Biological Soil Fertility

Civilisations rise and fall on the fertility of soil. Soil is all too often seen as simply a medium that allows plant growth. We need to be aware of and work with the importance of soil structure, soil biology and soil chemistry and all the interactions between these interrelated factors.

In the workshop I focused on Biological Soil Fertility as it has even greater relevance to organbic agriculture than it does to non-organic agriculture.

Soil Structure

Aggregation

When assessing a soil, are there well formed aggregates – do these remain stable when the soil is worked. There are many factors that affect soil structure including cultivation, soil biology, root types present, organic matter level as well as soil texture itself. Soil structure affects the ability of roots to penetrate and the ability to form a good seed bed. Good aggregation offers drainage and aeration while still providing water retention within the aggregates. A soil may have subsoil properties that affect drainage and the performance of particular crops e.g. a hardpan – checking the soil profile is valuable.

To assess soil structure, general observations can be made on whether the soil looks like it can receive water freely, drain away excess water, facilitate root growth, form a good enough seedbed without surface capping.

Assessing Soil Condition Before Cultivation

To preserve soil structure, soil should not be cultivated when it is too dry or too wet. Structural damage can take years to rectify. Soil should be assessed before cultivating. This can be done simply by testing soil consistency as below but in many cases, a more thorough examination is warranted.

Soil Consistency: Take a small sample of soil and try to roll it in the palm of your hand. If you can get it down to a diameter of 2 to 3 mm (within 20 repeats of hands moving backwards and forwards) without it breaking up then (for most soils) it is too wet to be cultivated without damage to soil structure.

Thorough Examination: Dig spade width holes to just below cultivation depth around the area to be cultivated.

- The soil should be friable and free of large clods when dug
- Upon breaking them up, aggregates should be rounded not angular
- The sides of a hole should indicate good pore structure and not a smooth wall
- The soil consistency test (see paragraph above) should be applied at various depths

Soil Colour

Darker brown to black colours are usually associated with humus (broken down and active organic matter) levels. Most of the colour of the mineral part of the soil is due to the presence of iron (more iron can lead to a darker colour but the absence of oxygen will leave iron reduced and so non-aerated soils are often a greyer or blue colour). Good cropping soils usually contain iron that contribute a brown colouration. Occasional waterlogging can result in a mottled effect of "rusty" areas again due to the iron or black areas of precipitated manganese – drainage will need attention.

Soil Organic Matter

Soil Organic Matter improves the structure, of soil including bulk density, aeration, water holding capacity, water infiltration (less damage from rainfall). It also provides a better habitat and a food source for soil organisms and plant roots. The net loss of soil organic matter is one of the greatest threats to soil condition and productivity. Levels should be maintained or improved.

For organically farmed soils, soil organic matter is an important part of a soil test because fertilisers are generally not relied on to provide readily available nutrients. The presence of good amounts of organic matter are needed for adequate plant nutrition.

Measurement of Soil Organic Matter Without the Lab

Relative organic matter level from one soil to another can be assessed roughly by colour (more organic matter, more humus) or feel (more organic matter, easier to penetrate soil and more friability) but caution is warranted as other factors affect these soil properties.

Farm Method: Air dry soil in an open cardboard tray for several days until the soil is almost bone dry (usually around 4% moisture left. Sieve the soil, breaking aggregates up and then place a known weight of soil into an oven tray and "bake" at 360^{o}C for 3 hours. Weigh the soil again, the difference from last time being the level of organic matter.

Soil Biology

The biology of a soil has a marked effect on soil structure and fertility. It is the biologically led process of nutrient cycling, decomposition of organic matter and release of minerals that determine true soil fertility.

Some soil scientists consider the soil biology to be the main way of describing major differences in functionality of soils. The two main types referred to are mull and mor soils. Mull soils are biologically active and typically contain good levels of active earthworms. Mor soils are typically less active, often acid and contain few if any earthworms and often a larger number of small soil animals including enchytrids (earthworm like but small and white/colourless) and springtails.

There is of course a continuum between mull and mor soils and the general rule of thumb is that the more earthworms the better and the more soil microorganisms and greater diversity of them the better. Earthworms are a bio reactor breaking organic matter down into smaller pieces, altering soil and organic matter pH, calcium availability, moisture and temperature within their body to favour a faster nutrient cycling rate. They also aid in the incorporation of organic matter and fertiliser into the soil and improve soil structure through their burrowing action, aggregate stabilising mucus and humus creation.

There are a number of ways of assessing soil biology, many of them involving laboratories. In this workshop we will be looking at some of the practical non-lab ways…

Digging for Earthworms

The most straightforward method of assessing earthworm numbers is to dig a square hole of spade width dimensions and as deep as possible. Carefully look through the soil to collect all earthworms present. An excellent number for a Canterbury soil is 2000 per square metre (40 per 20cm by 20cm hole) - >500 is good. More complex earthworm assessments can include worm species, size classes, and a count of worms in each horizon in the soil profile (e.g. to high organic matter, remainder of topsoil and subsoil.

Bait Lamina Probes

Litter Bags

Lab Methods for Assessing Soil Biological Activity

Soil Testing Without Labs

Sometimes before you do a test through a lab, it's worth getting an idea of what you could be looking for. Does a certain weed tell you something about a nutrient or pH level? Do the clover leaves show a nutrient deficiency? You might even see something a lab test won't tell you. But as with all living systems, your conclusions should be made with caution and be followed up with further proof including in many circumstances a lab test.

Weed Presence

Weeds are often a symptom of poor conditions for crop or pasture growth. When the conditions are improved, desirable plants might be able to outcompete the weeds. An example is the presence of common daisy in pasture, which is often a sign of potassium deficiency (the daisy can still grow well in poor potassium conditions while other plants suffer more). Caution is warranted here because the daisy could in fact be more a symptom of overgrazing in the winter period (when daisy can establish better than many other plants).

More weeds and their potential significance are mentioned in the table. Indicator plants can be useful but again be careful; plant composition is affected by more factors than soil nutrients including soil structure, moisture levels and grazing/cultivation management.

Patchiness of Pasture

Aside from insect attack, there can be a number of reasons for patchiness of pasture. If clumps of lush pasture are present in otherwise poor performing pasture, this can be due to urine patches. And if the urine patches contain good clover growth with more weedy growth elsewhere, suspect potassium deficiency (or it could be poor nodulation of clover), suspect nitrogen deficiency (generally fix this in the medium and long term by promoting clover growth).

Large areas of weedy annual grasses e.g. brome, sweet vernal and barley grass could be symptomatic of low soil fertility e.g. availability of phosphorus, potassium or molybdenum (resulting in poor clover levels which fail to drive good pasture). Browntop and sheep sorrel may both be symptoms of similar conditions and quite often of low pH. Dock can also be a symptom of low pH but is also a potential sign of poor drainage or soil compaction

What's wrong with the clover

A general lack of clover can be due to any of a large number of reasons (nutritional reasons often best being diagnosed with a clover only herbage test – see later). In some cases the symptoms of poor growing clover give tell tale signs of nutrient deficiency. These symptoms are listed in the table and include observations on the overall form, size and colouring on leaves and nodulation.

Methods of Confirmation

Despite the title of the article, regular soil/plant tests are a valuable part of commercial farming and confirmation of a suspected problem may involve taking a soil of or plant tissue test. Soil tests could be used by comparing one area performing well and the area with an observed problem to see if it confirms visual observations before spending too much on one particular fertiliser.

Taking a clover only herbage test is a good way of finding (or getting further confirmation on) nutritional deficiencies that are holding back clover and therefore the whole pasture. Select only clover that shows the symptoms of the problems rather than healthy looking clover that may be present in patches. With crops, it may be worth taking a sample of an area of good performing crop to compare with an area of poor performing crop of the same type and planting time. In most cases, there are big differences in nutrient levels according to time of year and age of plant as well as the type of leaves sampled so follow lab instructions precisely if relying on lab recommended values.

Experimenting

A more direct method of confirming an observation is to actually apply the element or otherwise address the suspected issue. This can be done by treating a strip or larger area of pasture or crop and hoping for a visual response compared to the surrounding untreated area. Unless the experiment is replicated you may never be sure that the treatment was truly effective but if the result is dramatic it should give you good confidence.

Weeds and their Possible Implications for Soil Condition

Weed Species	Possible Soil Implications	Other Possible Reasons
Annual Meadow Grass (Poa)	High N (if urine scorch present from high protein)	Quickly taking advantage of bare patches, dry conditions, pugging
Barley Grass	High N	Dry conditions, disturbed areas e.g. stock camps, tracks, overgrazing in summer or autumn
Browntop	Low pH, Low Nitrogen, Low Phosphorus, Low Potassium, Low Molybdenum, low fertility generally	Undergrazing, spread by cultivation and by late hay cuts
Californian thistle	Low N, moderate fertility generally	Under grazing in summer, over grazing in winter

Weed Species	Possible Soil Implications	Other Possible Reasons
Cats ear	Low K, Low P, Low fertility generally	Overgrazing, frequent hay cutting, insect damaged pasture
Chickweed	High fertility, though low fertility if this has caused bare patches	Quickly taking advantage of bare patches, relatively dry conditions, well aerated
Couch or Twitch	Low soil biological activity, Low Ca, High N	Overgrazing in summer, undergrazing in autumn, hay cutting
Creeping Buttercup	Poor drainage, Low N	Horse grazing
Daisy	Low Potassium, low fertility generally, poor drainage	Overgrazing in Winter
Dandelion	Low fertility generally (but not always an undesirable plant), friable	Overgrazing, cold winters
Dock	Poor Drainage, Compaction, Acid Soil, High Nitrogen	excessive trampling, preferential grazing (esp. cattle not eating it), shortterm pastures cut for silage, seed spread from effluent applications or infested hay
Fathen	High N, friable	Dry conditions, bare patches
Rushes	Poor drainage, Low pH	Pugging, wet conditions
Sheep Sorrel	Low pH, Low fertility generally	Overgrazing in summer, hay cutting, overcropping
Stinging Nettle	High N, friable	Recently disturbed fallow ground
Sweet Vernal	Low Potassium, Low fertility generally, Low friability	Unimproved, declining pastures
Yorkshire Fog	Low N, Low pH, Low fertility generally	Undergrazing

Approved Fertiliser Materials

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

Elemental Symbols

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

Phosphorus

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

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

Table 2.2 Source and Composition of RPR

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

Sechura	13 to 14	~1

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

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

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

Potassium

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

Potassium Chloride mined (48%K) (Restricted)

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

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

Sulphur

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

Elemental Sulphur (98-99%S)

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

Magnesium

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

Calcined Magnesite (52%Mg) (Restricted)

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

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

Calcium

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

Limestone (24-39%Ca)

Effective at lifting soil pH and supplying calcium requirements for soil biology and plants and improving soil structure through flocculation (aggregation). Lime varies from source to source in total calcium carbonate content but the biggest difference in effect is usually related to particle size. Agricultural lime (AgLime) has large particle size and although crop fine lime is finer and much faster acting, it is not so suitable for aerial application.

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

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

Gypsum (18%Ca, 23%S)

Rockdusts

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

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

Trace Elements

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

The following are some of the options other than trace element salts or minerals…

System Based Methods

Plant species that naturally accumulate the trace element
Deep rooting plants
Ensuring optimum pH
Good soil organic matter levels (provides colloids)
Active soil biological activity (microbes can then make trace elements available to plants)

Additional Inputs

Imported Organic Matter
Seaweed fertiliser
Rock Dust

Pragmatic Approaches

Trace elements might be limiting factors for a number of reasons including the parent material of the soil, the soil pH, and in the case of livestock, the pasture species present. It may not always be possible to fix a system completely and it may be that the problem is not solved by small amounts of traces contained in purely biological products. A compromise position might be biologically based fertiliser amended with extra trace elements as required or the use of trace element salts while the system is changed to be more self sufficient.

Compost and Farm Yard Manure

Artificial fertiliser didn't come around for no reason. Compost and Farm Yard Manure (FYM) is bulky for the amount of actual N, P, K and other elements it contains. Furthermore, the concentrations of elements are variable and the sources may be limited. As resources become more limited and as people realize the value of compost that goes beyond the elements added, there will hopefully be more recycling of these "waste" materials and an improvement in the sustainability of our wider society (including the use of composted sewage on e.g. green manure areas or tree crops).

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

Table 4.1. Nutrient Composition of Organic Materials (N,P,K)

Material	N %	P %	K %	Dry Matter %
Livestock Manure				
Cow manure	0.5-0.8	0.15-0.2	0.6-0.8	25-30
Horse manure	0.6-0.8	0.1-0.2	0.3-0.5	50-60
Pig manure	0.6-1.0	0.2-0.4	0.4-0.7	25-30
Poultry Manure (broiler)	2.0-2.5	1.5-2.2	1.0-1.5	60-75
Poultry manure (cage)	1.5-2.0	1.4-1.8	1.0-1.3	40-50
Sheep manure	1.5-2.0	0.4-0.7	2.0-2.5	50-60
Other Material				
Seaweed (kelp)	0.2	0.05	0.5	70-80
Fish meal	5.0-10	1.0	<0.1	80-90
Garden compost	2.0-4.0	1.0-3.0	0.5-1.5	65-80
Grain straw	0.3-0.7	0.1-0.15	0.8-1.3	70-80
Mushroom compost	0.3-0.7	0.1-0.3	0.7-1.2	70-85
Sewage sludge	3.0-8.0	1.0-3.0	0.3-0.8	60-80
Wood ashes	-	1	5	95

The benefits of applying compost and farmyard manure include:
- Provision of elements required by crop
- Improvement in soil organic matter levels

and potentially:
- Provision of beneficial microorganisms to the soil
- Provision of active substances (acting as a biofertiliser)

Green Manures

In cropping rotations, there are many benefits from including in green manures. The varied benefits are listed below and from any single green manure species or combination of two or more species, it will be possible to achieve several of these at once. There are some alternative names for green manures that partly reflect the aims of the crop. “Green manure” perhaps implies an emphasis on providing readily available nutrients (the nutrients gathered by and contained in the green manure will relatively quickly be released after incorporation to aid the establishment and growth of the next crop – perhaps mustard or a legume with the latter meaning another aim of nitrogen fixation). “Catch crop” might imply an emphasis on reducing leaching and capturing leached nutrients (e.g. the use of deep rooted chicory). “Cover crop” might mean a priority of protecting the soil surface (useful in extreme environments) or one of outcompeting or preventing establishment of weeds (perhaps choose a vigorous crops like mustard and buckwheat or very tall crops like ryecorn and triticale). “Restorative crop” places emphasis on soil structure (perhaps with a fibrous rooted grass component).

Table 5.1. The Benefits of Green Manure Crops

Benefit
Nitrogen fixation
Protect soil surface from rainfall and drying
Prevent erosion
Preserve soil surface organic matter and microorganisms from UV damage
Maintain or improve soil structure
Improve soil depth and drainage
Reduce susceptibility to leaching (N,S,Ca,K)
Return leached nutrients
Access nutrients from lower soil profile

Provide readily available nutrients to the next crop
Trap cropping of soil pests
Weed Control
Conservation Biological Control of Plant Pests

Green Manures and Organic Matter

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

Mulching

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

Table 6.1. Benefits of Mulching Types.

	Straw	Clippings	Compost	Manure	Plastic
Lift Organic Matter	++	+	+++	++	
Add Nutrients	++	+++	+++	+++	
Control Weeds	++	++	+	+	+++
Conserve Moisture	+++	+++	+++	++	+++
Reduce Temperature Fluctuations	+++	+++	+++	++	+
Increase Temperature	++	++	+	+	+++
Improve Microbial Activity	++	++	+++	+++	
Aid Earthworms	+	++	+++	+++	
Erosion Control	++	++	++	++	++
Control Leaching	++	+	++	++	+++
Long Lasting	++	+	+	+	+++
Biodegradable	+++	+++	+++	+++	

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

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

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

Biofertilisers

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

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

Most of these aspects lend themselves to testing and in the case of commercial products, manufacturers may or may not be able to provide research data of their own or from independent testing. It is possible to set up simple trials to go some way towards establishing whether the product is worthwhile in a particular system.
Many organic practioners will make their own products which saves money at the expense of taking time and energy. Such "home-made" products might utilize resources which are on-farm, nearby or relatively free. Some of the techniques used by commercial companies might make a higher value product that home-made products (this could be tested) and the extra financial outlay may be worthwhile – a case by case pragmatic decision. This does not, however, sit well with the idealistic aim of reducing outside commercial inputs.
All of the above benefits have some basis in scientific literature but results from biofertilisers are characteristically variable perhaps due to product quality and probably also due to environmental fluctuations and the vagaries of not understanding the actual modes of action. Any use should be on a trial basis preferably with appropriate experimental controls to assess effect.

Plant Roots

The bulk of mineral plant nutrients are taken up through the roots and the structure of roots affects the ability of the plant to access these nutrients. This section will look at some of the different root structures between plants and discuss why some plants are higher in certain trace elements, some plants require little phosphorus input and some plants save nutrients from loss by leaching and bring those nutrients back for other plants.

Effect of Plant Root Systems on Trace Elements

Some plants are richer in certain trace elements than others. One of the best examples of this is chicory and plantain within a mixed species pasture. Figure 1 (at rear of module) shows a Puna chicory plant and tap root. Under the right conditions the tap root and fibrous roots of chicory can reach to depths beyond 2 metres. The presence of fleshy roots in the subsoil is excellent for uptake of the majority of nutrients including phosphorus and metal trace elements such as copper and zinc (more available in the generally more acid and moist subsoil).

Effect of Plant Root Systems on Phosphorus

Traditional pasture fertiliser recommendations often include three or more times the phosphorus than is actually truly lost from the soil system. Contrary to popular and some technical belief the phosphorus recommendation has very little to do with making up for losses but it is to aid the performance of clover, which has poorer roots than surrounding grasses. The more fibrous and aggressive roots of grasses are more efficient at taking up phosphorus and a grass only system requires very little extra phosphorus. Some legumes (e.g. lupins, caucasian clover) have more substantial root systems than white clover and partly for that reason can cope well with lower phosphorus levels.

There are many ways in which to improve clovers performance without needing to put on excess phosphorus. The way to increase phosphorus efficiency (including for clovers) is to promote good root structure including increasing rooting depth. And nutrient cycling should be promoted such that dead roots, shoots and dung are decomposed efficiently and the phosphorus and other nutrients are not locked up for months or years longer than they should be.

It should also be noted that one of the reasons foliar fertilisers and biostimulants often favour clover more than grasses is that clover is relatively better at foliar uptake than grasses and less efficient at root uptake.

Effect of Plant Root Systems on Nutrient Efficiency

It makes good sense to take advantage of the different root systems of plants to increase the nutrient efficiency of a pasture or horticultural system. Some plant roots go very deep and effectively bring nutrients up and when roots or shoots die or leak nutrients (or shoots are eaten and dung is returned), the nutrients are made available to surrounding plants. Strategic selection of plants partly on the basis of root systems can mean a system of reduced competition between plants e.g. deep rooting plants with shallow rooting plants or using tap rooted plants as a cover or companion crop that does not inhibit crop or pasture growth (e.g. cow parsley in an orchard system rather than having potentially competing plant roots / or chicory in a pasture system).

In the orchard system, cow parsley (low competition with fruit trees, out-competes grasses in semi shade, reduces apple black spot re-infection in spring and provides flowers suitable for beneficial insects controlling caterpillars and aphids) and comfrey (extremely deep rooting outcompetes grasses, provides nutrients for trees) provide a functional understorey.

Deep roots reduce the loss of nutrients (for efficiency and environmental benefits). Chicory can for instance be used as a catch crop (even planted before a crop is finished in late summer it will complete little and establish quickly following crop removal) and prevent normal autumn and spring leaching loss of nitrogen and generally return other nutrients. Other plants with deep but fine roots are still good at picking up nitrates and potassium but generally not so good at picking up deep phosphorus and metal trace element reserves.