

# Nutrient Management on Organic Farms



AGRICULTURE AND FOOD DEVELOPMENT AUTHORITY

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**Dec 2008**







## *Introduction*

The management of nutrients in organic farming systems presents a formidable challenge, as the use of inorganic fertilisers is not permitted. Therefore organic farmers must optimise a range of soil, crop, rotation and manure managements to ensure a nutrient supply which will guarantee optimum crop yields and minimise losses to the environment. To achieve this objective, an appreciation of the nutrient cycles in farming systems is essential.

This booklet gives an overview of soil nitrogen (N) phosphorus (P) potassium (K) and pH management in Irish organic agriculture and horticulture. As for many other aspects of organic agriculture, it is not 'a recipe' of how to grow organic crops, but more of a guide on 'how to farm'. It must therefore be combined with other sources of production information as well as farmers own experience to create a nutrient management strategy that is tailored to the climate, soils and production system of an individual farm or holding.

With organic agriculture only having been a small proportion of total agriculture to date, and with its role as a counterpoint to mainstream farming, the volume of scientific research into organic agricultural techniques is disproportionately small. Therefore, much of the information in this booklet can only be of a more general nature, as the detailed research that is required to make firm recommendations does not yet exist.

There is little doubt that when great care is taken with the storage and spreading of animal manures on the farm, soil fertility can be protected to a considerable extent. Areas used for silage production must get priority when spreading animal manures and ideally the grazing and silage areas should be rotated annually. However, with the best will in the world, there will still be some loss of nutrients. In order for organic agriculture to be sustainable in the long term, these losses must be replaced.



## Section 1: Understanding the Soil Dynamic

### Healthy Soil - the Foundation of Organic Agriculture

Optimising soil health is a key foundation of organic agriculture. Particular emphasis is placed on maintaining good levels of soil biological activity and organic matter coupled with balanced / optimum nutrient levels. Organic agriculture aims to 'feed the soil to feed the plant' by maintaining soil biology and nutrients at optimum levels throughout the rotation rather than the non-organic approach of applying nutrients to feed the current crop to maximise yield. Organics therefore takes a long term, whole farm / systems approach to nutrient management based on regular soil tests and nutrient budgets to determine when soil nutrients must be replaced. As for non-organic farming, the results and fertiliser recommendations of soil tests are tailored to a fields cropping history and soil type to give specific recommendations for each field.

Organic agricultural practices contain something of a dichotomy regarding nutrient management. One view is the 'law of return' where it is considered essential that any nutrients removed in crops or livestock must be returned to maintain fertility i.e., a balanced nutrient budget. The other view considers the farm to be a 'closed system' for nutrients and that they should be carefully (re)cycled within the farm and the need to 'import' nutrients is considered a system failure. However, the latter approach does not consider the removal of nutrients in crops and livestock or losses from leaching or to the atmosphere. The scientific evidence is now conclusive, that both must be combined: efficient cycling of nutrients around the farm must be coupled with the law of return (balanced budgets). This means that it is absolutely essential that all nutrients removed from the land in crops and livestock sold 'through the farm gate' must be replaced. In addition, while livestock can be highly valuable in assisting the cycling and movement of nutrients around the farm, they do not replenish nutrients. Rather, exactly the same as crops, they cause the depletion of soil nutrients when they are taken off the farm and sold. So, while N can be replaced from atmospheric N (gaseous) via bacterial fixation, P, K, Mg and all the other nutrients, which only exist in non-gaseous i.e., solid or liquid, forms, can therefore only be replaced in solid or liquid forms (e.g., manure and slurry), either as biological

matter or permitted mineral fertilisers. There are emphatically no other means of replenishing these nutrients at sub-geological timescales. Failure to replace these nutrients will, within a few years, inescapably lead to soil nutrient deficiency resulting in declining yields and plant and animal health, which is contrary to organic principles.

The aim for organically approved fertilisers is to allow biological soil processes (microbial activity) to progressively release the nutrients contained in the fertiliser so plants get a more balanced and continuous supply. Many of these biological processes are temperature dependent, so more plant available nutrients are released during the growing season when the soil is warmer and when plants need them, while less are released in the cold of winter when there is a greater risk of nutrient leaching and many plants are barely growing. This also means that it is not normally possible to get a 'quick response' from organic fertilisers, so if a deficit occurs it will take some time to correct. This means that it is essential to have a long-term nutrient strategy, which is also a requirement under organic certification standards. In a nutshell, a nutrient strategy is based on regular, ongoing soil nutrient analysis, coupled with nutrient budgets, which are used to determine the need to apply manures, composts and permitted fertilisers.

### 1.2 Soil Organic Matter (SOM)

Soil fertility is linked intrinsically to soil organic matter (SOM), because it is important in maintaining good soil physical conditions (e.g. soil structure, aeration and water holding capacity), which contribute to soil fertility, and it is an important nutrient reserve. Organic matter also contains most of the soil reserve of N and large proportions of other nutrients such as P and sulphur. Typical ranges for SOM are from as little as 1.5% (of dry soil weight) in sandy soils under arable cultivation, to as much as 10% in clay soils under permanent pasture. At the upper end of this range, this can amount to between 5 and 15 t organic N/ha in the top 15 cm. Peat soils can have upward of 15% organic matter.

SOM also plays a pivotal role in soil structure management. Young SOM is especially important for soil structural development, improving ephemeral stability through fungal hyphae and extra cellular polysaccharides. To achieve better soil structure, workability and soil aggregate stability and the advantages that this conveys, frequent input of fresh organic matter is required. Practices that add organic material

are routinely a feature of organically farmed soils and the literature generally shows that, comparing like with like, organic farms have at least as good and sometimes better soil structure than conventionally managed farms.

The wider aim of soil management in organics is to create a healthy, biologically active soil flora and fauna by maintaining good levels of soil organic matter and minimising soil disturbance caused by tillage. Changing from a synthetic fertiliser regime to one based on legumes for N fixation, manures and mineral fertilisers can considerably increase soil biology, which results in many positive benefits. However, there is significant scientific evidence and farmer experience that this change takes several years and can result in an initial drop in crop yields in the first two to three years of conversion until the soil biological processes have increased sufficiently to support good yields again. This effect has also been documented when changing other production practices, for example from tillage to no-tillage. This effect is important to consider when deciding whether to continue cropping during conversion or to sow pasture. Maintaining cropping has the advantage of continuing income, but has the disadvantage of lower transitional produce prices while yields may be depressed. It is also likely that the soil will take longer to adjust to the new management system than under pasture. Growing a clover based pasture during conversion will help speed soil transformation, but unless there are stock on farm to graze the pasture, it is unlikely to generate any income so will be a financial burden in the short term. Farmer experience indicates that growing pasture during conversion has the greater longer-term advantage.

### 1.3 Soil Biology

The soil hosts complex interactions between vast numbers of organisms, with each functional group playing an important role in nutrient cycling: from the macro fauna (e.g. earthworms) responsible for initial incorporation and breakdown of litter through to the bacteria with specific roles in mobilising nutrients. Earthworms have many direct and indirect effects on soil fertility, both in terms of their effects on soil physical properties (e.g. porosity) and nutrient cycling through their effects on microfloral and -faunal populations (density, diversity, activity and community structure). Thus, although micro-organisms predominantly drive nutrient cycling, mesofauna, earthworms and other macro fauna play a key role in soil organic matter turnover. Factors that reduce their abundance, be it natural environmental factors (e.g. soil drying) or management factors (e.g. cultivation, biocides), will therefore also affect



nutrient cycling rates. Organic farming's reliance on soil nutrient supply requires the presence of an active meso- and macro-faunal population.

The soil microbial biomass (the living part of the soil organic matter excluding plant roots and fauna larger than amoeba) performs at least three critical functions in soil and the environment: acting as a labile source of carbon (C), nitrogen (N), phosphorus (P), and sulphur (S), an immediate sink of C, N, P and S and an agent of nutrient transformation and pesticide degradation. In addition, micro-organisms form symbiotic associations with roots and act as biological agents against plant pathogens, contribute towards soil aggregation and participate in soil formation.

Generally, organic farming practices have been reported to have a positive effect on soil microbial numbers, processes and activities. Much of the cited literature has made direct comparisons between organic/biodynamic and non-organically managed soils. The evidence generally supports the view of greater microbial population size, diversity and activity, and benefits to other soil organisms too. However, little is currently known about the influence of changes in biomass size/activity/diversity on soil processes and rates of processes. Nor is it possible to conclude that all organic farming practices have beneficial effects and non-organic practices negative effects.

### 1.4 Soil Testing

Whatever type of fertiliser is to be applied, e.g., mineral or manure, application rates must be determined by field-by-field soil analysis coupled with nutrient budgets. It is not appropriate to apply fertilisers and manures ad hoc, as this has the potential to waste valuable and sometimes expensive fertilisers, cause leaching and run off which pollutes waterways, and cause an imbalance of soil nutrients e.g., a high K with low P. Soil tests should be viewed as a long-term strategy and investment with each field being tested every three to five years depending on intensity of production. They should be taken at the same time of year, ideally at the same stage in the rotation. These should be cross-referenced with nutrient budgets for each field, which will give a useful double check if excessive, or insufficient amounts of nutrients are being applied. If the soil tests and nutrient budgets agree, e.g., more K is being applied than removed and K soil levels are increasing then the action required is clear (do not apply any more K until the level drops and budgets balance). If they are at odds, e.g., more P is applied than removed but the P level is decreasing, this indicates a loss from the system, which requires further investigation.



Soil tests also need to be tailored to the production system. Lower intensity and livestock only farms have lower demands on their soils, and will be less affected by minor nutrient deficiencies. In comparison more intensive arable crops and very intensive horticultural crops can experience sizeable yield and quality reduction due to small deficiencies. On lower intensity farms, testing may only be required every five years with only the basic suite of tests, while three years is considered a minimum for intensive systems with the full range of tests required for horticultural holdings. Soil tests should also be viewed as an investment not a cost. While the tests may seem expensive, the information they provide can potentially increase product yield and quality dramatically which can improve profit many times that of the price of the tests. Soil tests can give some of the best return on investment of any farm expenditure.

### 1.5 Organic Certification Standards

With soil health being a key focus of organic systems, a significant portion of organic standards relate to soil management, particularly what materials can and cannot be used as fertilisers. Certification has three 'categories' that it puts farm inputs into, 'permitted', 'restricted' and 'prohibited'. Permitted are allowed to be used without restriction. Restricted are allowed to be used but normally only after permission has been given by the certification agent, and prohibited are completely banned. When deciding which fertilisers to use, whether it is mineral or biological, make sure you are clear which categories each is in and ensure you have the necessary permissions to use them. In addition, Certification standards are constantly changing so the advice in this booklet must be read in conjunction with the latest standards to ensure compliance.



## Section 2: Nutrient Cycling

Although nutrient management in organically managed soils is fundamentally different to soils managed non-organically, the underlying processes supporting soil fertility are not. The same nutrient cycling processes operate in organically farmed soils as those that are farmed non-organically although their relative importance and rates may differ. Nutrient pools in organically farmed soils are also essentially the same as in non-organically managed soils but, in the absence of regular fertiliser inputs, nutrient reserves in less-available pools might, in some circumstances be of greater significance.

### 2.1 Nitrogen

Nitrogen is the single most important nutrient required for herbage growth. In organic systems major emphasis is placed on N from mineralised soil organic N and from application of animal manures, but the ultimate source of nitrogen input into the system is atmospherically derived N fixed by legumes grown in pastures, the most common legume is white clover. The N resource in organic farming is therefore, a renewable resource in comparison to fossil-fuel derived artificial N fertilisers.

The primary source of N in organic farming is the fixation of elemental atmospheric N into ammonia by the bacterium *Rhizobium* that live in the root nodules of leguminous plants and also in the soil. Ammonia is rapidly converted into other mineral N forms, e.g., ammonium, nitrate and nitrite by other soil microbes (**Figure 1**). Nitrite is the primary form in which plants take up N although they can also take up nitrate and ammonium. The mineral forms of N are also converted into organic matter, by both microbes and plants, which is the form in which most N is 'stored' in soil. Therefore, growing legumes, in pasture, as green manures and as cash crops is essential for successful organic N management.

The amount of N which is built up by fertility building is only part of the challenge of good N management. Good management of the soil, crop and rotation is of

paramount importance to maximise the efficient use of the N built up. How effectively the N is used by the subsequent crops in the rotation will depend on many factors, including: the rate of release ('mineralisation'); the efficiency of uptake by crops; the N removal in harvested products; the N return in plant residues; losses of N; timing or cropping (spring vs. winter); timing and type of cultivation and location and rainfall of the site. The rate of depletion will be reduced if manure is applied or if the rotation includes further legumes during this phase (Briggs et al 2005).

The factors affecting N release from the soil, interaction with crop uptake and loss processes, and the methods of predicting N release are complex. After a ley is incorporated and before the next crop can use the accumulated N, it has to be converted ('mineralised') into plant available forms (nitrate and ammonium). Some will already be in this form; most will need to be mineralised by microbial action after cultivation. Generally, the organic forms of N associated with the fertility-building crop are termed 'residue N'. It should also be noted that not all of the residue N will necessarily be fixed N – some will have derived from uptake of (a) N released from the native soil organic matter, some will be from atmospheric N deposition and some will be from (c) soil mineral N in the soil at the time of establishment of the fertility-building crop. The proportion of non-fixed N will depend on many factors as described above.

The release of Nitrogen via mineralisation is performed by soil micro-organisms when they use organic N compounds as energy sources. Plant available N is a by-product of this microbial degradation.

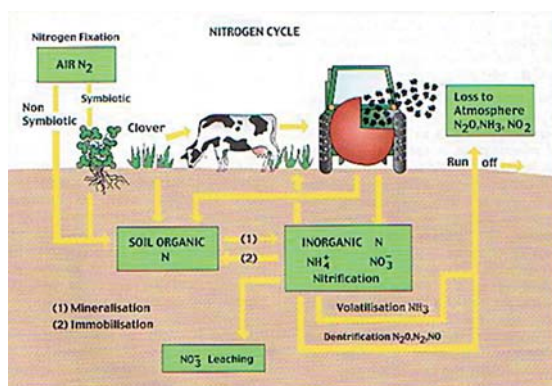
The rate at which they undertake the mineralisation is affected by many components including; soil temperature and moisture; soil biological 'health'; Soil texture; Soil physical condition; Soil disturbance; and the type of residue.

Temporal patterns of N uptake by the crop may be particularly important in organic systems where N is released gradually by mineralisation of organic matter. For example, maximum uptake of N by winter wheat occurs in spring when soils are only beginning to warm and mineralisation is still slow. This is likely to limit the supply of N at a critical time for wheat crops on organic farms.

Mycorrhizal fungi have been shown to absorb and translocate some N to the host plant, so maintaining good mycorrhizal fungi populations can be beneficial in N utilisation.

A balance therefore has to be struck between exploitative and restorative phases of the rotation to ensure that as N drops during the exploitative cropping phase it is replaced by restorative crops and pasture so maintaining N levels over the rotation as a whole.

**Figure 1. Simplified diagram of the nitrogen cycle**



Predicting the actual amount of nitrogen fixed is notoriously difficult as it depends on many factors including legume species and cultivar, proportion of legume in the ley, management, weather conditions and the age of the ley.

Nutrient supply to crops depends on the use of legumes to add nitrogen to the system and limited inputs of supplementary nutrients, added in acceptable forms. Manures and crop residues are carefully managed to recycle nutrients around the farm. Management of soil organic matter, primarily through the use of short-term leys, helps ensure good soil structure and biological activity, important for nutrient supply, health and productivity of both crops and livestock. Carefully planned diverse rotations help reduce the incidence of pests and diseases and allow for cultural methods of weed control.

### White Clover

White clover, has the unique ability to fix atmosphere nitrogen, and can transfer the equivalent of 80-100 kg N/ha to the growing grass. In addition to contributing to herbage growth, a proportion of the atmospherically fixed N is stored in the roots and stubble or is immobilised in the soil organic matter i.e. it contributes to the

longer term build-up of soil organic matter and soil nitrogen status. It is therefore vital that if organic grass farming is to be productive, white clover, and /or red clover must be introduced into pastures.

It is essential to maintain clover in the pasture so management practises must be tailored to achieve this objective – poaching must be avoided at all costs. On wetter farms the persistence of clover is problematic and low cost methods of clover introduction must be implemented.

There are losses of nitrogen both as gaseous emissions to the atmosphere and leaching during spreading and storage of animal manures. It is essential to minimise these losses by covering the manure during storage to minimise the effect of leaching by rainwater. Losses to the atmosphere can be reduced by using a band-spreader or shallow injector rather than a splash plate vacuum tanker.

**Table 1** gives a few examples of the maximum and minimum amounts of N fixed by crops and pasture and the amount remaining after harvest. These are collated overseas figures so should not be taken as representative of Ireland. From the perspective of N management, it is better to grow legume cash crops towards the end of the rotation when soil N will be lower, as this will promote the plants to fix more N than if they were grown at the start of the rotation where soil N is higher.

Table 1. Examples of the amount of N fixed per hectare per year by mixed pasture and two crops and the amount remaining after harvest (overseas figures, not necessarily representative of Irish conditions).		
Crop	Amount fixed kg N/ha/yr	Amount remaining after harvest kg N/ha/yr
Red clover silage	160 to 450	50 to 150
White clover & grass silage	70 to 420	20 to 180
White clover & grass grazed	60 to 250	50 to 210
Forage peas	80 to 290	40 to 110
Field bean grain crop	200 to 380	90 to 150



0.22% P, and their grains contains around 0.4% P. The nutrient content of such materials should be included in nutrient budgets. Further details on manures and other biological materials are given below.

The main mineral source of P available in Ireland is natural rock phosphate called ground rock phosphate (GRP) that has a P content of around 13 to 40% depending on source. This should be generally available as it is used by the forestry industry; however, it may not be stocked by farm fertiliser merchants and may have to be ordered in. GRP is not suitable for soils above 7.5 pH as they are insufficiently acid to decompose GRP and release the phosphate. Organic standards recommend calcined aluminium phosphate rock for soils above pH 7.5; however, this is not currently available in Ireland and would have to be ordered from the United Kingdom. In this situation, specialist advice should be sought. However, clover is known to acidify the area around its roots which assist it absorb soil P, which means that GRP may decompose above pH 7.5 under clover rich pasture. Unfortunately, there is little research studying this effect, so no advice regarding it can be given.

GRP contains about 35% calcium (Ca) which helps balance the acidifying effect of the P compounds. This means that most GRP's have little effect on soil pH. This contrasts with super-phosphates, which have an acidifying effect. GRP also contains useful amounts of some trace nutrients.

GRP is a slow release fertiliser as the P and calcium are released by soil acids and biological activity. About a third of the P is released each year, which means that it takes about three years to decompose fully. This also means that it takes at least six months to a year for the fertilisation effect to be seen. This is in contrast with super phosphates, which are water soluble, rapidly plant available and give a quick crop response. This delayed fertilisation effect must therefore be planned for, with the GRP applied a year before the P is required. The slow release action can also help reduce P loss to the environment.

Phosphate rocks naturally contain heavy metals, particularly cadmium, in varying amounts. Certification standards require that lower cadmium content rock should be used and depending on quantities used, soil analysis may be required to ensure that cadmium levels in soil do not build up. Basic slag is a restricted input for P, K and micro nutrient sources in organic agriculture. However, some forms / sources are prohibited and the P level content can be quite variable, to the point of containing



only traces of P. Always consult your certification body before purchasing or applying basic slag and ask for a full nutrient analysis of the product.

The sources of P loss and the pathways of P loss are the subject of considerable controversy. There are three main sources of P losses:-

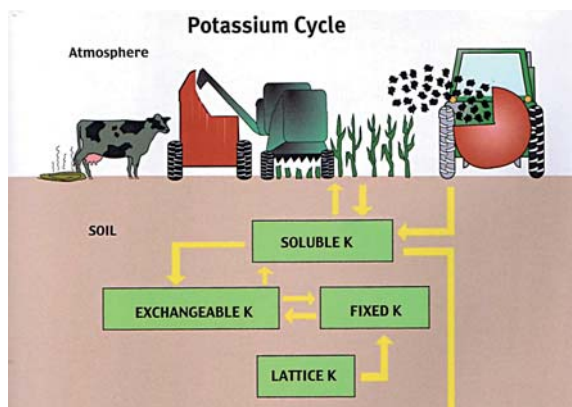
- 1) Seepage of soiled water from farmyards is one of the main culprits and there is little doubt that if farmyard design and maintenance were improved, there would be less P pollution of our waterways.
- 2) Slurry spreading, in itself will not lead to run-off of P. It is spreading slurry at the wrong rates, or in the wrong place, or at the wrong times that lead to slurry finding its way into drains, rivers and streams. Spreading slurry at reasonable rates, during the grass growing season in places where there is no risk of runoff into rivers/lakes will ensure no loss of P.
- 3) Elevated soil P levels. There is evidence that increasing soil P levels can lead to increased P runoff in areas where run-off to water-bodies is possible.

### 2.3 Potassium (K)

The behaviour of potassium K in the soil is in many ways similar to that of phosphorous. Inputs of K from the atmosphere are usually negligible; therefore its quantities and forms in the soil depend on the nature of the parent material, the degree of weathering, and their management. It exists in the soil partly in the structure of soil minerals (lattice K), partly fixed inside clay minerals (fixed K), partly on cation exchange sites (exchangeable K) and partially as  $K^+$  ions in the soil solution (soluble K). The potassium cycle is outlined in Figure 3.

Soil K levels will drop dramatically from grounds where silage/hay is continuously cut and manures are not reapplied to.

Figure 3; Simplified Potassium Cycle



As for P, the main source of K is on-farm produced manures, slurries and compost, which have K values ranging from 0.2% for cattle manure to 2% for poultry manure. Brought in materials, such as manure and compost as well as production inputs such as feed and straw can contain useful amounts of K, for example, grain contains 0.4 to 0.6%, with straw containing 8 to 15% K depending on species and K status of the soil they were grown on. As for all other nutrients brought in materials should not form the basis of an organic farm's nutrient sources, rather effective internal cycling should be the main approach, supplemented with brought in materials to balance those lost from the system. For K this is principally in crops and livestock as K does not readily leach from soils. As for P, detailed records of all K sources and losses must be recorded to allow accurate nutrient budgets to be compiled.

Alternative sources to biological materials include wood ash, which has around 1 to 7% potash, and is permitted under certification rules. However, it must be mixed with compost or manures, the wood must be untreated and sources are limited. The increased interest in wood chip and other biomass boilers may see this situation change.

If K soil levels are lower than the desired value and on-farm sources are insufficient to meet needs, an application to your certification body to use Potassium Sulphate ( $K_2SO_4$ ), more commonly referred to as sulphate of potash (SOP), must be made. However, ongoing use of SOP may be restricted depending on circumstances. There are a limited number of SOP supplies in Ireland; these are outlined in the table below.

### Sources of Sulphate of Potash

*Sulphate of potash  $K_2SO_4$  (SOP)* (a generic and widely available product)

41% K (as 50%  $K_2O$  / potassium oxide)

18% S (as 45%  $SO_3$  / sulphur trioxide)

*Sulphate of potash with magnesium and sulphur: (e.g., Patentkali ®)*

25% K (as 30%  $K_2O$  / potassium oxide)

6% Mg (as 10%  $MgO$  / magnesium oxide)

17% S (as 42.5%  $SO_3$  / sulphur trioxide)

*Sulphate of potash with sodium and sulphur (e.g., Magnesia-Kainit®)*

9% K (as 11%  $K_2O$  / potassium oxide)

3% Mg (as 5%  $MgO$  / magnesium oxide)

20% Na (as 29%  $Na_2O$  / sodium oxide)

4% S (as 10%  $SO_3$  / sulphur trioxide)

The two propriety products, Patentkali ® and Magnesia-Kainit®, have EU level organic approval at the time of writing while SOP may require case-by-case organic certification body approval depending on source. It is essential to check the current approval status before purchasing and/or using such materials.

All three forms are highly water-soluble so they will be rapidly taken up by any plants present before the K is absorbed into the soil. Potassium leaching is less of a problem than P and N, except if applied under very unsuitable conditions, e.g., where there is active surface run off.

### Lime Requirement & pH

Our high rainfall sometimes causes an increase in the acidity of our soils, regardless of the system of farming. Maintaining soil pH between 6.3 and 6.6 is essential for many microbiological processes in the soil and is therefore essential for nutrient cycling. It is also absolutely essential to maintain pH at optimum levels to allow the satisfactory establishment and growth of clover.

The maintenance of optimum pH is as, if not more, important in organic production than non-organic. The correct pH is essential for optimal soil biological activity,

especially the mineralisation (decomposition) of organic material into plant available nutrients, which is the main source of N in organically managed soils. High pH also limits the rate of rock phosphate dissolution, so pH in organic system should tend towards the acidic rather than alkaline, within the range of 6.2 to 7.0. High organic matter levels also helps dissolve rock phosphate due to the presence of biological acids.

Most sources of lime are permitted in organic systems, but it is important that the particular product to be used is either organically certified or that your certifier confirms that the source is permitted. Similar to rock phosphate, lime is relatively insoluble and the calcium and other constituents have to be released by biological decomposition, which means it is released slowly, often over five years or more. The finer the lime is ground the quicker it will decompose and the quicker it will raise pH. However, finer material is more expensive and difficult to apply (it blows away), so that in most cases it will be more economic to apply larger amounts of courser material to rapidly rectify high pH than smaller amounts of finer material.

Determining when to apply lime to maintain an optimal pH is achieved by the use of regular soil testing, just as for soil nutrients. With lime taking several years to have its full effect on pH it needs to be used 'pre-emptively' before pH drops too low.



## Section 3: Manure Management

The components of a manure recycling system on grassland farms are manure production, storage, application and utilisation. The level of control that a grassland farmer exerts on the production of manure is limited. However, farm management practises that optimise the quantities of bedding materials used will significantly reduce the quantities of manure production. For example, significantly less straw is used in cubicle systems compared with loose housing (120 versus 530kg) over a 180 day winter. For liquid systems, reducing the amount of water entering the slurry store will reduce the volumes produced.

Animal manures, composts and brought in biological materials must be handled carefully to minimise nutrient losses. The primary cause of nutrient loss, mainly N and K, is due to rain exposure. Biological material must therefore be protected from the rain, for example, by being in a shed, under plastic sheeting or other suitable rainproof covering. However, tight fitting, air proof covers, such as plastic sheets, can impede airflow into and out of material that is undergoing rapid aerobic 'hot' composting. These are mostly best left uncovered until the composting process is finished unless there is so much rain that the compost cannot absorb it. Storing biological material in fields and/or on soil is not recommended due to the potential for leaching and environmental pollution. Ideally, material should be stored on an impermeable base that allows the collection of any liquids produced. Silage pits and stock sheds are well suited for this; however, silage pits must be thoroughly cleaned before being used for silage.

On-farm produced livestock manure and slurry can be valuable sources of N, especially for early season pasture growth. This is because white clovers need temperatures above 20°C to grow vigorously and fix significant amounts of N, so Irish spring soil temperatures are too mostly too cold for white clovers to meet grasses' high N demand in spring. Slurry and manures can therefore help meet this spring N requirement shortfall.

Organic standards state that the total amount of manure applied to the holding must not exceed the equivalent of 170 kg of nitrogen per hectare of agricultural area used, calculated over the whole area of the holding or linked units

3.1 Nutrient Content of Animal Manures

The quantity of nutrients in manures varies with type of animal, feed composition, quality and quantity of bedding material, length of storage and storage conditions. Surveys on manure composition suggest that the dry matter and nutrient contents of manure can vary up to ten fold even from the same type of animal. In organic systems it is particularly important to conserve manure nutrients for both economic and environmental reasons. On mixed and livestock farms animal manures an important means of re-distributing nutrients as it is important to ensure that excessive fertility is not built in some fields at the expense of others. Manure use should be planned with regard to both farm system and field nutrient budgets. Manures play a key role in fertility building and maintenance in many organic rotations. Understanding their nutrient composition and nutrient availability is therefore important for optimising their use on farm. Typical estimates of total N, P & K contents of common animal manure types are outlined in the table below.

Typical N, P & K levels in animal manures			
Animal Manure type	N kg/t3	P kg/t3	K kg/t3
Farmyard Manure	4.5	1.2	6.0
Cattle Slurry	5.0	0.8	4.3
Compost	7.5-15.0	1.0 – 2.0	7.0
Poultry Broilers Deep Litter	11.0	6.0	12.0
Layers	23.0	5.5	12.0
Turkeys	28.0	13.8	12.0

Manures are a valuable source of nutrients (and organic matter), and can be seen as a method of transferring nutrients around the farm (for home produced manures) or as a method of importing fertility (imported manures or composts). Good manure management offers a ‘win-win’ opportunity: benefits to soil fertility and benefits to the environment (less pollution).

When not applied appropriately, animal manures applied to agricultural soils can be significant contributors to nitrate leaching. Large amounts of N can also be lost from the soil in surface run-off when heavy rain falls in the first few days after slurry application. It is the 'readily available' nitrogen fraction that is most at risk from leaching: ammonium-N, uric acid-N (poultry manures) and nitrate-N (generally only trace amounts in most manure). In organic farming most manures are produced from either slurry or straw-based systems.

The straw based systems have a relatively small readily available N content, thus presenting a small nitrate leaching risk. Some manures are also composted, which tends to reduce their ammonium N content still further. However, it should be noted that nitrate can accumulate during composting and it may be that well-composted manures have potential to leach substantial nitrate (either from an uncovered heap or after application to land in autumn). Another route for N loss is that of direct run-off of N in leachate from manure stores. Clearly, manures have to be managed in such a way as to minimise this risk by having facilities to collect the leachate. Covering the manure will not necessarily eradicate the risk, because much of the N is contained in the liquid that leaks from the FYM heap in the first few days). The N content in leachate leaving the heap declines with time, because the readily available N becomes assimilated into the organic fraction of the manure heap.

Ammonium N, the principle plant available source in animal manures is also susceptible to losses. The ammonium-N is readily converted to ammonia gas ( $\text{NH}_3$ ), which can be lost to the atmosphere. Exposure of slurry or farmyard manures to warm, windy and sunny conditions at time of application promotes high ammonia losses, therefore applications in a manner that minimises N loss will maximise the fraction available for crop growth.

### 3.2 Timing and Methods of Application

The application rate of manures should reflect the nutrient concentration of the manure and crop requirements. Slurries and manures should be analysed to provide some indication of nutrient content.

1. Apply at a time when crop demand is high in spring. Where soil conditions allow, aim to have 70% applied by the end of April. Opportunity for spring application on heavy soils may be increased by using application



methods that reduce soil compaction. Early application provides nitrogen for grass growth before clover starts to fixate atmospheric nitrogen from mid May onwards.

2. Application in dull, overcast or misty conditions will result in lower ammonia losses compared to application in warm, dry or sunny weather
3. Animal manures should not be applied when the soil is
  - Waterlogged
  - Flooded
  - Frozen or covered in snow
  - Heavy rain is forecast within 48 hours
  - The ground slopes steeply giving a significant risk of water pollution

Slurries with low dry matter contents will percolate and wash into the soil more quickly than material with higher dry matter, therefore reducing the duration of exposure to air. Dilution of slurries with soiled water will increase the volume to be managed and therefore increase spreading costs; however a 1% reduction in slurry dry matter percentage will decrease ammonia losses by approximately 5 to 8%. Using application methods such as band spreading, trailing shoe and shallow injection place the slurry in bands or lines rather than on the entire surface as with the conventional splash plate method.

### 3.3 Composting – on Organic Farms

Composting is recommended in organic farming as a management tool for controlling weeds, pests and diseases. Organic standards promote composting, anaerobic digestion, aeration of slurry and correct storage of manure. These treatments greatly reduce pathogen loads in manure by increasing the range of biological activity, which helps to suppress pathogenic microbial populations, and by heat pasteurisation. A well-managed aerobic digester or aerobic compost heap will reach temperatures of 55°C to 65°C, and will be maintained at this temperature for three days to destroy weed seeds and pathogenic bacteria. In addition, aerobic composting results in the stabilisation of nutrients, giving the compost nutrient release characteristics that are more in tune with the demand of crops throughout the seasons.

True composting of manures, i.e. aerobic decomposition at temperatures of around 60 Deg C, results in fundamental physical and chemical changes to the manure.

Composting results in some losses of nitrogen through volatilisation in the form of ammonia however the soluble nutrients, particularly nitrogen, are stabilised and hence subsequently less liable to leaching. Composted manure thus has a more long-term role in building soil fertility, and has been shown to be more effective in building soil microbial biomass and increasing activity than un-composted manure.

### 3.4 Importing Animal Manures

Many horticultural holding import manure from other organic farmers and conventional farmers. However, the opportunity to import from other organic farmers is limited due to the requirement for the manures to replenish nutrient levels on these farms.

Manure can be imported from conventional farms provided that it complies with the following conditions:

- Not from animals reared intensively i.e. above 170kg/ha of organic N
- Not from livestock fed diet which includes a GM component
- Sewage sludge
- Composted for three months when it arrives on the organic unit
- The total organic N for the unit does not exceed 170kgN/ha



## Section 4: Green Manures

Green manures are the next most importance N source after pasture. A green manure is a crop that is grown with the deliberate intention of returning it all to the soil. The name and technique is synonymous with 'cover crops', often with the same plant species being used for both. The names indicate the different intentions for the crops – for green manuring the main aim is to increase the N and organic matter in the soil, while for a cover crop, the main aim is to protect the soil and/or retain nutrients. In practice, both types of benefits accrue whatever the principle aim is.

A typical green manure consists of a cereal and a legume in about a 50:50 mix. This will produce the most biomass and can fix more N than a stand of pure legume. This is because the cereal takes up considerable quantities of soil N during growth, which temporarily reduces soil available N which in-turn maximises N fixation by the legume. This is because when there is plenty of soil N, legumes minimise N fixation and use soil N instead, because fixation requires considerable amounts of energy and nutrients that could be used otherwise. Low soil N due to the cereal taking it up 'forces' legumes to get most of their N via fixation thereby maximising the total amount of fixed N compared with a pure legume stand that is free to avail of soil N. The two crop species also occupy different ecological niches, which make for better resource utilization, for example, cereals have a fibrous root system, which effectively explores the surface soil layers, while legumes have a tap root system that can penetrate deeper into the soil. Research on crop mixtures has consistently shown that the yield from two or more cultivars or species grown together is greater than the yield from the same plants grown separately and then combined.

Green manures can be planted at any time of year; however, in most cropping systems cash crops will occupy the fields during the summer so the main use of green manures is over the winter. Species and cultivar choice are therefore critical. The species chosen must be able to grow during the cold winter period and ideally fix N rather than just using what is in the soil. However, cold soil and weather are much less favourable to N fixation than warmer summer conditions, so N fixation levels are often low. Green

manures can also be sown during the main growing season, especially if there are periods when land would be fallow for more than six weeks.

Often very fast growing species are used, e.g., Phacelia (*Phacelia tanacetifolia*) or brassicas such as mustard (*Brassica juncea*). However these species do not fix N so they only have a catch crop effect, i.e., they prevent N loss rather than increase it. Such crops also have limited benefit on soil organic matter and levels, due to their low dry matter content and low C: N ratios. Also, if too much tillage is used in their establishment and destruction, e.g., ploughing, then this is more likely to reduce soil organic matter and N levels than to increase them, due to the loss of organic matter, and therefore N, caused by soil disturbance / tillage.

On mixed farming systems where there is a restorative pasture phase followed by an exploitative cropping phase, green manures can help extend the cropping phase, but in most cases they will add considerably less N to the system than the pasture phase. They are therefore valuable additions to the system but are unlikely to be essential to its success. Therefore, less expensive, but potentially less productive green manure options can be used. For systems without a pasture phase, e.g., stockless arable or horticulture, green manures and crop residues will be a key source of soil N and therefore should be primarily selected on performance and looked after as well as any cash crop, to ensure that the best results are obtained. Even so, it is difficult for such systems to achieve a balanced N budget from green manures alone. Brought in N sources, typically manure or compost may be required, which are often expensive. The alternative is to take land out of production and into mixed pasture that is then managed (e.g., by mowing) to maximise pasture growth and nitrogen fixation. However, this approach is not without its problems, due to it removing land from production plus the cost of maintaining the pasture. Overseas, farmers who have attempted such stockless rotations have often found that they are better off re-introducing stock to their systems as it is more profitable in the long term.

To be useful, green manures have to be killed and the nutrients within them returned to the soil in time for the following cash crop to take advantage of them. There are two main approaches, grazing or mechanical destruction, for which there are pros and cons for both.

Grazing has the advantage that it breaks down the above ground plant matter in the livestock's digestive tract far quicker than soil organisms could, so there is a quicker

turn around between terminating the green manure and planting the following cash crop. This is even more critical with green manures that have a higher carbon:nitrogen ratio, i.e., they contain more fibrous material. This is because soil organisms need N to decompose the plants, which if there is insufficient within the plant tissues, they will have to use soil N. Soil organisms out compete plants for soil N, which results in a temporary N shortage called 'nitrogen robbery'. Grazing reduces this problem as the decomposition takes place in the animals gut, a good deal of the carbon (C) component is lost from the animal as carbon dioxide (though breathing) while much the N is returned to the soil in dung and urine. The exact amounts will depend on the type of stock, with growing or milking stock removing considerably more nutrients than stock just maintaining weight. Other advantages of grazing off green manures are that it requires no machinery, saving fuel, labour costs as well as machinery wear and tear. The green manures can also be useful feed.

The N in fresh dung and especially urine (i.e., urea) is more soluble, is produced in larger quantities so is therefore, more available to plants than the forms of N produced by soil organisms decomposing the same material. This means that N, and other nutrients, from grazed green manures are likely to be more rapidly available for the following crop, giving it an early boost that it is less likely to get from green manures decomposed by soil microbes. This can be particularly valuable in spring when N availability in soil is often quite limited due to low soil temperatures restraining the rate of N mineralisation. However, if conditions are wet or the land is unplanted after grazing then the N could be lost and end up in ground water via leaching or streams and rivers via run-off. This is clearly an undesirable loss of N from the farm and potential environmental pollution, so must be avoided.

The other key negative effect of grazing is that it will not boost soil organic matter or biological activity as much as mechanical destruction. The green manure crop contains not only nutrients but also energy that the plants have gained from sunlight. This energy content can be considerable, for example, in the old days, the heat from burning cereal stubble showed how much energy was stored in the straw. Soil organisms, like all organisms, need energy as well as nutrients to thrive. If the green manure is grazed off then much of the energy in it is used by the livestock, even if most of the nutrients are returned to the soil. This lost energy is then unavailable to the soil microbes so they cannot grow and multiply nearly as much as if they had 'dined' on the green manure directly. As noted above, much of the carbon content of the green manure will be excreted from the livestock as carbon dioxide, which means it will also be unavailable to soil organisms, which will further reduce soil organic matter because carbon is a major constituent of organic matter along with

hydrogen. Therefore, the loss of energy and carbon due to grazing is likely to lead to a less biologically active soil than had green manures been directly returned to the soil. Grazing off green manures is therefore something of a 'double edged sword'. It can be beneficial under the right conditions and harmful under the wrong conditions. Care and forethought must therefore be given to its use.

Mechanical destruction typically involves using a mower to cut down and/or pulverise the green manure foliage typically followed by some form of soil incorporation. Mowers that leave the green manure in a swathe, e.g., silage mowers, are not ideal as this results in an uneven distribution of the foliage across the field resulting in uneven soil nutrition, which can result in problems in the following crop such as uneven ripening. Also, green manures that are left mostly whole will take longer to decompose and release nutrients to the following crops. Flail mowers that pulverise and spread the green manure more evenly across the field surface will minimise the chance of uneven nutrient spread and speed decomposition due to the much greater number of sites that microbes can quickly attack the plant's tissues. This is at the cost of greater fuel use and often more expensive machinery.

Traditionally the view was that plant material left on the soil surface was 'wasted', the name 'trash' indicates its perceived low value. It was thought that the soil microbes could not 'get at' the material to decompose it, and therefore it should be incorporated into the soil, traditionally by ploughing. Research over the last forty odd years into no-till and conservation agriculture, which is widely used in the Americas and Australasia, has demonstrated that incorporation of plant residues into the soil by tillage frequently results in a net reduction of soil organic matter and lower soil health. This is because tillage causes considerable decomposition of soil organic matter due to the introduction of large amounts of oxygen into the soil. This often releases N and C (organic matter) in larger quantities than is gained from the incorporated residues. Continuous no-till cropping can restore soil organic matter to levels equivalent to, or even higher than, permanent pasture, and dramatically improves soil health, particularly soil structure and earthworm populations. Therefore, to maximise the benefits of a green manure it should be left on the soil surface or tilled into the soil surface as shallow as possible, i.e., only use the minimum amount of tillage.

However, high levels of crop residue on the soil surface can cause problems for later operations, notably drilling and weeding, e.g., clogging of drill coulters and hoe blades. If the green manure is still sufficiently young and green, with a low C:N ratio, so that it will rapidly decompose, then destroying the green manure a few weeks in

advance of needing to drill may give sufficient time to allow it to break down sufficiently that it will not effect later operations. For materials with a higher C:N ratio or where a faster turn around is required it may be necessary to ensure that the material is chopped as finely as possible when being mown off, and then worked into the soil surface with the minimum number of passes. Materials that have a C:N ratio higher than 20:1 are at risk of causing N robbery as soil organisms temporarily use up soil N to decompose the high C compounds, after which the N is made available again as the decomposers themselves die. Above 30:1, robbery is highly likely. Table 2 gives some examples of the C: N ration of a range of materials.

Table 2. Carbon: Nitrogen Ratios for a range of materials (Source Aggie-Horticulture Network of the Texas A&M University System)	
Material	C:N
Food scraps	18:1
Lucerne hay	10:1
Grass clippings	12-25:1
Coffee grounds	20:1
Vegetable trimming	12-20:1
Cow manure	20:1
Horse manure	25:1
Horse manure with litter	60:1
Rotted manure	20:1
Poultry manure (fresh)	10:1
Poultry manure with litter	18:1
Leaves, varies	35-85:1
Peat moss	58:1
Straw	80:1
Farm manure	90:1
Newspaper	50-200:1
Sawdust, weathered 2 months	625:1

Where residue with high C: N ratios have to be tilled in (rather than grazed off) and planted soon afterwards then ploughing may be the only practical option.



## Section 5: Trace Elements on Organic Farms

On well established organic farms, sound agricultural procedures should render normal supplementation unnecessary. The aim should be to reduce and eventually eliminate imported minerals by growing appropriate varieties of grasses and herbs necessary. Routine additions to food of mineral and vitamin supplements are prohibited.

### 5.1 Animal Requirements

The minerals and trace elements that are essential for animal health are calcium (Ca), phosphorus (P), potassium (K), magnesium (Mg), nitrogen (N), sodium (Na), and sulphur (S).

The trace elements that are essential for animal health are iron (Fe), manganese (Mn), copper (Cu), zinc (Zn), cobalt (Co), selenium (Se), iodine (I), and molybdenum (Mo). The trace element baron is not essential for animal health, but its absence can affect the survival of certain pasture species, in particular clover.

In organic farming the main sources of minerals and trace elements for livestock is the soil itself and the recycled materials generated from the farm. Table 1 outlines the concentrations of trace elements normally found in soils and herbage in organic farming. Herbage values are given as total concentrations. While those for soil are given as plant available levels. Soil levels for Fe, Se and I are not given soil values for Fe bear little relationship to herbage values. Se and I are easily leached and the soil concentrations are reduced by rainfall. Iodine values are also affected by proceeding to the sea. The factors that influence the availability of trace elements are numerous, interpreted and interrelated. The factors are soil type, drainage, grazing, management, pH and organic matter, grass species.

5.2 Soil Types and Drainage

Free draining sandy or gravelly soils are low in trace elements. The low status of these soils is associated with low clay, oxide and organic matter control rather than with the leaching of trace elements from the soil profile.

Poorly drained soils affect the trace element supply to livestock in two ways. Firstly, poor drainage can increase the concentrations of some trace elements soil and in pasture species. Secondly, poor drainage can increase soil ingestion by livestock and this can lead to further deficiency issues.

Table1. Range of trace elements in the soil and herbage of Organic Grassland		
Trace Elements	Soil Concentration (mg/kg)	Herbage Concentrations (mg/kg)
Iron (Fe)		50-150
Manganese (Mn)	50-250	25-250
Copper (Cu)	5-8	7-9
Zinc (Zn)	2-10	20-60
Cobalt (Co)	3-10	0.05-0.15
Selenium (Se)		0.03-0.30
Iodine (I)		0.08-0.30
Molybdenum	1-2	2.0-5.0
Boron (B)	0.8-1.5	2.0-10.0

5.3 Lime Application

The soil pH influences the availability of trace elements for uptake by pasture species. A soil pH of 6.5 is considered to be the optimum for soils containing trace elements in well balanced amounts. All soil pH values below 6.5 the availability of Mo and Se is reduced and the availability of Fe, Mn, Co, Zn and B is increased. Low soil Mo can lead to poor clover establishment, while Se deficiency can lead to cardiovascular problems in calves and afterbirth retention in cows. Soil pH above 6.5 the availability of Fe, Mn, Co Zn and B is reduced and that of Mo and Se is increased. In Irish conditions, leaching by rainfall can cause the pH to fall. This must be rectified by lime application.

## Soil Organic Matter

Organic matter (humus) is an important constituent of every soil because it is the most chemically and biologically active of all the soil phases. It is of particular importance in organic farming because the farmer is dependent on inherent soil properties to support crop and livestock growth. The beneficial effects of organic matter in soil are as follows:-

- Improves soil structure
- Improves the water holding capacity of a soil.
- Absorbs from 2 to 30 times as many cations as other active soil phases.
- Depending on content accounts for 30 – 90% of the adsorption power of mineral soils.
- Improves the ease of interchange of plant nutrients with soils.
- Can extract plant nutrients from the mineral phases of the soil.

The organic matter content of a soil is dependent on climate and soil type. In wet temperate regions soil organic matter is high. In arid regions soil organic matter is low. In heavy clay soils the organic matter tends to be high. In light, sandy or gravelly soils organic matter is usually low. The range of values across regions and soil types varies from less than 1% to over 15%. Values above 15% indicate poor drainage. At soil organic matter values greater than 20% soils are classified as peat soils. Intensive cultivation and liming causes a reduction in soil organic matter. Soil organic matter content is greater under permanent grassland than in arable land. In Ireland, in most grassland soils the organic matter is highly satisfactory at 8-10%.

Soil organic matter is strongly associated with the transfer of trace elements from the soil to the plant. Although trace elements may be fixed by the well decomposed organic materials such as the humic acids, the less well decomposed organic acids, polyphenols, amino acids, peptides, proteins and polysaccharides carry trace elements in loosely bound chelated form which are easily available to plants. From 98 – 99% of Cu, 84-99% of Mn and 75% of Zn are carried on organic complexes within the soil. It is clear from the above that practices that build up the organic matter in a soil will also increase the mineral and trace element supply to livestock. A low livestock density (1.0-1.5 LSU/ha) prevents over grazing and a reduction of organic matter input to the soil. The soil pH should be at 5.5 or slightly below.

Because of its excellent growth characteristics perennial ryegrass is likely to remain the mainstay of productive organic farming. However its mineral composition is low

compared to other grass species. Table 2 summarises some recent findings. Among the nine elements listed perennial ryegrass has the highest concentration of I. Rough stalked meadow grass contains highest concentrations of Fe, Mn, Cu, Co and Mo. Red and white clover has higher concentrations of Fe, Cu, Zn, Co and Mo than perennial ryegrass.

Table 2 Trace elements concentrations in pasture species (mg/kg)								
Species	Fe	Mn	Cu	N	Co	Se	I	Mo
Perennial Ryegrass	55	87	5.0	23	0.05	0.03	1.46	0.31
Rough stalked meadow grass	153	119	12.3	16	0.06	-	0.14	0.59
Italian ryegrass	148	65	4.3	11	0.05	-	0.85	0.29
Timothy	34	97	5.5	24	0.04	-	-	0.35
Red Clover	74	74	11.9	31	0.11	0.01	0.40	0.35
White clover	88	87	8.4	28	0.10	0.01	0.91	0.41

It can be concluded that to achieve the best balance of trace elements in pasture it is advisable to have perennial ryegrasses and clovers, and contributions from other species, if necessary.

Lack of Trace Elements in Soil

Where there is a known dietary deficiency in home grown feeds, or as a result of soil deficiencies, on there is veterinary evidence (e.g. blood, soil, or herbage) of a deficiency within the livestock, restricted supplementation will be permitted with approval from the Organic Certification Bodies. Only minerals and vitamins from permitted sources may be fed. All supplements must be GMO free.

<i>Recommended</i>	All stock should have access to green fodder and/or hay or silage on a daily basis as seasonally available.
<i>Permitted</i>	Additions to the diet of naturally occurring mineral/vitamin-rich supplements (e.g. seaweed, rock salt, cod liver oil, yeast)
<i>Restricted</i>	Mineral Boluses-where a deficiency is proven after laboratory analysis of blood, soil or herbage sample and long term management evaluated – details of specific bolus ingredients must be forwarded for certification body approval
<i>Prohibited</i>	Urea Vitamins and other products derived with the aid of genetically modified organisms Routine addition to feed of restricted mineral and vitamin supplements.

## Section 6: *The Role of Rotations in Nutrient Management*



Rotations are a key technique for managing overall nutrient supply on organic farms, particularly for mixed and stockless systems. The clover-grass ley is the most important fertility-building phase, principally for nitrogen, but it is also an appropriate time to be applying P and potentially lime. Applying P to the start of the pasture phase means that it will help maximise N fixation. At the same time, the higher levels of soil biological activity found under pasture plus the presence of clover will allow for the most effective breakdown of the mineral P and conversion into biological forms that will feed the following crops.

Likewise, applying lime at the start of the pasture phase allows it to be incorporated into the soil by tillage and it allows time for it to be converted from mineral to biological forms while optimising soil pH under the ley, thereby maximising pasture productivity. For lime sensitive but nutrient demanding crops such as potatoes putting lime on at pasture inception means they can be planted soon after pasture to make the most of the higher nutrient levels while minimising the risk of lime damage. Putting lime on at pasture termination risks over-stimulating organic matter mineralisation in addition to that caused by tillage, which could result in substantial nitrogen losses.

As the approved mineral forms of K are highly water soluble, putting them on at the start of the ley will result in them being converted to biological forms or entering the less available K soil reserves. If K levels going into pasture are below optimum, then K should be applied to optimise pasture production. If K levels are within recommended levels, consideration should be given to reserving K application for crops with a higher K demand, e.g., root crops.

The cropping sequence following a ley starts with the most N and other nutrient demanding crops, typically wheat, maize and root crops. These are followed by less demanding crops, such as brassicas, and ending with crops that are efficient nutrient scavengers, e.g., oats, or N fixing legume crops. The addition of manures (FYM, slurry, compost) is generally reserved for the last half of the rotation. While this can

be an effective way to 'top up' soil nutrients it is unlikely to be able to build soil N up to the levels found after the ley. The same is true of green manures, as discussed in the N section (above).

Unless a straightforward rotation is being followed, crops should be matched to fields at the start of each year, based on each field's history, crop needs and market requirements. This has to include an evaluation of the field's nutrient and general soil conditions, plus presence of pests, disease and weeds. This is then matched to the crops nutrient and soil condition requirements, the length of rotational gap it needs in relation to pest and disease carry-over and how competitive it is with weeds. Rotations are therefore not pre-ordained and fixed, but highly flexible and changed on a yearly basis.

Where insufficient soil nutrient replacement has taken place, and soil nutrient or pH levels have fallen too low, speedy action to replace the depleted nutrients must be taken. Probably the best option in such situations is to establish a grass clover pasture rather than attempting to crop depleted land. This is because yields and the nutrient content of crops are likely to be poor; the latter is clearly contrary to organic standards and the former means that profit will be reduced. It is also likely to be harder to rectify nutrient deficiencies under crops that are predominantly removing nutrients compared to pasture where removal will be lower and livestock assist with nutrient cycling through dung and urine. Other issues that make pasture the preferred crop when rectifying nutrient deficiencies are nitrogen fixation by clover, soil structure improvement by grass roots plus the absence of tillage, all of which will help build organic matter and biological activity resulting in most cases in faster improvement in soil health than under cropping.

However, if soil nutrient deficiency is severe, great care must be taken to ensure stock do not also develop nutrient deficiency, e.g., by providing supplementary fodder and/or mineral licks, the latter must however be approved by your organic certification body.





## Key Points

- In keeping with the key aim of organic agriculture of maintaining a productive and biologically active healthy soil and that nutrient levels and pH are maintained at optimum levels across the whole rotation. These levels are determined by regular field-by-field soil tests and nutrient budgets.
- Soil tests and budgets provide the information to establish the best fields on which to use farm produced manures and, when necessary, where to use bought-in biological and mineral fertilizers to replace nutrients exported in crops and livestock or lost to water or the atmosphere.
- Rotations are a key technique for managing overall nutrient supply on organic farms, particularly for mixed and stockless systems. The clover-grass ley is the most important fertility-building phase, principally for nitrogen, but it is also an appropriate time to be applying P and potentially lime.
- On well managed organic farms routine trace element supplementation is unnecessary unless there is an underlying soil deficiency.
- There is a range of National and EU level legislation covering the storage and use of biological manures which are often updated. **Compliance with organic standards does not guarantee cross-compliance with legislation** and advice from farm advisers or the appropriate Government agency should be obtained.
- When considering using an off farm source of fertiliser consult your organic certification body for permission.

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# Nutrient Management on Organic Farms

December 2008

