Future Growers 2013

Module 6: Composts and manure

Briefing paper
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1. Crop nutrition

The needs of plants and the supply of nutrients from the soil to the plant.

1.1 Principles of organic production

The soil is a complex ecosystem, home to a vast array of life from earthworms to bacteria. When soil is in good heart it will supply the needs of plants, keep plants healthy and maintain good soil structure. The principle of organic production is to work with the natural cycles in the soil ie to feed the soil. In practice this means maintaining fertility largely by the use of materials of organic origin, i.e. manures and composts, which require the action of soil organisms to release nutrients. The aim of organic management is to conserve and recycle plant nutrients as much as possible.

1.2. Essential elements for plant growth

Plant growth is governed by photosynthesis- the process by which sugar is synthesized in plant leaves from carbon dioxide (obtained from the atmosphere), and water (obtained through plant roots). Carbon from carbon dioxide, and hydrogen and oxygen, from water, are therefore the elements required in greatest quantity by plants. Plants also require other essential elements which they obtain through plant roots from the soil. Some are needed in relatively large amounts- the macronutrients, others in small amounts- the micronutrients (or trace elements).

<table>
<thead>
<tr>
<th>Macronutrients in relatively large amounts</th>
<th>Micronutrients in relatively small amounts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>Iron</td>
</tr>
<tr>
<td>Phosphorous</td>
<td>Manganese</td>
</tr>
<tr>
<td>Potassium</td>
<td>Boron</td>
</tr>
<tr>
<td>Calcium</td>
<td>Molybdenum</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Copper</td>
</tr>
<tr>
<td>Sulphur</td>
<td>Zinc</td>
</tr>
<tr>
<td></td>
<td>Chlorine</td>
</tr>
<tr>
<td></td>
<td>Cobalt</td>
</tr>
</tbody>
</table>

It is important to realise that however much of an essential element there may be in the soil, plants can only take up nutrients from the soil solution (i.e. dissolved in soil water), as simple ions (groups of atoms with a positive (cation) or negative (anion) charge). Some nutrients are taken up directly with the water taken up by the plant roots; some are actively transported into the root cell from the root surface (i.e. requiring energy). As nutrients are taken up by the root, concentration gradients are set up which causes diffusion of ions to the root surface.

The area round plant roots - the rhizosphere - is a complex environment. Roots exude sugars and carbohydrates which stimulate microbial activity and which solubilise nutrients so that the rhizosphere is more biologically active than the rest of the soil. Roots have associations with mycorrhiza - fungi which live symbiotically with plants- and the hyphae of the fungi become effectively an extensive root system accessing nutrients for the plant.

The three main macronutrients needed by plants are Nitrogen (N), Phosphorus (P), and
Potassium (K). To make good use of manures composts and fertilisers in the soil it is important to understand the sources and behaviour of these elements in the soil.

1.3 Phosphorus in the soil

Phosphorus (P) is the third most important nutrient supplied by soil to plants. It is needed by plants for phosphorylation - the process in which carbohydrates are broken down in the plant to produce energy. Phosphorus is especially concentrated in seeds and an adequate supply of phosphorus is necessary to good root development. A deficiency of phosphorus often causes stunted growth, delayed maturity or purple and yellow discolouration. Plants take up phosphorus mainly as the phosphate ion, mostly as $\text{H}_2\text{PO}_4^-$. Soils often contain large amounts of phosphorus in the mineral fraction but this phosphorus is not available to plants. Phosphorus is present in humus which has a carbon to phosphorus ratio of 100-200 (C:P = 100 - 200) and this can account for up to half of total phosphorus in soils. Phosphorus also exists in compounds held on clay and humus surfaces in the soil. Since this phosphorus is only released very slowly to the soil solution it is known as “fixed” P. The problem with phosphorus availability is that almost all phosphate compounds have very low solubility. In acid soils iron and manganese come into soil solution and they form iron and manganese phosphates which are insoluble and precipitate out (form solids). In alkaline soils the high concentration of calcium ($\text{Ca}^{++}$) in soil solution precipitates out as insoluble calcium phosphate. The optimum pH for the availability of phosphorus is 6-7. When phosphorus compounds are added to the soil they usually quickly form insoluble compounds or become fixed by the soil, and are released only very slowly.

Since the amount of phosphorus in the soil solution is very low plants have to work hard to obtain enough. The area around a root hair rapidly becomes depleted in phosphates so plants need to continually grow new roots and root hairs to reach new areas of soil. The activity of micro-organisms in the rhizosphere, the release of enzymes, and weak acids formed from carbon dioxide in the solution, help to dissolve phosphates and increase availability.

Where mycorrhiza are in symbiosis with a plant, since the hyphae of the mycorrhiza are smaller and more extensive than the plant roots, the plant can exploit much more of the soil. The major advantage to the plant of mycorrhiza is to supply the plant with phosphorous. Most plants except brassica have associations with mycorrhiza.

Being largely insoluble, very little phosphorus is lost to the soil through leaching (the movement of nutrients through the soil profile out of the reach of roots). This also means that phosphorus is immobile i.e. it cannot move in the soil. For example if compost or manure is used as a surface mulch, the phosphorus will not move into the soil.

The phosphorus in organic materials in the soil, whether as a component of humus, as fresh residues incorporated in the soil, or as manures or compost, is more readily available than the phosphorus in the mineral fraction. So the major source of phosphorus for plants is in the organic form. Phosphorus released from the organic form can be taken up by plants before it is fixed by the soil.
1.4 Potassium (K) in soil

Potassium is the second most important nutrient plants obtain from the soil, and in some crops uptake is greater than nitrogen. Potassium is important in many processes in plants: it is essential for photosynthesis and the translocation of sugars, increases resistance to diseases, encourages strong roots, and is necessary for fruiting and flowering. Plants deficient in potassium have leaves which appear dry and scorched at the edges and leaf surfaces show chlorosis (mottled discoloration).

As with phosphorus, most soil potassium is in mineral form and not available to plants. In other ways however potassium behaves very differently from phosphate. Compounds of potassium are very soluble, potassium in the soil solution being in the form of the cation K⁺. Cations are held in the soil on the surfaces of humus and clay particles which have a slight negative charge. (The extent of the soil’s ability to hold cations is known as the cation exchange capacity). This potassium acts like a reservoir of potassium, releasing potassium ions as the concentration in the soil solution decreases. Sandy soils, which have very little clay and often less organic matter, have a low cation exchange capacity and therefore little reserves of potassium. Special care needs to be taken with such soils to maintain adequate levels of potassium. Potassium can also be fixed by certain clays but in a form where the potassium can be released, but only slowly.

Because of its solubility, the uptake of potassium is easy for plants - in normal conditions there is sufficient potassium in the water plants take up, and in many conditions plants will take more than they need (luxury consumption). Potassium is released as organic matter decays but unlike with phosphate it remains available.

The solubility of potassium and its ready availability give rise to problems the opposite of those of phosphate ie it is highly mobile. This means that potassium will move with water through the soil profile i.e. becomes available through the profile. The disadvantage of this mobility is that any excess of potassium beyond the needs of the plant is susceptible to leaching. Losses of nutrients through leaching must of course be avoided in an organic system - an organic system relies on having a closed cycle for nutrients as far as possible.

1.5 Nitrogen (N) in soil

1.5.1. Plant requirement for nitrogen

Nitrogen is the nutrient required in the largest amounts. Nitrogen is a component of amino acids, which are present in all proteins, and therefore it is often the level of nitrogen availability that governs growth and therefore the requirement for other nutrients. Adequate nitrogen gives plants a deep green colour. A lack of nitrogen will stunt growth, restrict roots and lead to pale leaves, especially older leaves and will reduce protein content of grain. An excess of nitrogen encourages soft sappy growth which makes a crop more susceptible to attack by disease and pests. Too much nitrogen in cereals causes “lodging” (the crop is not strong enough to stand up in strong winds and lies flat). However in some crops sappy soft growth can be desirable e.g. lettuce, leafy salad crops, radishes.

There is no nitrogen in soil minerals- this is why newly formed soils (volcanic ash) or sub-soil brought to the surface will not support growth. Nitrogen in soils is almost entirely in organic form, the humus fraction of soil is therefore the reservoir of nitrogen. The ratio of carbon to nitrogen in the humus of any soil remains fairly constant at around 10:1, lower in dry hot
soils, higher in wet cold soils. All soil nitrogen originated in the atmosphere (79% N2), but plants cannot use this nitrogen: they take up nitrogen in the form of the ammonium ion (NH₄⁺) or nitrate ion (NO₃⁻). Both these forms of nitrogen are very soluble and plants are easily able to take up enough nitrogen if concentrations in the soil solution are adequate.

Nitrogen is a highly mobile nutrient and moves easily through the soil profile. As NH₄⁺ it can be held by the soil (cation exchange capacity) but as NO₃⁻ there is no such mechanism and an excess of nitrate is easily lost by leaching. As well as being a loss of fertility in what should be largely a closed system nitrates in groundwater are a pollutant to waterways and drinking water, causing eutrophication (a bloom of growth which depletes water of oxygen and destroys aquatic life). Management of manures and composts should aim to reduce leaching losses to a minimum.

1.5.2. The Nitrogen cycle

In a natural system nitrogen moves from plant to soil to mineral form and back again to plants. This cycle is known as the nitrogen cycle. See Fig 1. The forms of nitrogen and processes involved in the nitrogen cycle are described below.

a) Organic material
Crop production produces wastes from animal and plants - as manure, dead plant material and roots, etc. All these wastes contain nitrogen. This material is decomposed by micro-organisms in the soil (the process will be examined in more detail later). Usually some of the nitrogen in the material will be released as the ammonium ion - a process is known as mineralisation. However if the material has a low amount of nitrogen the microorganisms need for nitrogen may not be met by the material being broken down and they will take nitrogen from the soil solution as ammonium - a process known as immobilisation. The end product of decomposition is humus-soil organic matter. Humus is a relatively stable material but it does decompose slowly, about 1-2% a year, so that the nitrogen contained in the humus is eventually released and made available to plants.

b) Ammonium (NH₄⁺)
Ammonium in soil can be taken up directly by plants, mycorrhiza, and microorganisms and is also subject to leaching. Since ammonium ions have a positive charge they can be held in soil on the surfaces of clay and humus and, like potassium, can become fixed by some forms of clay in a form which becomes available only slowly. Most excess ammonium is taken up by a special group of bacteria known as nitrifying bacteria, which transform ammonium to nitrates. They use ammonium as a source of energy - the process of oxidation releases energy.

There are two stages:

\[
\begin{align*}
\text{NH}_4^+ & \rightarrow \text{NO}_2^- \\
\text{Ammonium} & \rightarrow \text{Nitrite} \\
\rightarrow & \rightarrow \\
\text{NO}_3^- & \rightarrow \text{Nitrate}
\end{align*}
\]

This process is known as nitrification. Nitrifying bacteria are only effective if the conditions are right. Aeration must be ideal with temperatures neither too hot or cold. Below 5 °C very little nitrification takes place and the rate increases up to the optimum of about 25°C. Therefore in spring, until soil temperatures increase, ammonium can build up. If the pH is high and the concentration of ammonium ions is high ammonium gas can be formed. As
well as being a loss of nitrogen, free ammonia is very toxic to plants.

Figure 1 The nitrogen cycle

c) Nitrate (NO₃⁻)
Nitrate from nitrification is the preferred form of nitrogen uptake by most plants, and by micro-organisms. If Nitrogen is in short supply micro-organisms are more effective than plants at utilising nitrate. In excess nitrate is easily leached from the soil. In anaerobic conditions (i.e. the absence of oxygen) nitrates are used as a source of oxygen by denitrifying bacteria (*denitrification*) producing nitrous oxide (N₂O) and nitrogen (N₂). Nitrous oxide is a powerful greenhouse gas (about 100 times worse than CO₂) and denitrification is a loss of nitrogen from the cycle. Anaerobic conditions can occur in wet soils even if they are not completely waterlogged, if the oxygen supply to an area of soil cannot match demand.

d) Plant nitrogen.
Mineralisation and nitrification release ammonium and nitrate to the soil solution which growing plants can take up. The residues from the plants, or manure from animals which
consume the plants, are eventually returned to the soil and this completes the cycle.

The aim of the management of crop residues, compost and manure is to minimise losses through leaching etc. i.e. to maintain a closed system as far as possible.

1.5.3. Nitrogen Fixation

Nitrogen is required in large quantities by plants and within a farm system nitrogen is lost to the farm when crops and animals are sold, i.e. a completely closed system is not possible. The shortfall can be supplied by a process called nitrogen fixation which puts nitrogen into the system. Nitrogen fixation is brought about by specialist bacteria called rhizobium bacteria.

Rhizobium bacteria can form a symbiotic relationship with legumes (the pea and bean family- leguminosae). The bacteria form nodules within the plant. They take sugars from the plant for their energy and they take nitrogen gas from the atmosphere and convert it to the ammonium ion (NH$_4^+$) both for their own needs and also for the host plant. Nitrogen fixing plants are the pioneer plants, the first plants able to survive new soils, and the nitrogen fixers are the original source of almost all nitrogen now in soils. The ability of legumes to build fertility has been known since at least Roman times; in traditional agriculture nitrogen fixation is the mechanism by which clover leys build up fertility prior to a grain crop.

Nitrogen fixation provides nitrogen to the host plant and not directly to the soil, though when the legumes die and the roots decompose, a small amount of nitrogen will be released in the soil. The benefits of nitrogen fixation are to the system as a whole. For example clover is a legume and a grass clover sward provides nitrogen to grazing animals, and their manure is returned to the soil. When legumes are grown as a green manure (a plant grown not as a crop but to build fertility) the nitrogen fixed by the legume is released to the soil when the plants are incorporated into the soil or composted. However when legumes are grown as a crop, most of the nitrogen fixed will be in the crop and therefore lost to the system, only a small amount remaining in the crop residues.

Nitrogen fixation is reduced in acid soils and in the presence of high concentrations of nitrates and ammonia in the soil solution. This is why when chemical fertilisers are used to supply nitrogen, nitrogen fixation will not take place.

Rhizobia are specific to closely related species of legumes and are classified in the following groups:

1. Alfalfa group - includes Fenugreek, trefoil and some clovers
2. Clover
3. Cowpeas
4. Peas and vetches - including sweet peas, lentils, horse beans
5. Soya beans
6. Beans
7. Lupins

The correct species of rhizobium may not be present in the soils and it may be necessary to use an inoculum to provide the bacteria, usually mixed with the seed before planting.
Amounts of nitrogen fixed can be large especially clovers and lucernes.

**Nitrogen Fixation in ideal conditions**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Fixation kgN / ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lucerne</td>
<td>300-550</td>
</tr>
<tr>
<td>Red clover/grass</td>
<td>230-460</td>
</tr>
<tr>
<td>Field Beans</td>
<td>155-285</td>
</tr>
<tr>
<td>White clover/grass</td>
<td>150-200</td>
</tr>
<tr>
<td>Field beans</td>
<td>150-390</td>
</tr>
<tr>
<td>Peas</td>
<td>105-245</td>
</tr>
<tr>
<td>Lupins</td>
<td>100-150</td>
</tr>
<tr>
<td>Vetches</td>
<td>60-90</td>
</tr>
</tbody>
</table>

Source: Growing Green, Jenny Hall and Ian Tolhurst

1.6. Summary of N P K supply

The aim of the management of nutrient supply in an organic system is to ensure adequate levels of nutrients, to recycle nutrients wherever possible by the good management of manures and composts, to minimise losses by leaching or as gases and to maximise inputs of nitrogen through nitrogen fixation.

**Summary of the major nutrients in soil**

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>P</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Form taken up</strong></td>
<td>NH₄⁺ (ammonium)</td>
<td>NO₃⁻ (nitrate)</td>
<td></td>
</tr>
<tr>
<td><strong>Form in soil; organic matter</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>In soil minerals</strong></td>
<td>Very little</td>
<td>Large reserves but unavailable</td>
<td>Large reserves Mostly unavailable</td>
</tr>
<tr>
<td><strong>In soil solution</strong></td>
<td>High solubility</td>
<td>Low solubility</td>
<td>High solubility</td>
</tr>
<tr>
<td><strong>Leaching losses</strong></td>
<td>NO₃⁻ very easily lost</td>
<td>Losses small</td>
<td>K⁺ Easily lost</td>
</tr>
<tr>
<td><strong>Gaseous losses</strong></td>
<td>N₂O N₂ (Denitrification) NH₃</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td><strong>Mobility</strong></td>
<td>High</td>
<td>Low</td>
<td>High</td>
</tr>
</tbody>
</table>
Crops vary widely in their needs for nutrients. The following table shows something of the range of amounts taken up in various crops.

<table>
<thead>
<tr>
<th>CROP</th>
<th>YIELD</th>
<th>N</th>
<th>P</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>t/ha</td>
<td>Kg/ha</td>
<td>Kg/ha</td>
<td>Kg/ha</td>
</tr>
<tr>
<td>Potatoes</td>
<td>30</td>
<td>96</td>
<td>18</td>
<td>120</td>
</tr>
<tr>
<td>Onions</td>
<td>30</td>
<td>72</td>
<td>11</td>
<td>47</td>
</tr>
<tr>
<td>Carrots</td>
<td>30</td>
<td>54</td>
<td>11</td>
<td>102</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>30</td>
<td>129</td>
<td>16.9</td>
<td>78</td>
</tr>
<tr>
<td>Courgette</td>
<td>33</td>
<td>58</td>
<td>10</td>
<td>67</td>
</tr>
<tr>
<td>Lettuce</td>
<td>10</td>
<td>19</td>
<td>2.6</td>
<td>26.5</td>
</tr>
<tr>
<td>Cabbage</td>
<td>40</td>
<td>100</td>
<td>12</td>
<td>200</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>250</td>
<td>438</td>
<td>67.5</td>
<td>610</td>
</tr>
<tr>
<td>(greenhouse production)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peas</td>
<td>6</td>
<td>60</td>
<td>1.2</td>
<td>19</td>
</tr>
<tr>
<td>Grass/Clover</td>
<td>45</td>
<td>216</td>
<td>29.3</td>
<td>202</td>
</tr>
</tbody>
</table>

Source: Growing Green, Jenny Hall and Ian Tolhurst

**N.B.**
For historical reasons NPK analysis is often given as N, P$_2$O$_5$, and K$_2$O - always check when using information.
To convert:
1kg P is equivalent to 2.27 kg P$_2$O$_5$
1kg K is equivalent to 1.20 kg K$_2$O

2. Composting

2.1 Recycling farm by-products

Farm operations produce materials other than the crop or animal grown for sale or on farm use. These materials could include manures and slurry, vegetable waste, paper and cardboard, weeds, leaves, hedge trimming, grass mowings. Since the aim of an organic system is to operate, as far as possible, a closed cycle, this means recycling such materials in the most beneficial ways, not seeing such materials as waste to be disposed of. Methods of recycling should be chosen in order to:
• minimise the loss of nutrients
• maintain or improve organic matter in soil.
• ensure that pathogens, diseases and weed seeds are not returned to the soil

Usually this means some form of composting or decomposition in the soil. Burning as an option should be considered very carefully. All nitrogen and at least half of the phosphorus is lost on burning materials only the potassium remaining in the ash. The ash of course has no organic material and adds no humus to the soil. Burning may be appropriate for wood waste which contains almost no nitrogen and phosphorus, and possibly for diseased material but otherwise is not usually appropriate.

2.2 Composting

Crop and green waste is recycled by decomposition either in the soil or by composting separately. The process of decomposition always involves microorganisms.

2.2.1. The Composting Process

During composting micro-organisms use the organic material as an energy source, i.e. carbon compounds are oxidised, producing carbon dioxide energy and water. The micro-organisms exude enzymes which break down more complex molecules into simpler compounds they can ingest and these compounds are used for respiration and the needs of the microorganism. If sufficient material is present microorganisms increase rapidly (in ideal conditions bacteria can reproduce every 15 minutes which give 96 generation per day!) but rapid decomposition and an increase in micro-organisms will only happen if the material is easy to decompose, fresh green material for example.

Resistance to Decomposition

<table>
<thead>
<tr>
<th>Rapid</th>
<th>Slow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple sugars carbohydrates</td>
<td>Cellulose</td>
</tr>
<tr>
<td>Fresh green material</td>
<td>Older tough material</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

During the breakdown of organic material the nutrients contained in the material are released, and used by bacteria for growth. If the material in the heap does not contain enough nutrients the growth of micro-organisms can be restricted.

In an ideal compost heap the process goes through various stages -

i. Mesophilic (approx. 2 days)

Decomposition of easily decomposed material begins, and there is a rapid increase in microbial numbers. The activity is so intense that heat is generated and the temperature of the heap begins to rise. (Just as photosynthesis requires energy the reverse process releases energy).

ii. Thermophilic (approx 2 weeks)

Once the temperature reaches 40°C only certain actinomycetes and bacteria can
operate - they are known as the thermophilic organisms. Above 60°c fungi are killed. The thermophilic bacteria continue to increase in number, using the easily decomposable material. Once this begins to run out activity declines and therefore the temperature begins to fall. Fungi reinvade below 60°c and at this stage more resistant compounds like cellulose are broken down.

iii. Maturing
This stage takes several months to complete. During this phase the more resistant materials are slowly broken down, many micro-organisms die because the easily decomposed material has gone, there is intense competition, microbes consuming others, antibiotic formation. Macrofauna reinvade the heap - mites, ants, worms etc. During composting much of the mass of the compost is lost as CO₂. The end product of composting is humus and some undecomposed material. Humus is formed from residual resistant molecules in the original material and compounds of microbial origin. Humus is a colloidal material (of similar particle size as clay) with a very large and active surface area. The nutrients from the original material will have been recycled many times through various organisms, but (assuming no losses) are present either as part of the humus or held by the humus. Heaps must always be covered to avoid the leaching out of nitrates and potassium.

During the composting process the intense heat will have killed most weed seeds and plant pathogens and diseases.
Compost is a stable product i.e. the nutrients are held in the compost and will not easily leach out. A typical garden compost will have 1.5%N, 1.2%P and 2.1%K.

The description above is the ideal- it is not always easy to achieve the ideal! Some of the factors to consider to achieve the ideal are described in the sections below.

2.2.2 Carbon to Nitrogen ratios
One factor which is very important is the amount of nitrogen present in the material, in particular the amount of nitrogen relative to carbon or the C:N ratio. Bacteria contain a high proportion of nitrogen so that if the heap contains too little nitrogen, the growth of more bacteria is restricted and the population explosion of bacteria cannot occur so the heap will not heat up. With too much nitrogen in the heap during decomposition more nitrogen is released than the bacteria need, and the excess nitrogen will be in the form of nitrate or ammonium ions in the water of the compost. In this form the nitrogen can be lost by leaching if there is an excess of moisture, or as ammonia. It is important therefore to find
the right balance in the materials being composted. The following table gives the ratio of carbon to nitrogen in various materials:

**C:N ratios of materials**

<table>
<thead>
<tr>
<th>Material</th>
<th>C:N</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Humus</td>
<td>8:1 - 15:1</td>
<td>Low in hot dry soils, Higher in cold wet soils, 10:1 Average</td>
</tr>
<tr>
<td>Plants</td>
<td>20-30:1</td>
<td>Higher in mature plants, Low in green leafy materials, especially legumes</td>
</tr>
<tr>
<td>Bacteria</td>
<td>4:1</td>
<td></td>
</tr>
<tr>
<td>Fungi</td>
<td>9:1</td>
<td></td>
</tr>
<tr>
<td>Urine</td>
<td>2:1</td>
<td></td>
</tr>
<tr>
<td>Pig manure</td>
<td>5:1</td>
<td></td>
</tr>
<tr>
<td>Poultry manure</td>
<td>10:1</td>
<td></td>
</tr>
<tr>
<td>Comfrey</td>
<td>10:1</td>
<td></td>
</tr>
<tr>
<td>Grass mowings</td>
<td>12:1</td>
<td></td>
</tr>
<tr>
<td>Kitchen waste</td>
<td>12:1</td>
<td></td>
</tr>
<tr>
<td>Farmyard manure</td>
<td>14:1</td>
<td></td>
</tr>
<tr>
<td>Seaweed</td>
<td>19:1</td>
<td></td>
</tr>
<tr>
<td>Green arden waste</td>
<td>20:1</td>
<td></td>
</tr>
<tr>
<td>Horse manure</td>
<td>25:1</td>
<td></td>
</tr>
<tr>
<td>Weeds</td>
<td>30:1</td>
<td></td>
</tr>
<tr>
<td>Straw</td>
<td>80:1</td>
<td></td>
</tr>
<tr>
<td>Woody pruning, bark</td>
<td>100:1</td>
<td></td>
</tr>
<tr>
<td>Newspaper, cardboard</td>
<td>&gt;200</td>
<td></td>
</tr>
<tr>
<td>Sawdust</td>
<td>500:1</td>
<td></td>
</tr>
</tbody>
</table>

The heap overall should have a C:N ratio around 30. If older tougher parts of plants dominate the heap it should be mixed with richer materials - “activators”. As you can see from the table fresh manure, comfrey, grass mowings make good activators.

During decomposition the C:N ratio within the heap reduces as the carbon is lost and the N is retained; at the end of the process the C:N ratio will be around 10.

**2.2.3 Moisture content**

A dry heap will not work. Bacteria can only live in water and it is important to try to avoid dry pockets in heap. On the other hand a heap can often be too wet and this is the most common cause of bad compost. Bear in mind that during decomposition carbon dioxide and water are formed and this increases the moisture content. Also, during decomposition, around 50% of the mass of the material will be lost as carbon dioxide. This means that a heap which is initially seems only damp can easily become too wet. Decomposition should be aerobic, ie the process needs oxygen, and a wet heap restricts oxygen supply since the movement of oxygen in water is 20,000 times slower than in air! Without oxygen decomposition becomes anaerobic; this is a slow process, the heap won’t heat, and the end product is not crumbly humus, but a rather smelly slurry of organic acids - not good for the soil.
During anaerobic decomposition the nitrogen can be lost by denitrification forming nitrogen and nitrous oxide, or can be leached out of the heap if leakage occurs. Compost heaps must be covered. If the heap has approximately the right moisture content initially, covering will prevent rain from making the heap too wet, and evaporation making it too dry.

2.2.4 Type and size of heap
A small heap will not generate heat - around 1 m$^3$ is the minimum to be effective. The process works best if the heap is enclosed and covered - unenclosed heaps have large volumes at the outside which do not heat up. The larger the heap the less this is a problem. A heap which is too large will have a problem with oxygen supply - large heaps are often made as windrows for this reason.

2.2.5 Turning the heap
It is good practice to turn the heap after the initial heating up. This gives a second heating and makes sure all material is decomposed.

2.2.6 Building the heap
The heating up can only happen if the heap is built in one go. Adding material day by day to a compost heap does not allow the rapid population explosion to take place which is necessary for the creation of heat.

2.3. Other types of compost

2.3.1 Woody material
The process described above is suitable for most green waste on a farm. For more resistant materials, especially those containing lignin, a cold composting process can be used. Lignin (in woody and woody material, cardboard etc.) can only be broken down by specialist organisms, mostly fungi, and the process is slow. If woody material is put in a hot heap, even though the overall C:N ratio is adequate and the heap heats, the woody material is not broken down. Woody material can be shredded and left to decompose for at least a year. Shredding increases the surface area, which gives the micro-organisms access to the material. The finer the material is shredded the faster the decomposition will be.

Leaves are also best composted separately to make leaf mould. Both these materials are very low in nitrogen and nutrients, and the resulting compost is best used as a mulch, for paths, or as a basis for potting compost. If it is dug into the soil, as it decomposes further, it will rob the soil of the nitrogen the decomposing microorganisms need to the detriment of any crop. However it contains humus - it should be seen as a soil conditioner rather than a fertiliser.

2.3.2 Worm compost
Using worms to compost organic waste does not generate heat and is a slow process. The worms used are not the common earthworm but brandling worms (Eisenia foetida). They need a temperature of 5-40$^\circ$C, cannot stand acid conditions, drought or too much water. Worm bins should allow for drainage for this reason. Worms ingest the material, and the microflora in their gut and their enzymes digest the material, producing worm-casts. The worm-casts being the end product of the digestion and still include many micro-organisms. Worm compost is rich in nutrients and the worm liquid draining from the compost is a good liquid feed.
This method of composting is not a hot process and it therefore allows for adding material day by day. A worm compost bin must be enclosed to prevent the worms escaping, so they will also be vermin proof. This makes worm composting a good option for kitchen waste which tends to attract rats and mice in a normal heap. Of course this should never include any meat waste. Household waste in a worm bin produces a lot of water as it is processed by the worms- adding newspaper will help to absorb the water.

2.3.3 Incorporating plant residues
Sometimes organic residues are allowed to decompose directly in soil e.g. when straw stubble is ploughed in, weeds are hoed off and left to decompose, grass mowings or organic waste is used as a mulch. This form of decomposing is much less controlled than composting. There will be no heating so weed seeds, crop diseases are not killed.

If the material is rich in nitrogen (C:N of less than 30:1), nitrogen will be released during decomposition and could be leached out if water moves through the soil profile. To avoid loss of nitrogen and potash ensure that plants are growing and able to take up the nutrients. Incorporating a grass clover ley, a crop of mustard, or pea and bean residues when the soil is bare for some time after incorporation would be bad practice.

On the other hand if the material is poor in nitrogen (C:N more than 30:1), straw for example, when the soil organisms try to decompose the material they will have insufficient nitrogen and will take any nitrogen available in the soil even in preference to plants. This is known as immobilization or nitrogen robbery and will disadvantage any crop growing. However if organic residues are used as a mulch (e.g. straw, hay, shredded wood, cardboard) nitrogen robbery will not occur, since contact with soil is limited to the soil surface. Mulching is a good way of recycling high C:N materials, especially paper, cardboard, straw. The mulch covers the soil which is good for the soil structure and soil organisms, it helps to prevent weeds, conserves moisture, and eventually contributes to the levels of humus on the soil.

2.4 Using compost
Compost contains some nutrients (typically 1.5% N, 1.2% P, 2.1% K) but it also adds to and maintains soil humus. Humus decomposes only slowly - about 1-2% of humus decomposes per year - i.e. compost contributes to long term and short term fertility.

If compost has been made with care the nutrients in the composted material will have been conserved. Equal care must be taken when using the compost to make sure the nutrients are not lost. Compost is a relatively stable product i.e. the nutrients are held by the compost and are less liable to leaching. However when it is incorporated into soil nutrients will be released and can be lost. It is best practice (recommended in S.A. Standards) to apply compost in spring and summer i.e. when crops are growing and can absorb the nutrients. However it can be applied in autumn to a crop which will stand through the winter, or on ground which is covered for the winter or in protected cropping.

Compost can be incorporated into the soil (e.g. rotavated in) for general soil improvement. It may be placed in bands e.g. in trenches. This will provide nutrients and a moisture holding layer at depth for deep rooting crops, eg brassicas, and potatoes. Compost used in this way can be more coarse or even partially decomposed. Compost can be used as a mulch e.g. in a no-dig bed or around fruit bushes. This is easiest, provides a layer which helps retain water
and allows soil life to come to the surface. The compost will gradually become incorporated. This method will mean that phosphorus, being an immobile element, will not move from the surface and this may restrict availability, especially in a no-dig system where all organic materials are added as a mulch.

3. Animal manure and slurry

3.1 Composting manure

In an organic system animals will be kept on bedding, usually straw, and the resulting farmyard manure is a mixture of straw, faeces and urine. Since faeces and urine are very rich in nutrients (see earlier table for C:N ratios) manure represents a very valuable resource in an organic system. However the high nutrient levels means that losses from manures are likely to be greater than from plant wastes, so even more care must be taken when composting or storing manure.

The principles of composting described above apply to manures as well as plant wastes. If there is too much nitrogen in the heap nitrogen can be lost as ammonia to the atmosphere or as nitrate by leaching. Ammonia is a very pungent gas so it is easy to know if ammonia is being lost. If there is too little nitrogen the heap will not heat up. With manure the problem is likely to be too much nitrogen. The amount of straw in relation to the dung and urine is important so that the straw “balances” the nitrogen.

With animal manures there is the risk of pathogens being redistributed on the land with implications to farm animals and humans. In particular e-coli may be present. Proper composting should eliminate this risk.

The standards recommend that manure should be stacked for 6 months or composted for 3, but this is not obligatory. With justification manure can be used from non-organic sources but there are strict rules about which livestock systems are acceptable. None organic manure MUST be stored or composted. Composting manure is best practice because the composting process is controlled and the nutrients in the end product are held in the composted manure and less susceptible to losses by leaching etc. Uncomposted manure will continue decomposing in the soil and the nutrients released may be lost.

The most important measure to reduce losses is to keep outdoor heaps covered at all times. It is best practice to compost and store manure on hard standing so that run-off can be collected- liquids coming out of a manure heap will be very rich in nutrients, and should never be allowed to enter water courses. Manure which is stored or composted outdoors must be 50m from any waterway or 100m from any borehole.

Since manure is high in nitrogen and the material is very rich for the microorganisms, composting manure becomes very hot, and the activity is so intense that the requirement of the microbes for oxygen can be a limiting factor. If the heap is too big in any dimension aeration could be restricted because the oxygen cannot reach the middle.

The restrictions on the use of manure (see below) means that manure must often be stored for some time before there is an opportunity to use it. It is not always predictable when manure can be spread because it depends on weather. It is very important that a farm must ensure that there are adequate facilities for storing manure.
3.2 Using manure

Losses of nutrients can also arise when manure is applied to the field and the standards are designed to minimise these losses.

- Manure should not be spread within 10m of a watercourse or 50m of a well to minimise the risk of nitrate polluting the water from leaching.
- Manure spread on ground which is very wet is at risk of losses by leaching or run off. In wet ground there is a risk of anaerobic conditions and nitrogen can be lost by denitrification.
- Manure should be spread on ground where plants will be actively growing so that nutrients released are taken up by plants. In practice this means spring and summer. Increased rainfall in winter and less evaporation and crop uptake means that leaching occurs mostly in winter, at a time when nutrient uptake is minimal. Anaerobic conditions are also more likely in winter. This means that high nitrogen losses are likely from manure applied in winter. This does not apply to protected cropping.
- Manure applied directly to horticultural crops MUST be composted prior to use.
- If too much manure is used an excess of nitrogen beyond what a crop can use will result in losses. The standards therefore restrict the amount of manure that can be applied. Over the whole area of a holding the limit is 170 kg N/ha/yr and no more than 250kg N/ha/yr to any area. The standards give information you can use to calculate this.

Typical analysis of farmyard manure

<table>
<thead>
<tr>
<th>Type of Stock</th>
<th>N (kg/tonne)</th>
<th>P (kg/tonne)</th>
<th>K (kg/tonne)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cattle</td>
<td>1.5</td>
<td>2.0</td>
<td>4.00</td>
</tr>
<tr>
<td>Pigs</td>
<td>1.5</td>
<td>4.0</td>
<td>2.5</td>
</tr>
<tr>
<td>Poultry deep litter</td>
<td>10</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>Broilers</td>
<td>14.5</td>
<td>13.0</td>
<td>10.5</td>
</tr>
</tbody>
</table>

3.3 Slurry storage

Slurry is faeces and urine diluted with water and is usually stored in tanks or lagoons prior to being spread on to land.

Storing a high nitrogen material in water is highly likely to lead to anaerobic conditions. This can cause anaerobic decomposition and the build up of organic acids which can be toxic to plants and denitrification with the loss of nitrogen as N₂O and N₂. Ammonia can also be lost from slurry.

- Slurry should be stored to allow complex organic compounds to break down before it is applied to soil.
- Periodic aeration maintains aerobic conditions and should aim to keep the pH below 8 and the temperature below 40°C. Over aeration can increase the temperature as the decomposition becomes too rapid and leads to losses of ammonia. 6 hours aeration every 24 hours is considered adequate.
- A round tank is best to avoid anaerobic zones.
• Adding straw to balance the nitrogen reduces nitrogen loss.

3.4 Application of slurry

The same restrictions apply as for manure. The amount of liquid means that run-off, leaching, and the creation of anaerobic conditions in soil is more likely than with manure so extra care must be taken.

• Slurry is best spread in moderate quantities and in dry weather.
• There should be an interval of at least 14 days between application and grazing.
• Slurry should not be applied to ground grazed by the species of animal creating the slurry.
• The nitrogen in slurry can inhibit clover so use sparingly.
• Pig slurry is high in copper sulphate and copper can build up in soils.

4. Green manures

4.1 Lifters and fixers

Green manures are plants grown not to produce a crop but to build fertility in the soil. They are grown and incorporated into the soil or removed for composting and can be divided into two categories.

• Lifters are crops grown on ground that would otherwise be bare and are grown to mop up any available nutrients thereby preventing losses. By incorporating the crop into the soil the nutrients become available to the next crop.
• Fixers are crops grown because they fix nitrogen. They will also mop up other nutrients. Growing legumes in this way is a good way of adding nitrogen into the system. Following incorporation the nutrients become available to the following crop.

4.2 Ways of using green manures

4.2.1 Overwintering

Land is often unused over the winter. Bare ground in winter, when rainfall exceeds evaporation, means leaching of nutrients will occur. A green manure will mop up these nutrients. The green manure crop must of course be frost hardy. One of the difficulties of using green manure in this way is sowing early enough to establish the crop before the winter. In spring the green manure can be removed for composting, cut and left as a mulch, or incorporated in the ground before the following crop is sown. There can be some immobilization of nitrogen following incorporation (not usually if the green manure was a legume) and this can rob the following crop of nitrogen. It is best to wait 2-3 weeks between incorporation and planting the following crop.

4.2.2 Catch crops

If there is a gap between harvesting one crop and planting the next a green manure can be grown and incorporated before sowing the next crop. This is known as a catch crop. This is usually a quick growing crop eg mustard.
4.2.3 Undersowing
A green manure can be planted as a companion plant with a growing crop e.g. clover with tomatoes, courgettes, tares with sweet corn. The green manure can continue growing after the crop is harvested to maintain ground cover. The type of green manure must be chosen so that it does not compete with the crop. For example white clover does not grow tall and compete for light with the crop.

4.2.4 Leys
Some growers and farmers include leys or a fallow period and use this time as a fertility building phase in the rotation. For this purpose the green manure should be chosen appropriate to the period of the ley. For example red clover or alfalfa will last for some years and can be cut, whereas tares are an annual and will die down after flowering.

4.3 Advantages of green manure.

- Maintaining ground cover - A growing crop protects the soil surface and this helps to maintain soil structure. Most soil organisms dislike direct sunlight and a growing crop means that they will come closer to the soil surface - eg earthworms.
- Mopping up nutrients - The main way that nutrients are lost to the system is through leaching. Having a crop growing at all times helps to prevent this since the nitrogen or potassium will be taken up by the plant roots rather than carried through the soil profile.
- Adding nitrogen to the system - good management of manures and compost can conserve nutrients but there will always be losses from the system when crops or animals are sold off the holding. Green manures which are nitrogen fixers are a major way of replacing the nitrogen and should be used wherever possible.
- Increasing organic matter content in soils - since the entire crop is composted or incorporated, green manures will add to the humus levels in soils. This benefits the soil in many ways - humus improves water holding capacity, soil structure, long term fertility, and nutrient retention. Also increasing humus levels is sequestering carbon ie is locking up carbon, reducing carbon dioxide levels in the atmosphere.
- Phosphorus availability - as we have seen phosphorus in the mineral fraction of soil is available only very slowly to plants, whereas in organic form it is much more available. Thus the more phosphorus which is recycling through the organic material the better it will be for the crop. Since green manures are composted or incorporated and all the phosphorus returned to the soil in the organic fraction, they help to bring more phosphorus into the organic fraction of the soil.
4.4 Types of green manure

The following tables summarize the type and properties of common green manure.

<table>
<thead>
<tr>
<th>Nitrogen Fixers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Common Name</strong></td>
</tr>
<tr>
<td>Field Beans</td>
</tr>
<tr>
<td>Alfalfa (Lucerne)</td>
</tr>
<tr>
<td>White Clover</td>
</tr>
<tr>
<td>Kent wild white clover</td>
</tr>
<tr>
<td>Crimson red clover (Italian)</td>
</tr>
<tr>
<td>Alsilike clover</td>
</tr>
<tr>
<td>Vetch, tares (Tares/winter tares)</td>
</tr>
<tr>
<td>Yellow</td>
</tr>
<tr>
<td>Common Name</td>
</tr>
<tr>
<td>-------------</td>
</tr>
<tr>
<td>Trefoil</td>
</tr>
<tr>
<td>Lupin</td>
</tr>
</tbody>
</table>
## Lifters

<table>
<thead>
<tr>
<th>Common name</th>
<th>Latin name</th>
<th>Sowing dates</th>
<th>Hardy</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perennial Ryegrass</td>
<td>Lolium perenne</td>
<td>Sep.-Nov.</td>
<td>Yes</td>
<td>Pasture grass forming dense sward, quick growing and long lived. Often combined with red and white clover. As catch crop cut back or incorporate before seedheads form. High cellulose makes it hard to cut.</td>
</tr>
<tr>
<td>Italian Ryegrass</td>
<td>Lolium multi Florum</td>
<td>Sept.-Nov.</td>
<td>Yes</td>
<td>As above but used as annual or short lived perennial, quicker to establish and easier to cut.</td>
</tr>
<tr>
<td>Barley</td>
<td>Hordeum</td>
<td>Sept.-Nov.</td>
<td>Yes</td>
<td>Less hardy than Rye but more biomass, used for grazing.</td>
</tr>
<tr>
<td>Oats</td>
<td>Avena satiuum</td>
<td>Sept.-Nov.</td>
<td>Yes</td>
<td>Good on all soil types, fibrous roots, best grain for grazing because of good tillering.</td>
</tr>
<tr>
<td>Buckwheat</td>
<td>Fogopyrum esculentum</td>
<td>April-Sept.</td>
<td>No</td>
<td>Quick growing for summer catch crop. Good on poor soils. Incorporate before seed formation or cut for regrowth</td>
</tr>
<tr>
<td>Rape</td>
<td>Brassica rapus</td>
<td>March-Sept.</td>
<td>No</td>
<td>A brassica so must fit in rotation, deep rooting and used for forage, and taking up nutrients. Best composted if mature.</td>
</tr>
<tr>
<td>Phacelia</td>
<td>Phacelia tanaceti folium</td>
<td>April-Aug.</td>
<td>No</td>
<td>Extensive roots improve soil structure. Usually incorporated before flowering but flowers are attractive and attract bees and beneficial insects. Competes well with weeds.</td>
</tr>
</tbody>
</table>

### 5. Organic and mineral supplements

#### 5.1 The need for supplements.
In an organic system nutrients are recycled within the system. Where there is a need for supplements there are many products available but they should be seen as supplementary and not in place of good management of nutrient recycling.
5.2 Supplements of organic origin

5.2.1 Green waste and household waste.
Green waste is compost from household collections, and does not contain food waste or animal by-products. Household waste will contain food waste. Both green waste and household waste may not be of organic origin but the standards allow the use of green waste provided it has been composted, and household waste but only with SA approval. In either case you must be able to prove it is GMO free. Green waste is unlikely to supply high levels of nutrients and should be seen as a soil conditioner and contributing to long term fertility.

Many local authorities now collect green waste and have large scale composting facilities. This compost is produced to standard PAS100 (Publicly Available Specification) which guarantees the quality of the compost:

- limits on human and animal pathogens
- limits on the concentration of toxic elements
- limits on the microbial respiration rate – this indicates that the decomposition process is complete and that the compost is stable.
- limits on the amount of physical contaminant
- limits on the amount of stones and weed seeds.
- Germination tests should show that the germination rate is at least 80% of those of a control medium.

If you use green waste produced to PAS100 you will have a guarantee of quality and can obtain an analysis of the nutrient content and a list of inputs to the compost and a list of the purposes for which the material is suitable eg some can be used as a potting compost.

An organic farm or holding tries to operate as closed a system as possible. On a wider level we need to do this on a national level. The use of green waste compost is a step towards achieving this.

5.2.2 Mushroom compost
Mushroom compost is allowed as a supplement by S.A. standards even from non organic mushroom production. It generally consists of wheat straw, dried blood, horse manure and ground chalk. Although much of the nitrogen is used by the growing mushrooms, the compost is a good source of nutrients and trace elements, and provides useful humus. Since it contains chalk, overuse can raise pH levels.

5.2.3 Seaweed
The standards allow the use of seaweed with justification. It may be used as seaweed meal or fresh seaweed. It has good levels of iodine, potassium, silica and sodium and contains cytokinins - plant hormones which stimulate growth. Calcified seaweed is no longer permitted under soil association standards due to the unsustainable harvesting methods used.

5.2.4 Compost teas
Compost tea is an extract in water from compost. Although some nutrients are extracted, the main purpose is to extract bacteria and fungi from the compost. Simply mixing compost with water will not achieve this as some force must be used. Unless the mixture is aerated during extraction and storage the tea will become anaerobic and the organisms extracted.
will die. Sometimes the tea is sprayed onto leaf surfaces so that the organisms cover the leaf surface. The organisms out-compete any disease organisms present and thus keep in check diseases on a crop. The teas are also sometimes used to re-inoculate areas of soil which have lost the population of microorganisms, e.g. by flooding or the use of chemicals.

5.2.5 Comfrey liquid
The comfrey plant is low in fibre and high in nutrients and it decomposes to form a liquid and very little residue. The comfrey plant has very long tap roots and draws minerals, especially potassium, from low down in the soil profile. Adding water to comfrey is unnecessary and results in a smelly liquid. To make comfrey liquid, add cut comfrey liquid to a container with a hole in the bottom, weight down the leaves, and make sure the container is covered. The liquid which drips out is a high potash feed suitable for tomatoes, courgettes, and cucumbers etc. which require high levels of potassium. Water the plants with diluted liquid (about 20:1). It is sometimes used as a foliar feed sprayed onto leaf surfaces.

Comfrey can have many uses. The leaves can be cut and used as a mulch which supplies nutrients and suppresses weeds e.g. around tomatoes or runner beans. It is an excellent activator for compost heaps. If comfrey is planted around a compost heap, the comfrey will take up nutrients lost to the soil from the heap, and provide an activator near at hand when building a heap.

5.3 Mineral supplements

5.3.1 Lime (calcium carbonate)
In most soil and especially in free draining sandy soils, there is some leaching of nutrients especially of the cations held on the clay and humus surfaces - K⁺,Ca⁺⁺,NH₄⁺. These lost ions are replaced by hydrogen -H⁺ and therefore the results of leaching is that the soil becomes more acid.

Lime is used to counter soil acidity and maintain a pH of 6-7. This is very important for a healthy soil. In an acid soil earthworm activity and numbers are reduced and microorganism activity is suppressed. In clay soils, soil structure is improved by correct pH levels. Phosphorus availability is reduced in acid soils. The more soluble forms of lime (quicklime CaO, or hydrated lime Ca(OH)₂) are not used in organic farming so lime is applied in the form of calcium carbonate CaCO₃.

Calcium carbonate has a low solubility so improvement in pH from liming takes time. It is best to apply lime in autumn or winter to benefit the following crop and is often applied in the autumn. In a horticultural rotation lime is often used before brassicas are planted since they are affected most by a low pH and liming reduces the susceptibility of brassicas to club root. It should not be applied the same time as farmyard manure since lime causes the loss of nitrogen as ammonia - there should be a 6 week gap.

Liming should be carried out when a pH test shows it is necessary. Over-liming resulting in a high pH makes phosphorus and trace elements such as iron, manganese and boron, less available.

5.3.2 Rock phosphate
Rock phosphate is a natural mineral which has been used in very large quantities over the
last 60 years to make superphosphates (chemical fertilizer supplying phosphorus in a soluble form). As we have seen the low availability and solubility of phosphate in the soil makes it hard for plants to obtain enough phosphate—conventional agriculture relies on superphosphates. Supplies of rock phosphate are running out and it is likely to become much more expensive. The reliance on mined phosphates is one of the ways in which conventional agriculture is not sustainable.

Organic standards do not of course allow the use of superphosphates but rock phosphate, being a natural mineral, is allowed if you can justify its use to rectify a phosphate deficiency. However relying on rock phosphate as the source of phosphorus in organic systems is not sustainable.

Rock phosphate is very insoluble. Because phosphorus is much more available to plants in organic form and because micro-organisms are more able to solubilise phosphate, it is best practice to add rock phosphate to a compost or manure heap before the composting process.

5.3.3 Wood ash
Wood ash contains phosphorus and potassium. The standards state that wood ash can only be used in compost heaps, not applied directly to soil.

5.3.4 Potash
Sulphate of potash is very soluble but some forms of rock potash take longer to dissolve and can be used to treat a deficiency. They are allowed under the standards with justification. As a pure chemical sulphate of potash can be used to treat a severe deficiency in some situations but requires Soil Association approval.

5.3.5 Trace elements deficiency
Granular rock salts can be used to correct trace elements deficiency e.g. boron, copper, iron, manganese, molybdenum, selenium, zinc, sodium. To use such minerals you must demonstrate that it is necessary through a soil analysis and have approval from the Soil Association. With approval liquid feeds can be used to correct trace element deficiencies. A liquid feed sprayed on to leaves is a quicker way to correct a problem.