ones you select are low cadmium (an undesirable heavy metal).

Higher quality lime products are selected. Dolomite is used only if magnesium levels dictate that it is necessary.

Potassium sulphate would be preferred rather than potassium chloride (potash).

Of course if you are converting to organic farming and are going to be certified you will have to consult with your certifying agency and ensure that you use only those products allowable or get permission before you use any restricted fertiliser.

The fertilisers will be discussed in Chapter 3 Soil Fertility.

Salt based fertilisers

When we think of the word 'salt' - we typically think of table salt - sodium chloride. When we look at the chemical bonding of this product we find that the sodium is a positively charged ion (cation) and it has a negatively charged ion of chloride. Technically, if you go back to the science books the definition of a salt is one that is formed when acid reacts with a base. There are therefore a lot of different types of salts that can be formed when you consider all the different acids and bases that could be mixed together.

When we look at types of fertilisers (compounds) applied to soil they have a similar chemical structure like table salt and can be referred to as salt-based fertilisers. When you look at potash or potassium chloride - the potassium has a positive charge and the chloride a negative charge. When salts dissolve in water, the two ions separate. These can then become available for the plant but if the root doesn't need the positive ions they can be bound to the soil if there is some exchangeable hydrogen ion present that can be dislodged. If there are no roots, no microbes and no holding sites these ions can be leached out of the soil along with the negative ions - nitrate and sulphate if they are free.

Salt fertilisers give a quick release of soluble, readily available ions - like giving a steroid boost to the plant. Too much salt causes an imbalance as we have discussed elsewhere and is very detrimental to the soil micro-organisms.

Phosphate ions can also be tied up very quickly in the soil and become insoluble or unavailable to the plant roots, unless made available by the soil micro-organisms.

Some salt fertilisers cause a greater drying out effect to roots and micro-organisms than others and this is measured by a salt index. A higher salt index indicates greater damage.

Let's look at the salt index for some of the common fertilisers that are put on soil:

Fertiliser	Salt Index
Potassium chloride (potash)	116.3
Ammonium nitrate	104.7
Urea	75.4
Potassium nitrate	73.6
Ammonium sulphate	69.0
Calcium nitrate	52.5
Potassium sulphate	46.1
Sulphate of potash-magnesia	43.2
Diammonium phosphate DAP	34.2
Monoammonium phosphate MAP	29.9
Triple superphosphate	10.1
Calcium sulphate	8.1
Superphosphate	7.8
Sodium chloride (Salt)	1.0

Source - Zimmer Gary F. 2000. *The biological farmer.*

For those farmers who want to gradually wean their farms off the less desirable fertilisers like potassium chloride and urea (both high salt index fertilisers) you can select other types of fertilisers to supply your potassium and nitrogen, for example so as to limit or reduce damage done to soil microbes or plant roots.

In certified organic farming only natural forms (mined and not treated with any chemicals) of fertilisers are allowed, including natural phosphate rock and reactive phosphate rocks (only the low cadmium types), natural potassium sulphate, and lime.

Step 3: Eliminate pesticide and herbicide use

You are not allowed to use any of these products on a certified organic farm, including a farm which has started formal conversion to certified organic Farmers moving towards organics move from blanket spraying to band spraying and then to spot spraying. At all times trying to reduce the amount of active ingredient going on to the farm by adding products to the spray e.g. seaweed, molasses, sugars or humic acid solutions.

Farmers notice that the need for pesticides and herbicides decreases as the soil comes into better balance and becomes more biologically active.

Some pests or weeds can be controlled by 'biological control', like the releasing of natural enemies such as predators, parasites or pathogens. For example, ragwort beetle for the ragwort weed, a parasitic wasp for a maize-eating caterpillar, and Bacillus Thuringiensis (Bt) to control many moth and butterfly larvae (caterpillars).

Step 4: Nourish the soil micro-organisms

This is one of the most important steps and most often underrated or unrealised. There is potentially a huge untapped army of ready and willing workers in every teaspoon of soil if only all farmers could appreciate this and look after them! These micro-organisms need the identical living conditions to work in as the farmer does. They need a comfortable home (soil with the correct minerals, the correct ratio of water and oxygen), food (in the form of organic matter), warmth (biologically active soils maintain soil temperature within a narrow range compared to conventionally farmed soils) and freedom from poisons or chemicals. Once the micro-organisms are fed then the crop or pasture will be fed - the micro-organisms eat at the table first! This point is important. If you put a lot of organic matter into the top layer of the soil and then plant a crop, the crop will suffer deficiencies, as some nutrients (like nitrogen) will be used by the micro-organisms first denying the plant its requirement. You must allow enough time for the organic matter to break down.

Other nutrients or biological stimulants that can be used to feed or enhance the soil life include seaweed (kelp), fish, molasses, sugar, vitamins, humic and fulvic acids, hormones from kelp, paramagnetic materials and biodynamic preparations. It is interesting to observe that a number of farmers who decided to change their fertiliser programme often started with seaweed sprays first and noticed benefits from using this and then went on to experiment with the other stimulants. Other options include the use of compost teas and bacterial, fungal or algae, nematode, worm inoculants. It is still important to get the major elements 'balanced' first as a lot of these products are used to fine tune the biological system.

Step 5: Increase the variety of plant species in the pasture and plant trees on the farm

There generally has to be a change in the type of pasture grown, not only for grazing livestock but to assist with soil development. This will usually happen soon after herbicide spraying is stopped! A pasture that contains only rye or fescue plus a little clover (when it is not eaten by the clover flea and weevil or shaded out by nitrogen boosted rye or fescue) offers little variety to the grazing animal. Each pasture species or herb has a different mineral and trace element profile, different root depth, different growth rates and no doubt an individual taste, not to mention its own variety of micro-organisms associated with it! Pastures are often over-sown with a variety of herb species (see chapter 4). Many of these have tap roots which enable the plant to source minerals at a depth that the rye and clover roots cannot get too. These roots also help to break the soil up.

On those farms where there is no natural shelter nor trees, many organic farmers have experimented with non poisonous tree species for food snacks for stock, stabilise erosion prone soil, harvest minerals from deeper layers in the soil, attract bees and birds and provide another source of organic matter (litter diversity) or leaves to the soil section. See also the section on trees for further information.

References: Chapter Two

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Bio Dynamic Farming and Gardening Association in NZ
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Phone: (04) 589 5366
Fax: (04) 589 5367
Email: biodynamics@clear.net.nz
Website: www.biodynamic.org.nz

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Look to the left under Quick Access. First click "Soil Quality" then click "Soil Biology"

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Appendix: Brix %

- Farmers can monitor improvement in pasture and crops by taking a Brix reading from the sap squeezed from the plant onto a refractometer
- Higher Brix readings in plants mean higher quality produce and more efficient use of this food by animals
- High Brix testing crops will resist insect damage and frost damage and will store longer than low testing plants or crops
- Brix readings are quick to do and the cost is in 'time' once the instrument is purchased

Brix is measured with a refractometer. Dr. Carey Reams devised a chart that shows how fruits, vegetables and grasses can be ranked as either poor, average, good, or excellent based on their Brix measure. Brix % is a measure of the dissolved sugar content of the sap of the plant being tested.

The refractometer reading is only an indirect measure of the soil's fertility and condition. This instrument can be used to measure the dissolved sugars (technically, the soluble solids which will include minerals, vitamins, sugars and amino acids) of the juice or sap of plants.

How to test for Brix%?

The plant is squeezed in a tiny press, garlic squeezer or other device and the drop or two of sap is put onto the surface of the refractometer, the lid closed and then this instrument is turned towards a light source and then by looking through the eye-piece the reading can be taken. The upper region will be blue in colour and the lower area is white and where the intersection cuts the scale is the value of the Brix % for that sample.

What do the Brix readings mean?

Generally, the higher Brix reading indicates a healthier plant growing on good, fertile soil. However, there does need to be some consideration given to the situations prevalent at the time of testing. A low sugar reading may indicate cool temperatures; cloudy weather and young plants can test low. It is important to test the same part of the plant at a similar time of the day in the same weather if you want to make daily comparisons - since all of the above affect photosynthesis or sugar content.

Normally the readings will be highest at midday. They will be lowest in the morning. A high reading in the morning may indicate a sick plant, as there may be a problem with translocation of sugar from the leaves to the root the way it should.

As a general rule, a Brix reading below 6 is considered poor for most crops and above 12 is considered excellent. Brix for pastures should be 12 or above if possible.

There are some who believe that when the sugar readings are above 12 Brix, the crop will not be bothered by insect pests and in many cases this does seem to hold true but if a plant is dehydrated the Brix reading will be elevated and hence will not be a true reading.

Why consider using a Brix measure?

Sending plants off to a laboratory for analysis does give excellent information but if you want to regularly test a crop or pasture then monitoring Brix readings might be considered. A refractometer reading only takes a couple of minutes to do, and a sample of a crop or fruit can be measured each day to observe trends if you are dealing with a valuable crop or you want to determine whether inputs you are using are working. This method costs nothing after the initial outlay for the purchase of a refractometer.

The testing of crops, pasture, fruit etc. is just another way of monitoring changes happening on a farm. It is just another tool that can be used.

Is it worth Brix testing weeds?

Any plant can be tested and you might be surprised to find that so called 'weed' species have higher Brix readings than the so called good plants in a field. Generally, as a farmer turns his or her soil over towards better 'balance' and looks after the soil food web by not applying herbicides or soluble fertilisers, there will be a trend for the weed species to be not so prolific and the Brix readings will drop in these plants and the pasture species Brix readings will tend to increase.

Additional notes on Brix readings

The darker the demarcation between the upper blue and the lower white area, the lower the calcium levels.

Thus, samples with same Brix may have different taste due to acidity.

The fainter the line between the upper blue and the lower white area, the sweeter it will be at that Brix.

Plants with the same Brix, but with higher pH will have a higher yield and be sweeter.

Brix testing of silage

Yes, even silage can be tested. This is a cheap easy quick way to see what potential you have in a silage crop.

Brix %	Result
4	no fermentation
4-8	poor fermentation
8-10	good fermentation
10	increased feed value with inoculant
20	optimum feed

The refractive index of crop juices (Brix %)

Fruits	Poor	Average	Good	Excellent
Grasses				
Alfalfa	4	8	16	22
Grains	6	10	14	18
Sorghum	6	10	22	30
Rye grass	**6**	**8**	**19**	**12**

Chapter Three: Soil Fertility

Soil fertility is fundamental in determining the productivity of all farming systems. Soil fertility is most commonly defined as the ability of a soil to deliver nutrients to crops. This is a very narrow definition which might be true for conventional systems. For organic systems soil fertility would be better seen in a broader concept, integrating the diverse soil functions, including soil fertility, which promote plant production.

There is more to soil fertility than N-P-K and chemical soil fertility. In organic systems there is an even greater importance in looking at the biological and physical fertility of the soil, as discussed in the previous chapter about the soil. In the last hundred years or so, our attitude has been to add what we thought was missing in the pasture or crop (crop response, production oriented). This attitude has driven us away from recognising the 'natural' potential of the soil - the humus and clay colloids making nutrients directly accessible by active root systems.

There are two major food groups in soils; minerals and organic matter supplying cations, anions and trace elements. You have an absolute deficiency if there is an essential mineral missing in the rocks from where the soil originated. You will need to add missing mineral(s), popularly called re-mineralising the soil. Functional deficiency arises when a nutrient is in the soil, but not (sufficiently) taken up by the roots. This is largely the result of biological processes that are not functioning properly.

Management of soil organic matter plays an important part in sustaining and enhancing soil fertility in organic farming systems and biological processes are stimulated to supply needed nutrients to soils.

Ideally the inputs used in organic farming systems to manage soil organic matter should come from the farm itself, to become fully sustainable. However the input of (off farm) natural materials is allowed to build up soil organic matter levels and to stimulate soil biology.

In this chapter we will firstly discuss the essential elements, the essential mineral nutrients and the trace mineral nutrients needed to maintain balanced levels for optimal plant and animal growth. The most common soil tests will be discussed to check the levels of the individual nutrients in the soil and sources of inputs, including organic matter, effluent and biofertilisers.

Important: Although the products recommended in this manual were consistent with the organic standards at the day of print, organic standards change constantly, and it is important that you check any product that you plan to use meets your certifier's requirements before using.

IFOAM Organic Principles and Recommendations (2005) for soil fertility

Organic Soil Fertility

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

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 minimised. Nutrients should be used in such a way and at appropriate times and places to optimise their effect.
- Accumulation of heavy metals and other pollutants should be prevented.
- Naturally occurring mineral fertilisers and brought-in fertilisers 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.
- Manures containing human faeces and urine should not be used.
- Careful attention to hygiene is required and it is recommended that they are not applied directly to vegetation for human consumption or to soil that will be used to grow annual plants within the next six months.

Organic soil physical fertility

General Principle - Organic farming methods conserve and grow soil.

Recommendations

- Operators should minimise loss of topsoil through minimal tillage, contour ploughing, crop selection, maintenance of soil plant cover and other management practices that conserve soil.
- Operators should take measures to prevent erosion, compaction, salination, and other forms of soil degradation.

Essential elements or macro-nutrients?

The essential elements carbon, nitrogen, phosphorus and sulphur have in common that they are part of nutrient and energy cycles. At some stage of each of the nutrient cycles, these elements will be built into organic matter. These nutrients are released from organic matter by soil organisms.

Carbon in the form of carbon dioxide (CO_2) and most of the nitrogen (N_2) in the soil are delivered from the atmosphere and stored in the soil organic matter. Although sulphur can be found in the atmosphere as sulphur dioxide SO_2, most of the earth sulphur is tied up in rock or salts or incorporated in organic matter. Phosphorus can be found on earth in water, soil and sediments as inorganic and organic phosphorus. Unlike the compounds of other nutrient cycles phosphorus cannot be found in air in the gaseous state. In the atmosphere phosphorus can mainly be found as very small dust particles.

Carbon - C

Carbon is the element that conveys life to the biological system through photosynthesis. It is the energy storehouse for the living system - all living systems must have carbon (see also organic matter and humus).

Photosynthesis:

$6\ CO_2 + 6\ H_2O$ SUNLIGHT > $C_6H_{12}O_6 + 6O_2$

Carbon dioxide + Water GREEN PLANTS > Glucose + Oxygen

Carbon controls the water content of soils. Each kilogram of biologically active carbon can hold 4 parts of water. Every effort must go into retaining carbon in the soil system.

A paradox with carbon

It is possible when developing an organic or biologically active system to reduce the fertility of that system! If the carbon content of the soil is increased and humus levels increases too, there will be an increase in the cation exchange capacity for that soil so there will be more binding sites on the soil to hold cations. With the increased carbon there will also be a four-fold increase in the water holding capacity of the soil, which will dilute the minerals in the soil. So it is possible to have reduced yields unless this is compensated for!

Biologically active carbon or the humus content of the soil ultimately determines the sustainability, efficiency and the productivity of the soil system. It sequesters atmospheric carbon (carbon sink). Carbon buffers the soil, improves the tilth, and improves nutrient holding capacity (CEC).

The greater the amount of carbon, the greater the energy reserve in that system.

Sources of Carbon

Compost: Is perhaps the best source of carbon but not all compost is equal (see later section)

Carbohydrates: Sugar, molasses, starch

Crop residue: This must be incorporated in the first few inches of the soil and be broken down by micro-organisms and with oxygen - must be aerobic

Manures: Can be green manures - as above for crop residue

Can be animal manures -as above for crop residues

Humates and humic acids: Must use judiciously - a little is great - a lot can be disaster

A very finite resource - best to build the soils own humates

Useful for chelating elements

Have a high CEC

Organic carbon (as total carbon) is measured in the laboratory, and organic matter is calculated from this using as standard factor derived for soils:

Organic matter (%) = Organic carbon (%) * 1.72

Guidelines

Level	Organic Carbon (%)	Organic Matter (%)
Very low	< 2	<3
Low	2 – 4	3-7
Medium	4 – 10	7-17
High	10-20	17-35
Very high	> 20	>35

Source: Hill - Roger & Kay - Tony 1998. *Field consultants guide to soil and plant analysis*

Nitrogen - N

- A major element, vital for the production of proteins
- A versatile element in nature that can exist in organic and mineral forms
- Some nitrogen forms can be lost by leaching
- Nitrogen has crucial significance in the nitrogen cycle in the soil

Nitrogen gas is a colourless, odourless and tasteless gas. This element makes up 78% of the atmosphere, which would make one wonder how it could ever be in short supply for farming systems anywhere in the world.

This element is vital for the production of proteins, the main constituent of animals other than the skeleton. The percentage of protein is often calculated (rightly or wrongly) by multiplying the nitrogen content in an analysis by 6.25 or 6.4. However, nitrogen presence does not guarantee protein presence or protein manufacture, as protein formation requires both nitrogen and carbohydrate added to it.

There are many forms of nitrogen in a biological system.

There is:

nitrogen gas in the air - N_2

ammonia - NH_3

ammonium - NH_4+

nitrite - NO_2-

nitrate - NO_3-

amino acids -NH_2 (this group is attached to all amino acids)

proteins - made up from many individual amino acids

This versatile element is able to alternate between the nitrate form and the ammonium form via various processes in the soil and even the air.

What is the nitrogen cycle?

It is a cycle where nitrogen is constantly changing from one form to another and moving from the air to the soil, plants and animals.

There is the fixation of nitrogen by lightning in the atmosphere and also by the micro-organisms in the soil with the formation of nitrate and ammonia.

N_2 (gas) > lightning > * NO_3- (nitrate)

N_2 (gas) > bacteria in legumes > * NH_4+ (ammonium)

There is temporary immobilisation of nitrogen in proteins and other organic molecules. Mineralisation of organic matter releases nitrogen back into ammonia and nitrate.

There are also soil bacteria that can change ammonia into ammonium which is called ammonification, ammonium into nitrite and then nitrite into nitrate which is called nitrification (see soil chapter under bacteria for further information).

Finally, yet other bacteria can convert nitrate into gaseous nitrogen or nitrous oxide, which results in the loss of nitrogen into the air. This is called denitrification. These processes occur in anaerobic conditions. Other losses of nitrogen can come from leaching, soil erosion, escape of ammonia gas and the removal of nitrogen by harvesting crops or by the grazing by animals.

Both nitrate nitrogen (NO_3-) and ammonium nitrogen (NH_4+) can be taken up by plants through the roots.

Nitrate nitrogen is a negatively charged anion and is very mobile in water. Due to its mobility nitrate nitrogen can be lost by leaching. It primarily promotes growth responses in the plant. During rapid growth the uptake by the plant of nitrate nitrogen is also rapid. If the growth stagnates temporarily, nitrate nitrogen gets stored in the plant and sometimes reaches toxic levels. The amount of nitrogen taken up by plants through the roots is closely related to the amount available in the soil. If concentrations of nitrate nitrogen in the soil are high, the plant will take it up with water regardless of the need for it. Nitrate nitrogen must be altered before it can become a part of true functional proteins so consequently it is not the most efficient means of transporting nitrogen into the plant.

Ammonium nitrogen is bound to clay and organic matter, and costs more energy to be taken up by plant roots. Ammonium nitrogen promotes fruiting or a seeding response.

The nitrogen cycle is the cheapest and most efficient way of harnessing nitrogen on your farm.

How does the nitrogen cycle work when we consider the system happening within the soil?

If we analyse the Carbon: Nitrogen ratio from bacteria we find it has a C:N ratio of 5 carbon and 1 nitrogen.

If we analyse the C:N ratio from protozoa we find it is 30 carbon and 1 nitrogen.

For a protozoa to obtain its 30 parts of carbon, it must eat 6 bacteria.

How many units of N has it eaten? 6

How many units of N did it need? 1

What happens to the five in surplus? These get put back into the soil! A nitrogen source!

Now let's take a look at a nematode.

When you break this down it has a C:N ratio of 200:1

How many bacteria must he eat to get enough C? 40

How many units of N have been taken in? 40

How many units of N did it need? 1

39 units of N get excreted back into the soil.

In summary, many micro-organisms work together to break down organic matter into a form that plants can use. The above mathematics example has probably over simplified the complex nitrogen cycle, however, maintaining soil conditions that satisfy the micro organisms' requirements should be the aim of all farmers – not just the organic ones.

It is imperative that this natural nitrogen cycle is nurtured by your farming methods so that nitrogen efficiency is enhanced.

Soil test reporting of nitrogen

The following tests may be seen on reports - available nitrogen and total nitrogen. They tend to be used in cropping situations.

Available Nitrogen (Anaerobically mineralisable N)

This test gives an indication of the quantities of nitrogen that could be readily mineralised from the soil organic matter under ideal soil conditions. Anaerobically mineralisable nitrogen is a good indicator of biological activity. It is closely related to microbial biomass. The actual amounts of nitrogen that will mineralise from the soil will depend on soil moisture and temperature. It gives an indication of the potential of the soil to provide nitrogen to growing plants. This test is widely used for arable soils, not so much for pasture soils.

Guidelines

Level	Anaerobically Mineralisable N (μg/g)	Available Nitrogen (kg/Ha)
Very low	< 35	< 50
Low	35 - 50	50 - 150
Medium	50 - 80	150 - 250
High	80 - 240	250 - 350
Very high	> 240	> 350

Source: Hill - Roger & Kay -Tony 1998. *Field consultants guide to soil and plant analysis*

Total Nitrogen

This test estimates the total nitrogen content of the soil and excludes nitrate-nitrogen. It does include nitrogen that is not available to the plant. The major use of this test is to provide nitrogen levels for the carbon/nitrogen ratio.

Guidelines

Level	Total Nitrogen (%)
Very low	< 0.1
Low	0.1 – 0.2
Medium	0.2 – 0.5
High	0.5 – 1.0
Very high	> 1.0

Source: Hill - Roger & Kay - Tony 1998. *Field consultants guide to soil and plant analysis*

Sources of nitrogen

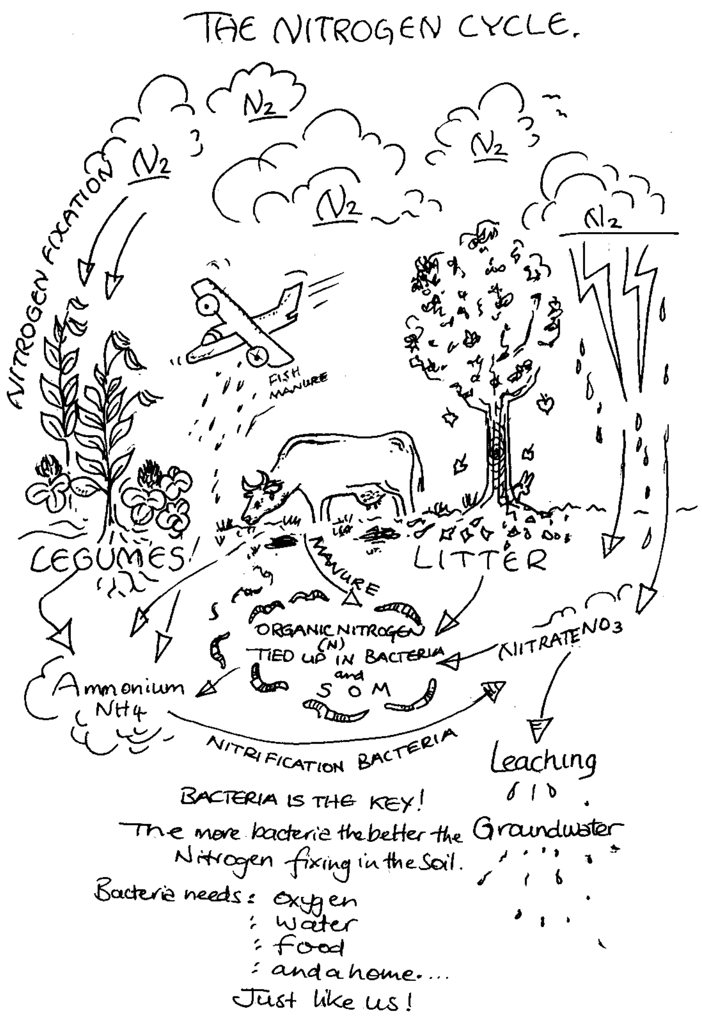
Under a certified organic system there is no ability to use synthetic nitrogen. The goal is to get the soil food web working efficiently so that the natural nitrogen cycle supplies the nitrogen. There will be times of the year where nitrogen will be lacking. This is most likely when certain microbes are absent (even critical elements may be not be available) or when temperature and moisture availability are limiting the system e.g. when the soil is either very dry, as in a drought or the soil is very cold and the bacteria have become dormant.

Nitrogen can come from animal manure, compost and fish. Animal manure should ideally be composted before application. Compost must be of excellent quality and be suitable for the crop or pasture you are trying to grow (see section on compost). Fish is a good source but is best if it is digested to some degree or composted.

Green manures provide anywhere from 0.5 to 5% nitrogen. These are 'crops' that are grown up to the stage of going to seed and then they are mulched/roto-tilled or mixed into the soil aerobic zone - the first 50 to 70mm or so. These plants then feed the soil food web so that the next crop that is planted has access to these minerals etc.

Legumes such as lucerne, sweet clover, red clover, beans etc. provide the most nitrogen. Grasses such as rye are also good in the growing phase and should be ploughed in before seeding. Biological farmers always strive to keep the soil growing something so that the soil microbes always have a food source.

Trees can supply nitrogen. Nitrogen fixers like Tagasaste (tree lucerne) are another option.



Phosphorus - P

Phosphorus (P) is one of the major nutrients required by plants, along with nitrogen and potassium. Phosphorus exists in organic and inorganic forms in the soil. In well developed agricultural soils most of the phosphorus (more than 75%) is available from decomposition of organic matter by microbial activity.

Phosphorus is contained in all tissues with concentrations most pronounced in young plants, seeds and flowers, and later distributed internally to the rapidly growing parts of the plant. Phosphorous is the major catalyst in all living. It is essential for building sound bones and teeth (in conjunction with calcium) and for the production of sugars (key to obtaining high crop refractometer readings), carbohydrates and fats. It necessary for enzyme activation - especially the phosphate energy cycle.

It is beyond the scope of this resource manual to get into the details about this energy system but there are molecules that have the ability to gather and release phosphate ions and energy. Adenosine mono-phosphate can hold another phosphate and become adenosine di-phosphate (ADP). This requires an energy input. If it collects another phosphate ion, ADP can become ATP or adenosine tri-phosphate, which requires an energy input as well. If ATP is converted back to ADP, energy is released and a phosphate ion is available. Without this energy cycle of phosphate everything in a plant would come to a grinding halt. This energy system also functions in soil micro-organisms, plants, animals and humans. It is a vital enzyme system so it is needed for the lifetime of the plant, microbe or animal.

Inorganic phosphorus from soil minerals or fertilisers undergo chemical and physical change into the soluble orthophosphate form before they can be utilised. Phosphorus is adsorbed into a plant as orthophosphate ions $H_2PO_4^-$, which has a single negative charge or HPO_4^{2-} which has a double negative charge. Plants can uptake phosphorus directly in the soluble orthophosphate form through the roots or indirectly through symbiosis with mycorrhizal fungi.

Since phosphorus is made available primarily by micro-organisms from soil organic matter, its availability dependents upon soil moisture, soil temperature, soil structure, and the pH of the soil. At a soil pH of around 6.5 you are going to have good availability of phosphorus in ideal growing conditions. Cold weather can cause a temporary deficiency of phosphorus, especially in spring. Hence, a deficit may exist even though the soil chemistry shows surplus phosphorus.

Phosphate deficiency symptoms are much more noticeable in young plants, as these have a greater relative need for phosphate than mature plants. In general plants will appear weak, and will not mature as fast as they should. They appear stunted and generally the leaves and stems turn dark green.

There is on-going debate about the relative performance of rock phosphate versus acid phosphate with longer term research indicating that rock phosphate out-performed acid phosphate (superphosphate) in studies lasting more than three years. However, rather than getting involved in an argument over the relative merits of the two types of phosphate lets keep in mind that the key to phosphate availability is through a suitable pH and soil micro-organism activity. For those that use the rock phosphate it is even more important that you have micro-organism activity in your soil as you do not have the benefit of soluble phosphate like that available from superphosphate within the first two months of application. If there was a choice between rock phosphate and soft rock phosphate (colloidal phosphate) get the soft rock phosphate. There are few sources of soft rock phosphate available now.

Laboratory reporting of phosphorus

A lot of soil test reports from overseas will report the phosphorus (the element P) as phosphate just to confuse us all. If you need to convert phosphate, which is written as P_2O_5 to P then divide by 2.29. $P=P_2O_5 / 2.29$.

There are several tests for phosphorus depending upon whether the soil is analysed in New Zealand or offshore. In New Zealand it is common to see an Olsen P test or a Resin P test.

Olsen P test

There are many biological advisors who question the use of the Olsen P test on soils analysed in New Zealand. Olsen P estimates plant available inorganic phosphorus levels. It makes no assessment of the organic phosphorus levels that can be mineralised from the organic matter. Olsen P test can over-estimate the levels of plant available phosphorus in acidic soils (pH <5.5). Also Olsen P test tends to under-estimate the available phosphorus in recently limed soils, or where slow release P fertiliser RPR or liquid fertiliser have been used.

The guidelines for the Olsen P have been set at a range between

- 20 and 30 mg/L for pasture/crop soils
- 35 for pumice and peat soils
- 12 for sedimentary soils

The Resin P test

Resin P is an alternative test and is one that is particularly recommended for soils where RPR (reactive phosphate rock) or other slow release P fertilisers have been used. This test gives a more accurate estimate of plant available phosphorus.

The guidelines for the Resin P test is for a figure in the range:

- 50 - 100 mg/kg for dairy soil and
- 40 to 75 mg/kg for dry stock soil

Anion storage capacity (ASC) or P retention

Phosphate retention refers to the phosphorus immobilisation property of the soil. This value is an inherent property of the soil and does not change (unless the soil is a peat soil that is mineralising). High phosphate retention soils may require 2 to 3 times the amount of phosphorus as capital or maintenance fertiliser than low phosphate retention soils. However a retention of 80% does not mean that 80% of the applied P is rendered unavailable to plants.

Guidelines

Level	Phosphate retention %
Very low	< 10
Low	10 - 30
Medium	30 - 60
High	60 - 80
Very High	> 80

Source: Hill - Roger & Kay -Tony 1998. *Field Consultants Guide to Soil and Plant Analysis.*

Total P

Total P measures the total of the organic and inorganic phosphorus in a soil.

Other phosphorus tests include BrayP, Melich3 and MorganP.

Sources of phosphate

Reactive phosphate rock (RPR) (12-13% P and 33% Ca, variable S) can vary in the levels of P and the ease of accessing P. Ideally you would want an RPR that tests high in phosphorus, has low levels of toxic elements e.g. cadmium or fluoride, and has a citric solubility of 30% or greater.

Composted RPR (12-13%P, 332% Ca and Variable S). The composting process makes phosphorus more available especially the citric soluble part of the RPR.

Other sources of phosphorus are chicken manure (1.5% P), liquid fish (2% P_2O_5)

Why isn't triple super phosphate allowed in organic systems?

An experiment was done where triple superphosphate was treated with a radioactive substance so that when the plant tissue was analysed it could be determined from where the phosphate came from - the fertiliser or from the soil. In the year tested it was a good growing season and it was found that the radioactive phosphate was taken up for only 8 weeks and that only 20% of the phosphate came from the fertiliser - the rest came from the soil! In poor growing seasons the phosphate was taken up for only 4 weeks and only 10% came from the fertiliser and 90% came from the soil. Triple superphosphate is therefore not a suitable fertiliser for organic systems - it has useful soluble phosphorous for only up to 8 weeks maximum under ideal growing conditions and then after this the phosphorous is bound up in the soil.

There is also potential for the soluble phosphorous and sulphur portion to be leached by rain and lost from the system if it is not utilised immediately. It has been proven by Massey University that the sulphate-S from superphosphate increases the losses of the critical nutrients calcium, magnesium, sodium, potassium and even nitrogen. This was published in the *NZ Journal of Agricultural Research* 1991, vol. 34.

The leaching of phosphate into waterways is a significant concern, as it only requires 0.1kg P/ha to cause eutrophication problems such as excessive weed growth and algal blooms. Typically from 1 to 3kg P/ha annually is lost to waterways.

Research by NIWA scientists have revealed that most P leaching from agricultural land occurs in run-off events (usually as a result of rain) in the first few days after application of the fertiliser. Where RPR was used instead of superphosphate, there was virtually no P run-off due to two main reasons: RPR is not water soluble as it relies on microbe activity in the soil and the acidity of the soil to release the phosphate slowly over time and secondly that RPR is heavier compared to superphosphate so particles are less inclined to move unlike the light granules of super that can be floated off the surface in run-off.

What happens with superphosphate?

Super phosphate granules have an extremely low pH - as low as 1.5 which means that when you put it in a soil with a high pH such as 5.8 or 6 it actually dissolves iron and aluminium which are present in the soil which then re-precipitate with some of the phosphate from the granules and form relatively insoluble iron and aluminium phosphate compounds. This can in fact happen in any soils but is more significant in soils with high iron and aluminium such as ash soils. This part of 'fixation' cannot happen with RPR as these products are alkaline so the dissolution of soil iron and aluminium does not occur.

Sulphur - S

Most sulphur (95%) in the soil is in the organic form and becomes available by decomposition of organic matter by microbial activity. Elemental sulphur has to be used by the bacteria in the soil before becoming plant available sulphate sulphur. Sulphur is needed in approximately the same quantities as phosphorus.

Sulphur is essential for complete formation of proteins, vitamins and the synthesis of some plant hormones. Amino acids are assembled together to build a protein (a fundamental part of the muscles, enzyme systems and immune system immunoglobulins of plants, animals and humans) and there are 28 different amino acids. Three of these amino acids, cysteine, cystine and methionine, contain sulphur so if sulphur is insufficient or unavailable in your soil you will not have the manufacture of complete proteins in crops and pasture nor will they be available for animals and people. Sulphur is part of the B vitamins thiamine and biotin and coenzyme A (calves with thiamine deficiency will go suddenly blind and if not treated progress to a staggering gait and then have fits and die).

The inorganic sulphate sulphur ions are very mobile and readily leach from the soil. Sulphur is also acidic and will acidify the soil. In soils with a high base saturation of magnesium, sulphate ions can leach out excess magnesium. In waterlogged soils sulphate and organic sulphur can be converted to toxic sulphides by bacteria and escape into the air so there is an important lesson here about avoiding waterlogged soils.

Since sulphur is made available primarily by micro-organisms from soil organic matter, its availability dependents upon soil moisture, soil temperature, soil structure, and the pH of the soil. Cold weather can cause a temporary deficiency of sulphur, especially in spring. Sulphate sulphur can be 2 to 3 times higher in soil in autumn due to moisture and temperature effects. Hence, a deficit may exist even though the soil chemistry shows surplus sulphur.

Sulphur is essential for the production of healthy, green leafy material. Without adequate sulphur, chlorophyll is not stable and plants suffer from chlorosis (lack of chlorophyll). Like calcium, sulphur is not mobile within plant tissues, so a continuous supply is needed for growing plants.

If sulphur is deficient in plants, young leaves will turn pale green or light yellow without spots. The symptoms are similar to nitrogen deficiency, except nitrogen deficiency shows up primarily in older leaves as it is reallocated to new growth.

In New Zealand you might see sulphate sulphur (sulphate -S) or Extractable Organic Sulphur (Org-Sulphur) on a soil test report.

Sulphate sulphur

This test measures the readily available sulphur in the form of dissolved plus absorbed sulphate. Sulphate is an anion like the phosphate anion and retention of sulphate sulphur by the soil is related to the phosphate retention, with high leaching losses of sulphate being associated with low phosphate retention soils. This should be taken into account when considering sulphur fertiliser options.

Guidelines

Level	Sulphate sulphur mg/kg (ppm)
Very low	< 4
Low	4 - 10
Medium	10 - 20
High	20 - 50
Very high	> 50

Source: Hill - Roger & Kay -Tony 1998. *Field consultants guide to soil and plant analysis*

Extractable organic sulphur

Most of the sulphur in the soil is in organic forms (95%). This test is a measure of the readily soluble fraction of the organic sulphur pool. The pool of sulphur is in a slow equilibrium with the plant available, inorganic form of sulphur. Being a natural source of sulphur, it is useful to have a way of assessing this component especially if the sulphate sulphur test indicates low levels of the readily plant available form.

Guidelines

Level	Extractable Organic Sulphur mg/kg (ppm)
Very low	< 5
Low	5 - 11
Medium	12 - 20
High	> 20

Source: Hill - Roger & Kay -Tony 1998. *Field consultants guide to soil and plant analysis*

Sources of sulphur

Elemental sulphur - Organic standards generally do not permit the use of soluble sulphur sulphate. The main choice of mineral sulphur is elemental sulphur which is 99 - 100% S.

Gypsum (Calcium sulphate) – This contains both calcium and sulphur and can change the physical properties of the soil. Gypsum is a restricted input. See also Calcium.

Organic sulphur - animal manures, which contain sulphur at low levels - (0.1 to 0.2%). This would also add organic matter plus many other elements.

Calcium - Ca

Calcium is the foundation of all biological systems. It is the fundamental 'growth' inducing nutrient and the base against which other nutrients are reacted to release energy for crop and microbial growth.

If it is economically possible calcium should occupy from between 70 to 75% of the base saturation for soil, plant and animal health. If this desired exchange capacity can be attained there will be improved soil structure by forming crumbs, phosphorous and other micronutrients will become more available and the environment for micro-organisms will improve.

Calcium helps plants form better root systems, stems and leaves for efficient use of sunlight energy, water, carbon dioxide, nitrogen and mineral nutrients. It is an essential building block for cell walls and is very important during the growth stage of a living organism and regulates permeability of tissue cells. Calcium is important in blood coagulation and lactation. It enables heart, nerves and muscles to function.

It should be realised that calcium cannot be transported once it has been built into a leaf or root. It cannot be moved from the leaves to the seed or fruit. Newly formed roots, stems and leaves need an additional supply of calcium from the soil. This means that a continual supply of available calcium is required throughout the growing season for quality and peak yield. Calcium can, and often does become a limiting factor in crop production.

Over -use of nitrogen and or many other salt type fertilisers (see later section) or excess of magnesium or potassium leads to acidity or tie-up of calcium even in soils testing high in calcium. Measuring the amount of calcium in a soil at the start of the growing season does not mean that there will be enough available for the life of the plant.

Lime products need to be finely ground thus increasing the surface area of the particle so that the soil micro-organisms can work the surface. Finely ground lime makes a greater surface area available so that any soluble calcium will be available directly to the plant root when water arrives. It may disappoint you to be told that carbonate limestone has approximately two kg of soluble calcium per tonne and for gypsum this is closer to twenty-five kg per tonne.

There is some controversy over the balance of calcium and magnesium. Most consultants involved with biological and organic farming systems agree with Albrecht's work, that it is desirable to attain a balance of 7:1 calcium to magnesium in kg per hectare if we are to achieve quality and quantity of crop or pasture grown.

What are the other benefits attained when getting the 7:1 ratio of Ca:Mg?

- Positive effects on soil structure
- Improved humus content
- The growing of high quality pasture and crops
- Improved animal health with time
- A soil teeming with micro-organisms and worms – assuming that the soil has not been damaged irreversibly with herbicides, fungicides or other chemicals etc.
- An improved soil nitrogen cycle

It is not just the calcium to magnesium ratio that we are interested in but also potassium and sodium. High soil potassium will decrease the plant's uptake of sodium and if there are free nitrates or ammonium available in the soil, it will often result in plants being low in both calcium and magnesium. Many pasture analyses done in New Zealand fit this profile all too often. Is it any wonder that farmers have trouble with grass tetany (staggers), downer cows and displaced abomasum to mention but a few.

Can we have too much calcium in a soil? Yes! The day you get above 85% base saturation for calcium you will tie up 90% of the iron. Calcium can tie up magnesium, potassium, boron, zinc and copper due to the swings in the pH.

Calcium does not tie up nitrogen though and crops grown on 80% base saturation calcium will be very green but the plants will have a weak stalk due to the easy access of nitrogen into the plant. High nitrogen influences copper and this nutrient is so necessary for stalk strength.

Sources of calcium

Limestone (24 to 39% Ca), calcium carbonate is the most common source of calcium. Lime varies from source to source in the total calcium carbonate content. Some of the 'less pure' lime rocks have a very interesting array of trace elements, which may be very useful. The biggest difference in effect is usually related to particle size: the finer the particle size the faster the calcium release.

Dolomite (20-25% Ca, 11-13% Mg) is a form of limestone (dolomitic limestone) consisting of calcium carbonate and magnesium carbonate. Dolomite becomes available after 3 to 18 months. It is an effective magnesium fertiliser in many cases although the release of magnesium might be too slow in some circumstances to overcome seasonal high levels of potassium which induce magnesium deficiency. In such cases, calcined magnesite (magnesium oxide) could be used (restricted input).

Gypsum (18% Ca, 23% S) is a mined calcium sulphate which provides readily available calcium and sulphur. It can be used to improve the soil structure, without raising the pH as the calcium is balanced by the sulphur.

RPR is reactive phosphate rock but also contains about 33% calcium (see phosphorus and RPR).

Magnesium - Mg

Magnesium is part of the chlorophyll molecule in the plant cell. It is a very necessary element for plant health. Also involved with protein production, enzyme functions, energy release in cells, aids phosphorus uptake and starch translocation. Magnesium causes instability of nitrogen in the soil and contributes to hard, tight compacted soil if available in excess in the soil. The ideal range for magnesium is 10-12% base saturation, and a calcium to magnesium ratio of 7 calcium to 1 magnesium.

Most of the magnesium in soil is found in the mineral form, that is, as part of clays. Some of the soils in New Zealand with a high clay content therefore have a magnesium base saturation above the ideal range e.g. moraine clay soils. Other lighter soils such as the pumice soils of the Central North Island are often deficient in magnesium.

In medicine, magnesium is an antacid and mild laxative and in the animal it is essential for nerve and muscle activity and in bone structure and aids in growth promotion.

Sources of magnesium

Dolomite (20-25%Ca, 11-13% Mg) – see sources of calcium.

Calcined Magnesite (52% Mg) or magnesium oxide contains high levels of very available magnesium. It is a restricted input due to its fast release nature.

Magnesium sulphate (20% Mg, 26% S) or Epsom salts is mostly chemically derived and a restricted input. It can be used as a foliar input to give a rapid response.

Kieserite (15% Mg, 20% S) is a natural, mined form of magnesium sulphate. Due to its fast release kieserite is a restricted input.

Organic Patentkali (25% K, 17% S, 6% Mg) is not generally used on pastoral soils unless there is a severe shortage of potassium. See potassium.

Potassium - K

Potassium is very mobile in water. It is an important element of the cell fluid and regulates the water in cells (turgor). Potassium is a catalyst and a prime requirement in chlorophyll construction. It is also a governor for taking free nutrients from the air - carbon, hydrogen and oxygen. Potassium is needed so that plants can make starches, sugars, proteins, vitamins, enzymes and cellulose.

Potassium can be fixed by clays and thus cause a reduction in the expandability and the cation exchange capacity of the clay (makes the clay tight). Potassium can leach in certain soils - especially sandy soils. Aim for a potassium base saturation percentage of 2 - 5%. In animal production systems aim for 2 to 2.5%

Excessive potassium in the soil is usually mirrored exactly in the plants that are forced to grow in this medium and the stock eating these incorrectly mineralised plants may suffer many health problems in the guise of udder infections, foot problems, milk fever and staggers. Excess potassium can result in potassium substitution for calcium thus weakening the plant. It is far easier for a plant to take up potassium compared to calcium. Grazing ruminants do not find plants with excessive potassium content palatable and will avoid them if there is an option.

Soil test report of potassium

It is not uncommon on some soil test reports to write the potassium as water soluble K_2O.

To convert K_2O to the element K divide by 1.4

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Sources of potassium

Potassium chloride (48%K) or muriate of potash is the most common form of potassium for farmland and is the cheapest and provides highly available potassium. This fertiliser is a restricted input so check before using. Generally, biological consultants tend to avoid using potassium chloride due to the potentially negative effects of chloride on soil life (see box). Recommended is the use of potassium sulphate especially if sulphur is required as well.

Potassium sulphate (40-42% K, 17-18% S) is a source of potassium and sulphate; both the potassium and sulphur are in a very available form. The natural (mined) form is a permitted input on organic farms.

Patentkali (25% K, 17% S, 6% Mg) is available as a mined mineral rather than being chemically extracted. Potassium is available as the highly soluble potassium sulphate. Some magnesium is supplied as well, avoiding magnesium deficiency due to excess potassium. This is a restricted input.

Other potassium inputs include sawdust, wood ashes and plant material such as straw sourced from organic systems.

It is questionable as to whether muriate of potash should be used on agricultural soils due to its chloride content (40% chloride). The chloride content is an effective bug killer and kills micro-organisms in the soil. Chloride can also harm crops with roots sensitive to chloride. Why would you add this type of product to the soil when it will kill off your soil friendly microbes and hurt plant roots when you could use the likes of potassium sulphate, of which the sulphate ion is more user-friendly, to both the roots and the soil microbes?

To kill all your bugs in your swimming pool chlorine is put in at a rate of 2 ppm. That is 2 parts of chlorine to 1,000,000 parts of water. This equates to 4.5kg of chloride per hectare. It is not uncommon for a fertiliser recommendation to supply 100 kg of potash per hectare100 x 40% is 40kg of chloride. Now 4.5kg of chloride equivalent can kill all the bugs in your swimming pool and yet farmers are often putting more than 10 times this amount on our soil.

Some farmers have noticed that there needs to be more fertiliser applied to attempt to keep the same yield of produce. Initially with the addition of muriate potash there will be a release of nutrient and non nutrient cations as they are squeezed out of the soil. This is great if there is a crop growing which needs these cations, a microbe that wants to use them or water to leach them away, but this is thought to be at the expense of soil structure and at the expense of net long term capacity.

What happens to the chloride part of the potash? Chloride salts alter the behaviour of clay, making it cluster in lumps and so more difficult to till. When muriate of potash is added to a clay soil which has high calcium content, when the potassium is fixed in the small pores, the chloride is left free to attach to calcium and also aluminium in the soil. We have the formation of two more types of salt that are even more effective in solidifying clays through aggregation. Sodium chloride (N_aCl) is bad enough at doing this but calcium chloride (C_aCl_2) and aluminium chloride ($Al(Cl)_3$) are worse. Now we have reduced pore space, decreased water holding capacity and oxygen levels.

So in summary with the overuse of muriate of potash and in conjunction with high nitrogen applications to the soil, the following features could be expected:

- Soil hardening
- Poor fertility
- Declining response to equal amounts of fertiliser
- Soil compaction
- Erosion
- Reduced water holding capacity
- Limited nutrient reserves (tiny pores that cannot fit the large cations but fit potassium and ammonium ions)
- Negative effects on the soil biology

Reserve Potassium

The amount of slowly released potassium is often more significant than the amount of immediately available potassium.

This test is used to estimate the long-term potassium supplying potential of the soil and appears to be unaffected by short-term treatments.

Guidelines

Level	Reserve Potassium (me/100g)
Very low	< 0.1
Low	0.1 – 0.2
Medium	0.2 – 0.35
High	0.3 – 0.5
Very high	> 0.5

Source: Hill - Roger & Kay -Tony 1998. *Field consultants guide to soil and plant analysis*

Sodium - Na

Sodium is not required in huge amounts in the soil: 1% base saturation in soil or at a ratio of 1 sodium to 2 potassium. Sodium deficiency in soils is generally a problem in New Zealand because of our proximity to the coast and strong winds. Inland areas may well need an input of sodium however. Sodium in excess will make a soil hard and elements unavailable. If soil potassium base saturation is very high then the sodium base saturation will have to be increased.

Sodium is very important for some particular plants and particularly for animal health. Sodium in a cell is a regulating element that governs osmotic pressure in cellular tissues and fluids. Lack of sodium is generally not a problem with plant growth in New Zealand. Production animals should always have free access to a salt block throughout the year as they will seek salt if they their bodies are short of sodium.

Manure and compost can add sodium, as well as seawater. It is wise to monitor the base saturation percentage level and ensure that it does not go above 3%.

Sources of sodium

Sodium chloride is restricted under the organic standards. There will have to be a demonstrated need if it is to be used. See the section on potassium chloride with regards to the effect of chloride on soil inhabitant well being.

Trace Elements or Micronutrients

Trace element absence can mean plant health problems and animal health problems due to eating pasture/crops which themselves have deficiencies. Trace elements can be bulk spread but it is vital to balance the major cations first - calcium, magnesium, potassium and sodium. As the major elements (especially calcium) adjust towards the ideal 'balance' the whole soil will change. The micro-organisms will be more active and with more organic matter more nutrients will be released.

Trace elements commonly looked at by consultants in New Zealand are selenium, copper, cobalt, boron, molybdenum and zinc. Manganese, silicon and iron are also another three trace elements which need to be occasionally looked at. In the case of iron it can be in an excess state rather than a deficiency and can cause animal health problems.

See also trace element deficiencies in the animal health sector.

Boron (B)

Boron is another very important trace element, which is often overlooked.

This element is involved with regulating flowering, fruiting, pollen production, seed production, cell division, salt absorption, carbohydrate metabolism, cell wall production, water use and nitrogen assimilation in plants. Boron is important for the filling of hollow stems of plants. Boron is also important for increased calcium uptake. Pastures deficient in calcium are generally low in boron too.

Boron deficiency is widely associated with soils derived from strongly weathered greywacke rock such as are found in Nelson, Marlborough, Canterbury, parts of Hawke's Bay and Central Otago. Boron leaches very easily from the soil so should be checked for in soils or pasture analysis.

It also functions in the synthesis of glycogen and the maintenance of body fat in animal life. Boron deficiency has been linked with vitamin B1 (thiamine) deficiency in animals (blindness). It is also needed for bone construction in animals. Boron is commonly found to be deficient in clover in New Zealand, causing a red discolouration of the leaf.

Boron is toxic to grazing animals. With solid application ensure rain washes the fertiliser off the pasture before grazing. Too much boron is also toxic to plants (especially maize) - more so when temperatures are cool and the soil is damp.

Sources of Boron

- Ulexite is a natural (mined) product and is allowed for use on organic farms.
- Boron chelates
- Chicken manure or compost - preferred

Cobalt (Co)

Cobalt is an element crucial for nitrogen fixation, especially in legumes' root nodules. It is also important for the formation of bark, cellulose and seed-coat formation.

Cobalt is the element in vitamin B12, which is produced by actinobacteria in the soil. Cobalt levels in pasture are commonly found to be too low, especially on volcanic and pumice soils. Cobalt in soil is sensitive to moisture and higher soil pH.

Soils in New Zealand are generally not tested for cobalt. Herbage is more regularly tested. One of New Zealand's native bushes called Rangiora (which has a large leaf bush - also called bush man's friend) has a very high content of cobalt, as do gorse seedlings!

Sources of cobalt

- Cobalt sulphate (21% Co)
- Cobalt chelate (3.75%)

Copper (Cu)

Copper is involved with many enzyme systems helping to form amino acids and proteins and is a vital element for microbes in the soil. Copper is vitally important to root metabolism. Copper helps produce dry matter via growth stimulation, prevents the development of chlorosis, rosetting and die-back.

A lack of copper is related to the soil and is common mainly on peat, sandy, and pumice soils. One of the other reasons for low copper levels in animals is that the pasture often has very low levels of copper in it especially if it is predominantly rye or fescue.

A sward with a greater variety of plant and herb species present will test higher for copper content then a rye/clover or fescue/clover pasture.

Copper can be made unavailable through an excess of minerals including iron, zinc, molybdenum, sulphur and phosphates which restrict the uptake of copper. High doses of zinc used to protect stock against facial eczema damage can cause copper deficiency. High levels of iron in pasture test results are often due to soil contamination. Animals at certain times of the year can eat a lot of soil when grazing sodden pastures so this iron source can tie up copper.

Sources of copper

- Copper chelate foliar sprays are available in New Zealand.

Iron (Fe)

Iron is needed for chlorophyll production, energy release in cells and in conjunction with cobalt is needed by nitrogen-fixing bacteria. Iron draws energy to the leaf by absorbing heat from the sun. It makes the leaf darker, thus absorbing more energy. Iron will increase the thickness of a leaf, which will increase the nutrient flow resulting in a greater production increase. Iron will increase the waxy sheen on a crop.

- Often seen in excess in soils and even in bore water levels can be very high

Iron is generally not tested for in soils by laboratories in New Zealand, as this element is not deficient.

Sources of iron

- Iron sulphate
- Iron chelate
- Black strap molasses - a very good source where acceptable. Ensure it does not contain preservatives.

There are three major types of molasses:

1. Unsulphured molasses is the finest quality grade because only a small amount of sugar has been removed. It is made from the juice of sun-ripened cane and the juice is clarified and concentrated.
2. Sulphured molasses is made from green sugar cane that has not matured long enough and treated with sulphur fumes during the sugar extracting process. The second boil molasses takes on a darker colour, is less sweet and has a more pronounced flavour.
3. Blackstrap molasses is from the third boil. Blackstrap molasses has the lowest sugar content and the highest mineral content of all commercially available molasses.

Manganese (Mn)

- This trace element is required for normal growth and photosynthesis, oil production, energy release in cells and enzyme functions. A seed that doesn't contain manganese is unable to germinate.
- It is generally considered that New Zealand soils have sufficient manganese. Low pH soils could have manganese available at undesirable levels.

Sources of manganese

- Manganese sulphate (28% Mn)
- Manganese chelate (7.5% Mn)
- Royal jelly – expensive

Molybdenum - Mo

Another important element for several enzyme systems, particularly nitrogenase and nitrate reductase i.e. the enzymes to break down or build nitrogenous compounds. Plants grown on nitrate nitrogen have an increased need for molybdenum because of the increased need for the enzyme nitrate reductase. Molybdenum is a catalyst for iron in the bark or plant skin and is important for their integrity. It gives the transparent look to the sheen on bark. It is most commonly used by legumes.

A deficiency of molybdenum can cause nitrogen deficiency in legumes. As soil pH increases, Mo availability increases. When present in excess in plant tissue, molybdenum can cause copper deficiency indirectly.

- Generally, molybdenum is not tested in the soil by laboratories in New Zealand.

Sources of Molybdenum

- Molybdenum glucoheptonate
- Molybdenum chelate

Selenium (Se)

Selenium is commonly deficient in plants, animals and humans throughout New Zealand. 30% of New Zealand is selenium deficient; mainly on sandy soils of all types including pumice soils and the loess soils. Selenium is deficient in a lot of pasture and forage crops grown in New Zealand. There is some debate as to whether this trace element is actually deficient in the soil or whether it is a case of the required biology in the soil being absent or functioning at a reduced level so that the end result is a deficiency in the plant which transfers to animal and human deficiency.

Currently in New Zealand no laboratories test routinely for the selenium content of the soil. A deficiency is usually detected in blood or liver testing from animals and then amendments are made to the soil.

Monitor selenium levels in animals regularly after application of selenium fertiliser to the soil (and keep your vet informed as well) before adding more to the soil.

Sources of Selenium

- Selenium prills (1% Se)
- Foliar sprays can be used

Silicon (Si)

Silicon is not generally recognised as a plant nutrient but it is vital to some plants such as watermelons. Silica is involved with protecting plants against mould penetration.

The soil has quite large quantities of silicon. It is difficult to find a laboratory that can do an analysis for silicon. Silicon often turns up as a missing link in certain finely tuned fertiliser programmes and seems to have some correlation to the carbon - calcium interaction in the plant and is generally used as a foliar additive.

The herb horsetail, also known as spring horsetail or scouring rush, is a perennial and grows in all temperature zones of the world. This non-flowering, non-seeding plant thrives on clay-like sandy soils and likes marshlands, streams; some plants have adapted to growing along roadsides and on stony ground. Refined foods don't have silicon so you will find abundant silicon in the shell of brown rice, bell peppers and leafy greens.

Sources of Silicon

- The best source is the herbal extract of the horsetail plant (Equisetum arvense)
- Biodynamic preparation 508

Zinc (Zn)

Zinc is an essential component of many enzyme systems. It is also involved in making acetic acid in the root to prevent rotting. It allows dead twigs on trees to shed off. Excessive zinc in soil promotes weed growth!

Excessively high phosphorous levels can depress zinc levels. Zinc deficiencies can be caused by over liming.

Sources of Zinc

- Zinc sulphate (36% Zn)
- Zinc chelate (7 to 10%, Zn) used as a foliar spray

Rock Dusts

Certain types of rock finely ground can improve fertility of soils. For those farmers who have access to rock dust this may be another way of improving crop or pasture quality and for those who have crops sensitive to frost damage, the application of ground rock in the fertiliser programme should be considered. It does pay to be aware of the constituents of the rock dust as most rock types can be crushed but you need to be wary of unwanted heavy metal content.

Available rock dusts

Reactive phosphate rock: Calcium and phosphate

Limestone: Calcium

Gypsum: Calcium and sulphur

Dolomite: Calcium and magnesium

Serpentine/Dunite: Magnesium, silica

Talc magnesite: Magnesium

Bentonite: Silica, potassium (as oxide), sodium (as oxide)

Basalt: Silica, trace elements

Granite: Silica, trace elements

Source of rock dusts

- Local quarries with crushers are a good source of material, the fine particles accumulating under the crusher being regarded as a nuisance. Ask at your local quarry and see if there is fine ground rock available. Rock dusts are also available commercially.

Paramagnetic Material

There may be a way of improving the fertility of a soil by adding paramagnetic material, such as basalt or granite. All volcanic soils and rock are highly paramagnetic and tend to be extremely fertile.

There are three types of magnetism:

- **diamagnetic** - diamagnetic materials are weakly repelled by magnetic fields.
- **ferromagnetic** - ferromagnetic materials are strongly attracted by an external magnetic field.
- **paramagnetic** - paramagnetic materials are affected by an external magnetic field because its atoms or molecules line up with (rotate into a new position) the external lines of force coming from the magnet. In paramagnetic materials this phenomenon is weaker compared to ferromagnetic materials. Paramagnetic materials are attracted toward magnets, but do not become permanently magnetised. These materials have unpaired electrons in the atomic make up which can be affected by an external magnetic field.

If you have movement in magnetic fields then by definition and the laws of physics, you will have a current induced in any nearby conductor. This opens the door to influence of biological process that depends on ionization (electrically charged particles). This influence sets the stage for paramagnetism of soils to have an influence on micro-organism and plant growth.

The mineral diversity of a soil determines the paramagnetic susceptibility, and the absorption of energy by the soil. Compounds of chromium, cobalt, copper, iron, manganese, molybdenum and nickel, all test high for paramagnetism. Strong paramagnetism is associated with rare trace elements. Some of the less pure calcium carbonate lime products available in New Zealand contain minute amounts of these trace elements, which may also account for some of the apparent plant growth responses which appeared to be greater than otherwise expected.

It should be noted that paramagnetic susceptibility can also be increased by soil aeration, as oxygen is also highly paramagnetic, and by growing a variety of green manure crops like mustard, rye-grass/clover, lupins and tilling them into the aerobic zone of the soil. Each cover crop will attract different minerals into its structure from the air and increase the soil mineral content and diversity when it is incorporated.

It would be beneficial to have your soil tested for paramagnetic susceptibility first before applying paramagnetic rock. There would be little point in applying paramagnetic material if you already have a high paramagnetic reading from your soil.

Radionics

Since the introduction of the Ag-Enviro Radionic device to NZ in the mid 1990’s, there has been a significant number of practitioners and farmers treating farms and animals with this frequency modality. It has been in use in many countries since the 1940’s, particularly the USA, UK, Europe, and Australia. It was even used by the Mayans 2000 years ago to increase soil fertility and control pests and weeds.

To explain how radionics works is beyond the scope of this resource guide. The reference work mentioned at the end of this will give you an understanding and the history of its development. Suffice to say that radionics identifies the frequency at which any life form (or part thereof) vibrate at, and if it is out of balance, generate the required frequency to correct that vibration and bring it into balance.

Treating a farm and herd with a radionic device requires constant vigilance and much time. The treatments (frequencies) available are only those given to the practioner/ farmer when he/she buys their machine. Using radionics as a tool on your farm is no excuse to forgo physical inputs. It is there to assist these inputs.

Compost and Effluent

Compost and effluent are bulky, and often a hassle to obtain and apply compared to mineral fertilisers. Moreover, the amounts of N, P, K and other elements are generally low. As resources become more limited, and as farmers start to realise that the value of compost and effluent goes beyond the elements that are added, recycling of these 'waste' materials will improve.

Compost

Composting is a useful way of returning organic material back to the soil with a complete array of micro-organisms and plant nutrients in an available form for microbes and plants.

Compost can be beneficial for a farming system or it can be neutral or even detrimental. There are quite a few factors, which influence the quality of the compost and whether the final product is suitable for your production system - growing grass or other crops. One of these factors is that compost must be must be made aerobically - in the presence of oxygen at all times.

There are many text books written on the subject of making compost and research continues to identify ways to improve the final compost product. You will find some references at the end of this chapter.

The composting process

In an aerobic composting process, the invertebrates (worms, millipeds, sowbugs), but more importantly the micro-organisms that decompose organic matter need oxygen and water. During the process, micro-organisms use carbon (C) in the organic matter as a source of energy and produce carbon dioxide (CO_2). The consumption of carbon results in the reduction in weight and volume of the compost pile. The micro-organisms use the nitrogen (N) of the organic material as a source of protein. The finished compost has many of the characteristics of humus.

The composting process has a breakdown phase and a build-up phase. While the invertebrates are in charge of the physical decay, the micro-organisms are responsible for most of the decomposition, as well as the rise in temperature that occurs during the first stages of the process. Thermophile aerobic bacteria are responsible for the breaking down process and in doing so they release heat. The temperature in the heap rises steadily and at day six the temperature should be around 65°C. The next phase is the build-up phase without the release of heat and the bacteria population will change from thermophile bacteria to mesophile bacteria. After 6 weeks the compost should be 20°C in temperature. If you purchase compost and it is steaming, the temperature is likely to be well above 20°C and the product is still in the breakdown phase. You should not purchase this product.

Temperature

Compost pile temperatures between 32°C and 60°C are considered optimum for micro-organisms and indicate rapid decomposition. The entire compost pile must reach a temperature that exceeds 57°C for at least three days, necessary to kill weed seeds and pathogens. This means that the pile will have to be turned regularly to enable it to heat up. This method ensures that all parts of the compost eventually reach that minimum temperature for a minimum of three days.

The temperature must not exceed 70°C. If you over-cook your compost there is no point putting it out on your soil as most of the micro-organisms in the pile will not have survived these high temperatures and you will find that the compost will have detrimental effects on your soil food web. To cool a pile you can turn it slowly, add water or add soil to it. The temperature of a pile will drop 7°C when it is turned.

A temperature probe is often used to monitor the temperature. If you are making compost on your own farm this is one instrument that you must obtain and use daily to monitor the temperature of your compost pile.

Raw materials and carbon to nitrogen ratios

The carbon to nitrogen ratio (C:N) is important when you combine your organic materials to make compost. The ratio should be approximately 30 carbon to 1 nitrogen by weight. See below for a list of C:N ratios for commonly used materials.

When the C:N ratio in your compost heap is too high, there is too little nitrogen and the decomposition slows. When the C:N ratio is too high, too much nitrogen, the nitrogen will leave the pile as ammonia gas and cause odour problems. Ammonia smells like fresh manure.

If you make your own compost, it would also be prudent to know where the raw ingredients originated from. Collecting and using raw organic matter like cow manure when the cows have had anthelmintics or antibiotic treatments or grass clippings that have had broad leaf herbicide sprays applied are not suitable for composting as some of the chemicals used in animals and on plants remain active and continue their action during composting. Any raw organic product that contains a preservative is not suitable for composting; this means any product that is used to kill micro-organisms. Shredding, chipping or chopping material will speed up the decomposition process, as this will give the micro-organicisms more material to digest.

The best source of raw ingredients would be from your own organic farm! If material is coming from outside the farm, organic certification will require hot composting, residue testing and documentation.

Biodynamic Compost preparations 502 – 507 inserted into your compost heap will hasten the process and help the anaerobic actions. See Biodynamic Preparations.

Compost pile site and size

Compost pile site:

- It should be close to the source of the materials to be used.
- If large tonnages are to be made then leave room for tractors/compost turners etc.
- Slope in one direction only - no side slope. The piles need to run the same direction as the slope so water

does not run under the pile.

- Consider a humus sink with plants to catch run-off at the bottom of the site
- Must have access to a good water supply
- A good base that allows turning the pile in all sorts of weather and protects against seepage into the ground.
- Should not be in a hollow where water can collect and turn the lower part of the compost stack anaerobic
- Consider compost covers. These must be permeable to allow oxygen to enter and carbon dioxide to leave. It should also prevent water from getting through (excess from rain) and keep heat in.

Compost pile size does seem to be important – ideally 1m high and 3m wide. If you build higher and wider piles you will have to turn it 4 to 5 times a day to keep the CO_2 (carbon dioxide) and temperature from building up too high.

Aeration

Now the catch here is to ensure that the pile of organic matter is aerated for the full 6 to 8 weeks or whatever time it takes to get to convert the organic matter to compost. During the composting process the material becomes deficient in oxygen (anaerobic), especially in the centre of the pile and carbon dioxide (CO_2) levels will begin to rise. You will have a putrefaction process occurring - one that draws oxygen from the organic matter instead and is dominated by anaerobic bacteria. Your compost pile will start to smell badly if this happens, like fresh manure (ammonia gas) or rotten eggs (sulphides). Regular turning will prevent this from happening.

The top of the pile should be turned to the bottom and the sides worked into the middle. There are implements that can be driven off a PTO on a tractor - otherwise a front end loader or by hand.

There are compost turners - the heart of which is a drum. The size of the drum and the tine angle and length are critical since drum design gives the pile its shape. The RPM of the drum must be kept low - excess speed destroys the crumb structure of the compost. Too much shielding of the drum will not allow CO_2 to escape from the pile as it is being turned.

Moisture

Making compost requires certain moisture content – between 40 and 60% moisture. An easy test to determine the moisture content is the 'squeeze test'. Material in the pile should feel damp to the touch, with just a drop or two of liquid expelled when squeezed tightly. Too much moisture will lead to a slow decomposition, leaching of nutrients and odours.

If a pile is too wet, turn the pile or move it to a new drier place or add dry materials. If a pile is too dry, you can add water or very wet manure.

pH

The pH of a compost pile will rise above 7 or 8 on the second or third day. It will stay above 8 or 9 throughout most of the composting process. pH will drop under 8 when the composting process is finished. If it drops below 6 then lime or soft phosphate rock could be added.

Important: Compost applications and the approximate amount of nutrients added to the land should be taken into account in the nutrient budget.

Compost recipe for farmers - bacterial dominated

All the following percentages are % by volume.

70% high N products - these are needed to make heat in the compost pile

Be careful with the products content of salt, antibiotics and heavy metals

Legumes - make sure that nodules are present otherwise these products will not be high nitrogen. Ideally animal manures should be added in the following percentages:

Fresh ruminant (cow, sheep, goat) - 25% of the pile by volume

Old ruminant - will need to have a higher percentage than fresh manure for the pile

Fresh poultry - make this only 15% of the pile as it has higher N

Pig manure - only make this 5% of the pile as it is very high in N

30% low N products or high C products (woody products)

Sourced from notes given at the biological farming workshop in 2001

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Summary of testing parameters for a compost Pile

pH	6.5-7.5 (if higher don't buy the compost)
oxygen	not under 8%
carbon dioxide	not over 8%
ammonium NH_4+	not above 2mg/kg
nitrate NO_3-	not more than 300mg/kg in summer, 50-100mg/kg in winter
nitrite NO_2-	zero in finished compost
sulphide H_2S	zero at any time during compost process
rH (redox potential)	25 -28 on finished product
humus value	60-80

Carbon to nitrogen ratio of various compost materials

High nitrogen materials	C: N
activated sludge	6 : 1
alfalfa	16 - 20 : 1
legumes	10 : 1
animal tankage	4 : 1
blood or bone meal	3 : 1
box stall manure	30 : 1
coffee grounds	20 : 1
cow manure	18 : 1
fruit wastes	35 : 1
garden weeds	19 : 1
grass clippings	12 - 25 : 1
horse manure (fresh)	25 : 1
horse manure with bedding	30 - 60 : 1
kitchen garbage	23 : 1
liquid manure	11 - 14 : 1
liquid sludge	10 : 1
municipal garbage	15 : 1
paunch manure	10 : 1
pig manure	5 - 7 : 1
poultry manure (fresh)	10 : 1
poultry manure (with litter)	13 - 18 : 1
seaweed	19 : 1
slaughterhouse wastes	2 : 1
urine	0.8 : 1
vegetable wastes	12 - 20 : 1

High carbon materials	
corn stalks	60 : 1
bark	100 - 130 : 1
fresh sawdust	500 : 1
leaves	30 - 80 : 1
lumber mill wastes	170 : 1
oat straw	50 : 1
paper	150 - 200 : 1
pine needles	30 : 1
rotted sawdust	208 : 1
rye straw	65 : 1
wheat straw	125 : 1

Effluent as fertiliser

All organic certifying agencies encourage the return of effluent to the land to create a nutrient cycle. There will be some exceptions to the rule, depending on where your farm is in relation to sensitive areas, but the majority of farms should be able to meet this requirement. Nutrient value of effluent varies at the time of the year and the area you are in. It is related to the type of feed and soil properties

Benefits as a fertiliser:

- Effluent is a valuable resource that completes the nutrient cycle.
- Effluent has available N, P, K, S and trace elements.
- Effluent returns valuable fertility and organic matter to the soil.
- The organic matter in effluent encourages microbial and earthworm activity.
- Effluent improves water retention ability, aeration, draining and friability of the soil.
- It helps create darker soils, which warm up faster.
- Nitrogen is applied in two forms: 50% ammonia, which is available immediately and is equivalent to urea in pasture production and nitrate leaching; and 50% undigested proteins and molecules which is in slow release form.
- Effluent can provide most of the potassium (K) in the available form needed for pasture production. In time, land application of effluent increases potassium levels in pasture and soil and can cause related metabolic problems. To avoid, monitor your K levels. See also animal health chapter.

At 37,000 litres/ha/year of effluent, based on average Waikato dairy data, this would deliver

Nitrogen	Phosphorus (P)	Potassium (K)
150 kg	25 kg	105 kg

Nutrient in effluent from 100 cows (kg/yr), all grass system, milking 270 days, twice a day

Nitrogen	Phosphorus (P)	Potassium (K)
590 kg	70 kg	540 kg

Effluent area needed to apply 150 kgN/ha (all grass system, milking 270 days, twice a day)

11% of your farm

4 ha/100 cows

Percentage of nutrients available in the first year

Nitrogen	Phosphorus (P)	Potassium (K)
50%	50%	90%

From: *Guide to managing farm dairy Effluent* (Dairy NZ)

The rules and regulations around effluent can be obtained from your local council or online at dairynz.co.nz. Regional Councils have permitted levels around 150 kg to 200 kg of nitrogen per hectare per year, depending on the climate and sensitivity of the region, but the maximum permitted levels of nitrogen per hectare per year could be lower for organic certification.

The discharge of effluent (except composted effluent) to land from dairy shed or other sites where livestock are concentrated in a confined area is a controlled activity, and requires resource consent.

Reusing dairy effluent – some methods and tips

There are many ways we can treat dairy effluent and there will be factors, which will influence the one you choose. The four main goals should be:

- To return it to the land in some form at a rate that delivers no more than 150 kg nitrogen per hectare per year.
- To use a nutrient budget. Soil test the area after application to ensure a balance is being achieved.
- To not allow runoff of waste and effluent, including detergents etc into the waterways until treated adequately.
- To spread at a time of year when rainfall does not exceed evaporation to avoid run off and leaching.
- To allow effluent to stay in any treatment pond 60 – 90 days to allow solids to settle and microbes to breakdown organic material.
- To monitor bacterial levels through soil and water tests, to ensure there is no risk to animal, human and water health.

Failure to do these will result in a breakdown of soil health, water quality and will affect any plant, fish, and insect life in the water.

Whatever system you choose you should minimise the amount of effluent and runoff you have to deal with. This avoids overflows and extra pumping, enables enough capacity to hold it longer and get more benefit from it. It also reduces the amount you need to spread.

How do I achieve this?

- Ensure there is no runoff of water from tanks, spouting, yards, surrounding hills, going into your holding ponds. Have a diversion drain around the ponds and shut off the access to your pond at the fill pipe, enabling that water to go to the diversion drain instead.
- Repair hose leaks.
- Pre-wet the yard before milking – this speeds up hosing down and reduces water used.
- Scrape the yard before hosing down.
- Use a chain on the backing gate to break down the cow pats.
- Reuse cooling water and store it for washing down.
- Keep cows as calm as possible and they will be less likely to mess the yard.

a. Stick to a routine.
b. Avoid stray electricity
c. Avoid feeding molasses or meal in the shed.
d. Watch your dog and workers.
e. Remove slippery surfaces.
f. Work the cows positively and gently.

Let the cows drop their cowpats in the paddock. Wait at the gate for them to get up, empty themselves, and move towards the gate in their own time. This will spread the fertility all over the paddock, without you having to respread it.

Systems for treating effluent

Holding Ponds

Holding ponds have the advantage that they have a large holding capacity, and lessen the risk of waterway contamination. The two pond system is the system that the majority of farmers are operating. These ponds should be sealed with a compacted clay layer or plastic liner.

The two pond system (this process should take 60-90 days before the end product is moved to another system or returned to the land) consists of:

(a) Anaerobic pond: It settles solids and breaks them down. This pond is usually 4 metres deep and it should bubble and be active.

(b) Aerobic pond (oxidisation pond): The oxidisation breaks down the organic material and changes minerals to a more readily available form for the plants. It needs sunlight and wind flow to help this process. It should be 2 metres deep. This is the pond that we irrigate from to the land.

(c) It can then be transferred to a wetland, sprayed onto pastures or put in a third holding tank for further treatment depending on its composition.

(There is a diagram of this system in the tree chapter under Pond/Dam/Effluent Pond Plantings).

Other information on this system:

- Check the pH of the ponds. It should be above 6.5. If not, correct using lime – 1.6 kg/1000 cubic metre of volume daily until the pH is 6.5 – 9.0.
- Poorer quality pasture eaten by the herd (kikuyu, paspalum etc) can create excessive crusting. This will need removing.
- Pumping oxygen can help reduce the nitrogen losses and increase available N to crops. Aeration can be enhanced by:

a. Using effluent pond conditioners commercially available
b. Adding biodynamic compost preparations and/or cowpat pits
c. Pumping air through the pond. This can be expensive. One cheap way is to coil PVC pipe with 0.05mm holes at the base of the pond. Use a compressor to push the air through it.
d. Wind movement
e. Circulating the pond contents through flowforms
f. Using a stirrer from time to time.
g. The use of clay products, such as bentonite, zeolite will help bind free nitrogen and make it available.
h. Covering the pond with straw, hay, old compost, sawdust (ensure it is not treated) will increase the carbon to nitrogen ratio, reducing the loss of nutrients through evaporation, and it keeps the rain out.

For more information of effluent storage see the DairyNZ website:www.dairynz.co.nz

Advanced Pond Systems (APS)

These are being trialed in New Zealand, where environmental restrictions do not allow land application. It is a four stage system:

1. Anaerobic pond.
2. High rate pond
3. Algae settling pond
4. Maturation pond

For more details from the NIWA website http://www.niwa.co.nz/news-and-publications/publications/all/wru/2004-09/pond

Barrier ditches/blind drains

This is the same principle as the two pond system, except they are elongated, or drains with no outlet. It is important there is enough space to hold 60 – 90 days of effluent. There must be at least 2, with a baffle between. The first is the anaerobic system and the second the aerobic. You can have as many ditches as you like. A 150 cow herd needs 6 x 930 cubic metre ditches at 1.5m deep and 300m long. The first sections will need cleaning frequently to avoid runoff.

Wetlands

Wetlands use plants, air, sunlight, insects and birds to filter out and remove the nasties before going into the waterways. This can be used after a pond system to further treat effluent. It should take 7 – 10 days to go through the wetland under this system. It is a good place to treat chemicals used, e.g. detergents, zinc and copper sulphates from foot baths etc. Constructed wetlands must not be part of a natural wetland, as the latter is classified as natural water and part of a natural aqua system. Check also the Wetlands section for more tips.

Other tips:

- Check the area has healthy plants throughout.
- Avoid bare areas.
- Avoid invasive plants and those unpalatable to stock.
- Monitor for pests – pukekos and rodents – they destroy the plants.
- Consider vegetation harvesting to ensure 75% is maintained in healthy plant growth.
- Fence it off.

Compost and vermicast

This is not common practice in New Zealand, but is currently being explored by some farmers here. Scrapings from the yard or stand off pad are collected and gathered into heaps and composted.

- Worms can be added to inoculate the heap.
- Biodynamic compost preparations can also be added to keep it aerobic.
- Your site should be carefully chosen to avoid runoff to waterways and sensitive areas.
- Covering it will enable it to be heated and would minimise the risk of runoff.
- Allow it to work for at least 6 weeks.
- When spreading, spread in thin layers to allow sunlight through to the plants and to kill any bacteria.

Applying fertiliser to the land

Northland Regional Council rules 16.1 (These are similar throughout NZ)

Permitted activities (disposal to land):

Disposal of farm dairy effluent to land is permitted provided that there is:

- No discharge directly to “water”
- No application within 20 metres of “water”
- No overland flow of sludge
- No application within the streamside management area
- No runoff to “water”
- No discharge within 20 metres of the property boundary

And that there are:

- Contingency measures in place to ensure that there is no discharge to water due to equipment failure, overflow or prolonged wet weather.

Please check with your regional council for specific rules and regulations and to apply for resource consent.

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Effluent cart

This can be your own, or contractors can come in to spread it. Ensure the contractor’s gear is washed out before starting on your property.

Advantages:

Reduces the animal and plant health risk because you can spray wherever you want, whenever, on your farm.

Disadvantages:

It can become a ‘round-to-it’ job and not applied at the best times. It also means the effluent could be sitting around for a long time, losing nutrients.

Sprinkler system

This is a system using sprinklers either direct from a holding tank at your dairy, or from a pond. It uses only a certain specific area of the farm and the sprinklers are either fixed in position, or can be shifted. The effluent is generally very fresh, and modern dairies have storage for as little as two days.

The rule of thumb for this system is that you need 12-15% of your farm under this system to meet the 150kg/ha/Year restriction, i.e. 370 square metres per cow or 4Ha/100 cows.

It is also important to do specific, regular soil and water tests for bacteria levels for sprayed areas, to ensure there is no build up of toxins and to check fertility, especially potassium levels.

Advantages:

Can be spread every day, and very little other fertiliser is needed on that area. It requires minimum labour input.

Disadvantages:

It is restricted to one part of the farm only. It is tempting to use effluent that is fresh, which has not had time to remove all the bacteria. There is possible ponding and leaching through constant spraying.

On areas where the maximum 150 kg N/ha is applied,

1 Tonne lime to ha every 4 years may be required.

This is why specific soil tests are so important.

Travelling irrigators

This can be mixed with water irrigation. The same principles as sprinklers apply with this system.

Another disadvantage with this system is possible air pollution.

Direct land application

This is where a suitable area is irrigated with effluent direct from the dairy on a daily basis.

Advantages:

There is good use of nutrients

Disadvantages:

It is a high maintenance system. It needs management to avoid contamination of pastures and waterways. It produces odour. Sufficient storage is often still needed in case effluent can not be irrigated to the land e.g. high water table, land too wet, mole or tile drainage.

Constant testing for soil and water is important here too.

Risks with applying effluent to the land

With long term application, increased potassium levels in soil and pasture in winter and spring can increase potential for metabolic problems.

- Avoid grazing effluent paddocks with springing cows and those recently calved.
- Have pasture analysed regularly.
- Increase your area or choose where you spread your effluent using muck spreaders.

Contaminating waterways through surface runoff, leaching, or spraying where there are tile drains.

- High BOD’s (biological oxygen demands), spread of diseases, such as salmonella and release of faecal coliforms destroy waterways and life in it.

Contamination of soil through worms, coliforms etc affect animal and human health.

- Soil test regularly to check these are not too high or building up.

Too much too often will destroy soil structure.

- Recommendation, apply three times a year.

Applying at the wrong time of the year.

- Do not apply when soils are waterlogged.
- Rule of thumb: When rainfall does not exceed evaporation.
- It needs sunlight to kill faecal bacteria.

Other tips

- Take care with personal hygiene.
- Apply to recently grazed grass and do not graze until 10 days have passed, or rain has washed it off the grass. This allows contaminants such as e coli, salmonella to be killed off or removed.
- Mix sludge with water to avoid plant damage.
- Never empty out the pond. Leave one third full to keep the process going.
- Take care when emptying the pond not to rip or crack the liners.
- Use a stirrer prior to emptying. This will mix the layers.
- Late summer, early autumn is best for the sunlight and temperature breakdown of any disease-causing micro-organisms.
- Spray at least six weeks prior to cutting hay or silage and use older manure to avoid contamination.
- Frequent spreading with thin layers is more beneficial than heavy dressings.
- Avoid damage to the soil if spreading effluent with a cart.
- Avoid loss to the air and evaporation.
- Keep a record of where you applied the effluent, how much and when.
- Treat effluent areas separately when doing soil and herbage tests.
- Avoid spraying at night.
- Think of your neighbours when spraying and spreading.

Biofertilisers

Biofertilisers is the generic term given to fertiliser formulations which are biological in origin and add more to the soil than the amount of elements contained in the product. There is a vast array of biological fertiliser options, seaweed extracts, microbial extracts, microbial inoculants and the like. We will discuss seaweed and fish fertilisers, compost teas, biodynamic preparations and vermicast in the next section.

Seaweed and fish fertilisers

With traditional fertilisers there are only a handful of elements that are being applied to the soil. Apart from carbon, hydrogen and oxygen, only 13 other elements are addressed in agriculture by consultants. It has been reported that the very first cell that sprang from the Precambrian Ocean contained 77 minerals. When one considers that nothing in nature is an accident it is a safe bet to assume that the other sixty or so minerals play some as yet unidentified role in cell nutrition - whether it is a plant, animal or human cell. No doubt in the future these roles will be revealed by scientists but why wait for science to catch up?

We could try and grow the roots of our plants to bedrock or parent material so that some of these elements can be acquired. Unfortunately there are few pastures that have roots below half a metre let alone many metres to get to the parent material. If these elements are not present in the bedrock, nor applied to the soil or pasture how do plants or animals get access to them?

Any product derived from the ocean contains the full spectrum of elements, as these elements are all present in seawater. There are, therefore, many benefits to be had by giving a farm an application of a liquid seaweed or fish solution. Not only are you applying a balanced solution with the elements already in an organic form, which are more plant available, but you are supplying some of the trace elements and a food source as well. These products supply complex carbohydrates and proteins and amino acids.

Seaweed products have other benefits. Along with up to 50 elements concentrated from seawater there are other plant stimulants. Cytokinins, gibberellins and auxins are plant stimulants, which particularly encourage root development, fungal resistance and rapid cell division during the formation of fruit, root crops, flowers etc. Phenolic compounds add to the effect of cytokinins encouraging cell division but particularly add to resistance to fungal attack. These products are food for the micro-organisms in the soil as well as a mineral supply for the plant and micro-organisms alike.

Those farmers who have used these products have noticed significant improvements in many aspects of their farming enterprise. Veterinarians often note that health problems on farms where a seaweed or fish application program is being run tend to reduce as well.

In the transition period to organics many farmers have reported using a number of fish and seaweed applications during the year and are reporting good results.

Compost tea

Compost tea is a water extract of a sample of compost that has come from a "brewer". This water extract ends up containing a huge array of organisms from the compost, which range from bacteria and fungi to protozoa and nematodes.

The process starts by first making good quality compost (see compost section) and then a sample of this is taken and added to a brewer along with an uncontaminated water source, oxygen (bubbled in) and soluble food (sugar, kelp, humates etc.) to feed the micro-organisms. These micro-organisms multiply, grow and even die to feed the next group. This is done for a set time until the solution is diluted with fresh water then immediately sprayed on the pasture, fruit tree, vine-yard or vegetable crop or what ever it is you want to treat.

This method then supplies a huge diversity of the various bacteria, fungi, protozoa and nematodes to your crop, tree, pasture etc. This is a method of returning diversity back to the environment after toxic insults - like chemical sprays, adverse fertilisers, herbicides etc.

The reason behind using a compost tea is to negate or actually remove some of the problem diseases or ailments in a crop by putting a set of diverse micro-organisms back into the environment so that a ' bug balance' is attained again.

Benefits of using a compost tea

Some of the benefits recognised include an ability to spread a small amount of compost over a large area, plant disease suppression, provide plant nutrients, increase nutrient cycling due to the presence of more micro-organisms, reduce the need for fertilisers and of course reduce the need to apply chemicals.

It is not within the scope of this manual to detail how to make compost tea but this is an area that can be looked at if there is a problem with a crop, whether it be pasture, fruit, vegetable or nut that all other attempts to rectify have failed. This is just another tool that can be used if it fits in with your farming system.

If you would like to make compost tea then the detailed information about the techniques can be found in Elaine Ingham's publication - the compost tea brewing manual. See reference section.

Making liquid fertilisers

Liquid fertilisers can be a combination of or quite specifically:

- Seaweed

  Seaweed contains trace elements and stimulates potash.
- Fish

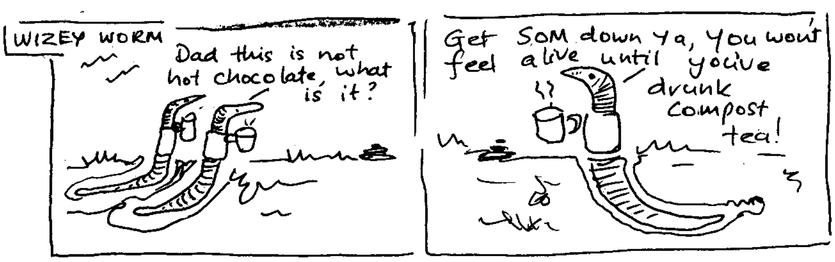
  Fish is full of trace elements and stimulates nitrogen.
- Liquid Compost

  Compost provides potassium and other minerals, depending on your plants.

These fertilisers are a very important part of organic farming to condition your plants and soil. It encourages the plants to grow and the soil to build up humus. Regular applications are recommended.

Some tips

- If collecting materials, ensure there is no contamination (pollution from run off etc). Record and describe where you collected it and possible pollutants.
- Please ensure what you use complies with your organic standards (check with your certifier if unsure). If buying-in materials, e.g. fish from a fisherman, get a certificate from the person, describing the product and guaranteeing there are no contaminants.
- Biodynamic (Demeter) farmers must put the compost preparations in the drums six weeks prior to applying to the land (2 sets per 200litre drums). A further biological reaction will take place during this time and you will see a lot of bubbles produced.



Biodynamic preparations

The biodynamic preparations have been developed from recommendations made by Rudolf Steiner. The following is a description of the key methods of biodynamic agriculture.

Horn manure (Preparation 500):

THE MOST IMPORTANT ASPECT OF BIODYNAMIC AGRICULTURE:

- Enhances healthy bacterial activity of the soil.
- Strengthens calcium activity.
- Encourages strong clover growth.
- Made from cow manure stuffed in a cow horn, buried in the soil over the winter and lifted in the spring. Changes into a sweet smelling rich humus soil-like material.
- Stirred in water for an hour and sprayed onto the pasture. Only mix the amount that you can apply within an hour.
- Spraying rates are 61.75gm, in 30litres of water per hectare, and is commonly reduced for larger areas to half that rate.
- Usually applied during spring and autumn when the ground is warm and moist.
- Sprayed during a descending period of the moon (marked on the biodynamic calendar), in the afternoon, so as to improve penetration into the soil.

Horn-silica (Preparation 501)

- Preparation 501 works on strengthening the plant and activity above the soil.
- Helps with photosynthesis.
- Strengthens the plant structure and cellular walls to resist infection.
- Strengthens silica activity.
- Helps plants to resist fungal attack.
- Made from treated silica quartz that is finely ground.
- Stirred in water for an hour, at a rate of 2.5gm in 30litres water per hectare and is commonly reduced for larger areas to half that rate. It is then sprayed onto pasture.
- Applied first thing in the morning in the winter before the sun generates too much heat in it. Usually used in spring and autumn when the grass has grown through a moist period.
- Beware, applying in the heat of the sun, or using excess rates can damage or even destroy your crop.
- Only apply during an ascending period and possibly on or near the moon opposition Saturn (also marked in the Biodynamic calendar).
- Do not apply unless you have applied at least two treatments of 500 and the compost preparations previously.

Methods of stirring preparations 500 and 501

There are good sections on spraying and stirring equipment and methods in Peter Proctor's book Grasp the Nettle (see refernce)

- The purpose of stirring machines is to create a vortex, similar to that seen in mountain streams, and to interrupt the vortex periodically allowing a few moments of chaos. Therefore a machine must go one way, then change direction to create a new vortex.
- There are many different, home built machines made using paddles and motors with gears.
- Flow forms are available and seem to be favoured by people with larger farms.
- For smaller areas a 200 litre drum and a 40mm rod or an oar suspended from the rafters, stirring by hand.
- Some farmers are using the preparations via decimal homoeopathy. The correct potencies must be chosen. The Biodynamic Association does not currently endorse this method.
- Use a smaller spray nozzle for preparation 501 than for preparation 500.

Compost preparations

These are a combination of preparations to enhance usage of the minerals within the soil. They are combined to create a balance of activities and can be added to compost heaps, cow manure composts (also known as cow pat pits), liquid fertilisers, liquid teas, liquid seaweed and effluent ponds. They have an amazing ability to convert a mass from an anaerobic condition to an aerobic one. It will boil and bubble away, removing any foul smells.

Preparation 502:

Prepared using yarrow flowers and a stag's bladder

Enhances the activities of sulphur, nitrogen, potash and trace elements

Preparation 503:

Prepared using chamomile plant and a cow's intestines

Enhances the activities of calcium, sulphur, potash, nitrogen, and oxygen

Preparation 504:

Prepared using stinging nettle

Enhances the activities of iron, sulphur, potassium, calcium, nitrogen, and magnesium

Enhances the plants' ability to take up light

Preparation 505:

Prepared using oak bark and an animal skull

Enhances calcium fixing

Preparation 506:

Prepared using dandelion and a mesentery

Enhances the activities of silicic acid and potassium

Preparation 507:

Prepared with the juice of valerian flowers

Enhances the activity of phosphorous, thus helping in the utilisation of RPR

Raises temperatures when sprayed on its own, e.g. in a frost

Preparation 508:

Equisetum (horsetail), a homeopathic solution to spray for pest and disease control. Equisetum has a high silica content

Cow Manure Composts or Cow Pat Pit (CPP)

This is a good way to get full benefit from your compost preparations.

Vermicast

Vermicast is quite simply worm farming. This means compost worms are turning organic waste, like cow manure and green waste into 'vermicast' within a farming situation.

The importance of earthworms to a healthy and productive soil ecosystem has been known since the times of the ancient Greeks. Darwin recognised their importance and commented on them in *The Origin of Species* (1859). Earthworms not only improve soil structure, aeration and drainage by their burrowing, but also produce vermicast.(see also Chapter 2, earthworms)

Vermicast is produced by the feeding action of earthworms. During normal burrowing and feeding, earthworms ingest organic and mineral matter, fragmenting and grinding it into a finely divided peat like material with high porosity, aeration, drainage and water holding capacity. The process enhances microbial activity and accelerates the rate of decomposition of the organic material. This leads to a humification effect where unstable organic matter or decomposing plant and animal matter is oxidised and stablisied. The process is similar to composting except it is non thermophilic or a cold process.

Vermicast has a large surface area and a high cation exchange capacity providing strong absorption and retention of nutrients. As a fertiliser, vermicast contains nutrients in a form that are readily taken up by plants, such as nitrates, exchangeable phosphorous, soluble potassium, calcium and magnesium. The ability of vermicast to influence plant growth is a reflection of the parent material the earthworms are composting.

Microbially, vermicast contains a far more diverse microbial population than other composts.

Biological make up of vermicast

Total Bacterial Mass µg/g	249
Total Fungi Mass µg/g	238
Flagellates (#/g)	11772
Amoeba (#/g)	94235
Ciliates (#/g)	2836
Total no Nematodes (#/g)	185

Note: Table data will vary, Perry Environmental.

Resources: Chapter Three

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