15. Nutrient Management in Organic Agriculture

15.1 Organic – Definition of the Term

There is some confusion over the word 'organic' in relation to 'organic agriculture' and the other meanings of the word 'organic'. For example, in other sections of this book peat soils are described as 'organic' meaning they are of biological origin rather than 'organic' as in organic agriculture. Therefore, in this section the term organic refers to 'certified organic agriculture' as defined in national and EU legislation while biological is used in place of 'organic' when referring to materials of biological origin.

15.2 Healthy Soil – the Foundation of Organic Agriculture

Optimising soil 'health' is the foundation of organic agriculture with particular emphasis being placed on maintaining high levels of soil biological activity and organic matter, coupled with balanced / optimum nutrient levels. Organics aims to 'feed the soil to feed the crop' 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 fertilizer recommendations of soil tests are tailored to a field's cropping history and soil type to give specific recommendations for each field.

15.3 The Organic Nutrient Dichotomy

Organic agriculture contains 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. 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 overwhelming that both must be combined: the law of return (balanced budgets) must be coupled with efficient cycling of nutrients around the farm. However, most English language standards are based on the 'closed system' concept which has resulted in organic agriculture setting high barriers for importing solid/non-gaseous nutrients such as P and K. On the other hand, 'importation' of the gaseous nutrient N via legumes is considered indispensable. The scientific evidence is clear; it is equally essential to replace P, K and other solid nutrients, using approved substances such as biological materials and mineral fertilizers. Therefore, modern organic agriculture takes a similar high-level position to non-organic agriculture in that all nutrients removed or lost from the farm system must be replaced.

On livestock farms, animal manures are vital materials for cycling nutrients around the farm, especially onto cropping ground, and should be handled carefully to minimise nutrient losses, e.g., preventing leaching from heaps due to exposure to rain. The nutrient content of manures varies widely, (Table 6-1). To ensure nutrient budgets are accurate, farm produced manures should be tested every few years rather than relying on the averages given in official information.

Unfortunately there is insufficient research to determine what the optimum soil nutrient levels for P and K are under organic systems as opposed to non-organic systems. There is some research showing that with the higher levels of biological, and especially mycorrhizal activity in organic soils, healthy crops can be successfully grown at lower nutrient Indices than in non-organic soil. However, until a fuller picture emerges, the recommendations for non-organic production should be followed.

Certification standards are constantly changing so this advice must be read in conjunction with the latest standards of the farmer's or grower's certification agent. In all cases, before importing nutrients onto a certified organic farm, the certification agency must be consulted.

15.4 Approved N, P and K Sources – Biological Materials

All nutrients can be imported into organic holdings as biological material. Caveats are that sources that originate from intensive livestock units (e.g., pigs and poultry) or from stock fed on transgenic ('genetically engineered') products are banned. Biological material from other organic holdings generally has minimal restrictions on its use. However, biological materials that originate from non-organic sources must normally be aerobically ('hot') composted and/or receive other treatments prior to use, as specified by the certifier. However, composting alters the nutrient content of the material, especially nitrogen which is lost in potentially large amounts as ammonia, thereby reducing its N fertilizer value. The exceptions for the need to compost non-organic materials are those brought in as stock bedding, e.g., straw and wood chips.

Purchased feed (which must be organic) contains high nutrient levels by its nature. Most of these will be excreted by the stock as manure and can contribute a significant proportion of the nutrient replacement needs of a livestock enterprise. Therefore, all biological sources of nutrients, whether they are compost, bedding, feed or other materials, must be included in nutrient budgets.

The lists of permitted fertilization materials in organic standards over the years have included a number of unusual materials e.g., kali vinasse and guano. Most of these lists originated in the earliest versions of standards and were designed to be exhaustive descriptions of allowed materials, i.e., anything not on the list was prohibited. However, despite their inclusion, many, if not most, have never been widely available, if at all, and it is likely that any effort spent trying to locate such materials will be unrewarded.

15.5 Nitrogen, Phosphorus and Potassium Nutrition

Nitrogen

The overriding source of N is from leguminous plants. Most imported biological materials have to be aerobically composted which considerably decreases their N content. The use of high N sources, e.g., blood and bone, which do not have to be composted, is heavily restricted by the certifiers and veterinary rules and most materials are prohibitively expensive for all but the very highest value vegetable crops.

There are two main approaches for using legumes: as a two or more year mixed pasture or as short term green manure crops. A multi-year pasture containing white or more especially red clover can fix large amounts of N and will always consistently and considerably outperform shorter term green manures (Table 15-1). The N is stored in biological material which is released by mineralisation. This N release is a temperature dependent process, which means that more N is released in the warmer summer months than cooler winter months. This pattern of N release reasonably corresponds with crop requirements, the exception being in early spring.

Table 15-1. Typical amount of N fixed in one year by different crops, and of the amount remaining after harvest.

Crop	Amount of N fixed kg/yr[1]	Amount of N remaining after harvest kg/yr[1]
Red clover silage	160 to 450	50 to 150
White clover & grass silage	70 to 420	20 to 180
White clover & grass grazed	60-250	50 to 210
Forage peas (summer crop)	80 to 290	40 to 110
Field been grain crop (summer crop)	200-380	90-150

1. These figures were obtained from overseas and may not be fully representative of Irish agriculture

For grazed pasture, white clovers are best as they survive regular defoliation better. For silage and stockless systems, red clover is preferred as this will fix more nitrogen and produces more dry matter (DM). To maximise mixed pasture productivity clover and grass should be in a 50:50 DM ratio which equates to practically 100% ground cover by the clover due to its leaf structure. Clover populations are also self regulating: as soil N builds up they become less competitive with grass and so populations reduce, while in low N soils they will dominate, this is known as the 'clover cycle'.

Due to the large amounts of N fixed under pasture, great care must be taken when terminating leys to avoid large N losses. Practices that minimise N loss are minimum-tillage and cultivating either when the soil is dry as this prevents leaching and/or cold as this minimises mineralisation. Practices that will cause large N losses are ploughing and other deep loosening cultivations and tilling the soil when it is both warm and when water is draining from the soil, i.e., typical autumn conditions. Losses of over 120 kg/ha N from inappropriate termination of leys have been recorded which represents a large financial loss to the farmer and significant environmental pollution.

Green manures are typically planted over winter. Generally a mixture of legume and cereal are used as this maximises nutrient scavenging, N fixation, and biomass production, as well as weed, pest and disease suppression. Due to their short duration and cold winter temperatures N fixation is however small compared with multi-year pasture.

Leguminous crops can fix considerable amounts of N; however, much of the fixed N is removed in the crop, with only limited amounts, e.g., 50 kg/ha remaining after harvest. Therefore, they should not be considered to be significant N sources.

Stocking rates and meeting crop N demand

For quality land with optimum nutrient levels, and good management, stocking rates of 1.3 to 1.6 LU/ha are achievable based on white clover and grass swards. This requires that all pastures on the farm have good levels of clover in them, not just the best fields. If red clover is used in place of white for silage, then stocking rates can range between 1.5 to 1.9 LU/ha, again based on land, nutrient levels and management.

With the ley being the main N source, it is essential to grow the highest N demanding crops in the first three years after pasture is terminated. Sections 12 (cereals) 13 (roots) 14 (other arable crops) and 16 (vegetables) give details of the most N 'hungry' crops. See section 15.8 below for more information on rotations.

Phosphorus

The nutrient Indexes where P is limiting are below Index 2 for extensive production (low stocking rate permanent grazing) and below three for more intensive systems (e.g., crop production and higher stocking rates). For general P advice, see sections 10 (grassland), 12 (cereals), 13 (roots) and 14 (other arable crops).

Phosphorus is the key nutrient for optimising N fixation by *Rhizobium* bacteria in legume root nodules, so it is essential that P levels are maintained above minimum levels to ensure sufficient N fixation.

The main mineral source of P is rock phosphate, which is ground to sufficient fineness to allow it to be biologically degraded into soluble forms and is called ground rock phosphate (GRP). It is typically released over three years with a third released in each year, so it will provide only a small amount of P if applied to a crop at sowing. The rate of release is also governed by soil pH with an optimum around 6.5 while above 7.5 there will be no dissolution. In such situations organic standards recommend calcined aluminium phosphate rock, however, this is not currently available in Ireland. In this situation, expert advice should be sought. Legumes also acidify the soil around their roots which assists them absorb P even if soil pH is at the higher end of the recommended level.

Phosphate rocks naturally contain varying amounts of heavy metals, particularly cadmium (Cd). Certification standards require that lower cadmium rock should be used and depending on amounts used, soil analysis may be required to ensure that Cd levels in soil do not build up. In addition, GRP contains about 35% Ca and has a small liming effect on soils. This is in contrast with superphosphates, which have an acidifying effect that has to be counteracted by liming.

Straw brought onto the farm for bedding contains small but useful amounts of P, e.g., wheat straw 0.15%, barley 0.25% and oat 0.22% and their grains contain about 0.4% P. These should be included in nutrient budgets.

Potassium

The nutrient Indexes where K is limiting are the same as for P (described above); below two for extensive production and below three for intensive systems (both cropping and livestock). As for non-organic production, root crops have a higher K requirement, so it is better to apply K prior to such crops than other parts of the rotation. Where soil tests show K levels are low a small number of unprocessed or minimally processed potassium sources are permitted after approval has been given by the certifier. These are: *(N.B. this figures are for element percentages not oxides)*

A. Potassium sulphate (also known as SOP or sulphate of potash)
    i. 41% K
    ii. 18% S
B. Potassium sulphate with magnesium and sulphur: (e.g., Patentkali®)
    i. 25% K
    ii. 6% Mg
    iii. 17% S
C. Potassium sulphate with sodium and sulphur (e.g., Magnesia-Kainit®)
    i. 9% K
    ii. 3% Mg
    iii. 20% Na

iv. 4% S

Magnesia-Kainit® and Patentkali® have EU level organic approval while SOP may require case-by-case certification agent approval, depending on the source. All three forms are also highly water-soluble so they will be rapidly taken up by any plants present before the K is absorbed into the soil matrix. The risk of K leaching is low unless it is applied under very unsuitable conditions, e.g., where there is active surface run off. For more detailed advice on the K, Mg and S requirements of grassland and crops; refer to sections 8.1 (micronutrients), 11 (grassland), 12 (cereals), 13 (roots) and 14 (other arable crops).

Imported feed and particularly bedding straw can provide a significant proportion of the K requirements of organic farms. The K content of grain is similar to P at around 0.4 to 0.6%, however, the straw contains much higher amounts of between 0.8 to 1.5% K depending on species. It is essential that this is accounted for in nutrient budgets.

15.6 Lime and Soil pH

The maintenance of optimum soil 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.

Most sources of lime are permitted in organic systems, but it is important that the particular product to be used is either certified or the 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 liberated slowly, often over five years or more.

Determining when to apply lime to maintain an optimal pH is achieved by the use of regular soil testing and nutrient budgets. With lime taking several years to have an effect, it needs to be used 'pre-emptively' before pH rises too high. See section 7 for detailed lime advice.

15.7 Micronutrients, Cation Exchange Capacity and Nutrient Ratios

Internationally, particularly in the United States and Australasia, considerable emphasis is given by some organic farmers and scientists to micronutrients, cation exchange capacity and the ratios between specific nutrients. While there is scientific consensus that exchange capacity and the ratios of various nutrients (and pH) are real and important aspects of soil quality and performance, their importance compared with NPK levels and pH is contentious. Furthermore, many of the soils and climates where the research was undertaken are quite different to Irish conditions and are not directly transferable. Until such ideas are authenticated under Irish conditions, recommendations for micronutrients given in Section 8 should be followed.

15.8 Managing Nutrient Supply – the Role of Rotations

Rotations are the key technique for managing nutrient supply on organic farms, particularly for mixed systems with cropping. 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 possible risk of lime damage. Putting lime on at pasture termination risks increasing mineralisation of organic matter caused by tillage which could result in loss of nitrogen.

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 (see section 11). 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, following the advice given in sections 12, 13 and 14.

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 manure (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 very 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 section 15.5

Unless a very simple rotation is being followed, then 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 occurred, and Soil Indices for any of the nutrients or pH are outside optimum levels, rapid action to replace nutrients must be taken. The best option is almost always 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 it will be much harder to rectify nutrient deficiencies under crops that are removing nutrients compared to pasture where off-take is much lower and cycling of nutrients through livestock is much higher which aids the building of soil biology.

15.9 Conclusion

In keeping with the key aim of organic agriculture of maintaining a productive and biologically-active healthy soil, nutrient levels are maintained at optimum levels across the whole rotation. These levels are determined by regular soil tests and field-by-field nutrient budgets. The optimum levels are similar to, and based on the guidelines in the rest of this book. Soil tests and budgets provide the information to establish the best fields on which to use farm produced manures and, where 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