Module 2

The Nature and properties of fertilisers and liming materials

Forms and formulations of inorganic fertilisers

Granules: made from a slurry of raw fertiliser ingredients by rolling a dry slurry in a rotary drum. Since each granule contains the required nutrients, spreading accuracy is potentially good.

Prills: made by cooling a stream of nutrient solution into a smooth and rounded prills. This is normally done in a cooling tower. Prilled urea and ammonium nitrate are typical examples.

Blends: physical mixture of individual fertiliser materials (e.g. ammonium nitrate with muriate of potash). More prone to nutrient separation in the bag and/or spreading inaccuracies than granular fertilisers, depending on the size grading of the fertiliser materials. A good blend will have **equal** sized particles.

Crystals: materials such as potassium chloride and Sylvinite (a mix of potassium and sodium chloride) may be supplied as crystals. Obvious spreading problems if there is a lack of uniformity in crystal size.

Compound fertilisers: contain more than one nutrient.

Straight fertilisers: used to supply a single nutrient but in horticulture fertilisers such as Potassium Nitrate used in fertigation often described as 'straights' to distinguish them from ready formulated feeds.

Semi-organic fertilisers: contain part of their nutrient content in organic form. Organic raw materials, such as fish meal, will be used in their manufacture. Nutrient availability may be slower for semi-organic fertilisers than conventional inorganic fertilisers.

Chelates: are complex organic chemicals used to chemically bind nutrients to enhance their availability for plant uptake. The chelate will prevent fixation of some trace elements in soils. Trace elements are commonly chelated to improve their plant availability from either soil or foliar application.

Controlled release fertilisers: a form of slow to release compound fertiliser. Solubility and immediate availability of the nutrients to plants has been reduced through coating granules with a variety of materials. Acrylic resins, polyethylene waxes, latex and sulphur have all been used. Resin and polymer-coated granules are the most widely used in potting mixes.

Slow-release fertilisers: contain nutrients which are not immediately available to the crop. Slow release is achieved through either physical or biological means e.g. a requirement for the dissolution of the nutrient before it can become available; or the nitrification of N before it can be absorbed by the plant. Some products contain additives which reduce biological activity.

Liquid fertilisers.: Clear solutions are liquid fertilisers where the nutrient content is completely in solution. Spreading accuracy is normally good with liquid fertilisers. Crop scorch is a potential problem but can be satisfactorily overcome through use of appropriate nozzles and avoiding application in hot sunny conditions.

Suspensions: are liquid fertilisers where the nutrients are partly in solution and partly as a fine suspension of solid particles. Suspension fertilisers will normally be more concentrated than clear solution fertilisers and must be kept suspended by continuous agitation during storage and application.

Base fertilisers: for container growing can be a single element, but they are usually a complex of nutrients which provides the 'base' nutrients in a substrate. These often contain both macro and micro elements.

Nutrient availability and types of inorganic fertilisers

Nitrogen:

- All inorganic forms of N are water soluble and rapidly available for plant uptake, but they are also susceptible to losses through **leaching and other processes**.
- Plant uptake of nitrogen will normally start within a few days of application, assuming good growing conditions.

- Nitrogen applied as **urea** is also rapidly available for uptake.
- Although plants do not **absorb** urea-N, it is rapidly hydrolysed to ammonium and nitrate-N within a few days.
- On calcareous soils and/or warm soil conditions, urea is susceptible to ammonia volatilisation losses.
- It should only be used in these circumstances with caution and there may be further restrictions on its use under new schemes to reduce ammonia emissions.

The main types of inorganic nitrogen fertiliser are:

- **Ammonium nitrate** (33.5-34.5% N). Used in both base fertilisers, liquid feed formulations and as a top dressing.
- **Urea** (46% N) - Do not use when soils are dry and warm. Urea is a light density material that can be difficult to spread accurately. Used in foliar feeds and in liquid feeds to supply long term N.
- **Potassium nitrate** (13-14% N). Used in both base fertilisers and liquid feeds.
- **Calcium nitrate** (15% N). Used mainly in liquid feeds and to counteract N immobilisation in growing media containing bark/wood fibre.

Phosphate: Inorganic P fertilisers may be water soluble or water insoluble. Because P is less mobile in soils P fertilisers will be less rapidly available for uptake than N or K fertilisers.

Water insoluble P fertilisers are only slow acting and are not suitable in responsive situations (low soil P Index, or responsive crop). Many are less effective at soil pH's over 6.0.

Soluble phosphates

- Triple superphosphate (46% P205)
- Single superphosphate (8.7% P or 20% P205). Used in some base dressings.
- Monoammonium phosphate (26.6% P or 61% P205). used as a source of P mainly in liquid feeds.

Insoluble phosphates

- Basic slag — by-product of the steel industry.
- Rock phosphates - finely ground, variable quality.
- Aluminium calcined phosphates - calcined and ground rock P.
- Mixtures of water soluble and insoluble P sources.

Potash: All inorganic potash fertilisers are water soluble and quick acting.

- Muriate of potash (potassium chloride, 60% K20), used in agriculture.
- Potassium sulphate (50% K20). Used in horticulture and liquid feed formulations, but it can be difficult to dissolve in cold water.
- Potassium nitrate (38% K or 45.8% K20). Used in base fertilisers and liquid feeds.

Magnesium: Magnesium fertilisers vary in their availability. Magnesium sulphate (Kieserite) is rapidly available, magnesium oxide (calcined magnesite) is slightly slower acting, and magnesium limestone is a slow-release source of magnesium (release over several months).

- Kieserite (magnesium sulphate, 27% MgO). used in substrate base dressings.
- Magnesium limestone (over 16% MgO)
- Calcined magnesite (magnesium oxide, 82% MgO)
- Epsom salts (magnesium sulphate, 17% MgO) - rapid acting, used as a foliar spray

Sulphur

Sulphur as sulphate (ammonium or potassium sulphate) is rapidly available, in a similar way to Nitrogen. Elemental sulphur is slow acting since microbiological conversion to sulphate is needed in the soil before plant uptake can take place. Elemental sulphur cannot be absorbed through leaf uptake.

- Ammonium sulphate (21% N, 60% S03)
- Potassium sulphate (18% K20, 45% S03)
- Kieserite (27% MgO, 53% SO4
- Elemental sulphur
- Gypsum (calcium sulphate, 38 - 45% S03). A slowly soluble source of sulphur; not effective as a liming agent; may be used to stabilise weakly structured or saline soils.

Trace elements:

- inorganic salts (commonly more concentrated than other forms)
- Chelates (more expensive, easier to use, can be less effective)
- Fritted trace elements (a slow-release form where elements are combined with sodium silicate).
- When iron chelates are used it is important to use the correct product for the pH of the growing medium:

Chelate	Suitability
EDTA	Up to pH 6.0 in growing media, not suitable for soil application. Used in hydroponic solutions and foliar feeds. For foliar feeds use at 0.5 g/l (can scorch if applied in hot, sunny conditions)
EDDHA	Highest stability in alkaline soils but expensive, resistant to clay absorption so good for soil, and loam-based growing media
DTPA	Effective u to H 7.5, useful for growing media where H >6.0
HEEDTA	Effective u to H 8.5

NB Chelates must be handled with care — see safety data sheet information.

Organic Fertilisers

- Ref. Defra Code of Good Agricultural Practice.
- This provides essential guidance on the application of organic manures to land.
- The Nitrate Vulnerable Zones Regulations are also relevant in designated areas (most of the country).
- The availability of the nitrogen contained in organic manures dictates closed periods when they may not be spread on land (e.g., poultry manure has a high available N content and timing of application is more restricted than for straw-based cattle manure).
- Full details of the nutrient value of different types of organic manures are given in AHDB reference book RB209 'Nutrient Management Guide'.
- This is an essential reference. Values are not duplicated here.

Types of Organic manures

- **Slurries.** Neat or diluted excreta (normally less than 1% DM).

- **Separated slurries.** Low dry matter liquid (<4% DM); commonly pumped to land through low-rate irrigation systems.

- **Farm-yard manure.** Excreta mixed with bedding, e.g., straw or shavings (commonly 25% dry matter).

- **Poultry manures.** May be neat (typically 30% DM) or mixed with litter (typically 60% DM). High nutrient concentration.

- **Sewage sludge.** May be liquid (typically 4% DM) or cake (typically 25% DM). Sludges may be undigested or digested to reduce pathogens. Sludges contain variable quantities of potentially toxic elements (e.g., heavy metals), hence soils must be tested regularly for potentially toxic elements where sludge is being applied.

- **Industrial wastes.** Materials such as ink sludge waste and vegetable washing waste which are commonly applied to land. The nutrient and toxic element content of these materials will vary.

- **Green compost.** May be produced from green waste only or green plus food waste (the latter will have been processed through an 'in-vessel' system). Composts are typically 50-60% dry matter. Low available N but useful amount of P and high K content. Before application to agricultural land an application to the Environment Agency for a license or exemption from the waste regulations is needed unless the compost is PASIOO standard and complies with the Quality Protocol. For further information see WRAP website. www.wrap.org.uk.

- **Digestate** (the solid fraction from anaerobic digestion systems) has a higher available nitrogen content than compost. There is also a BS Publically Available Standard for digestate (PASI10).

Composts: Typical total nutrient contents (fresh weight basis)

Compost Type	Dry matter (%)	Nitrogen (kg/t)		Total (kg/t)			
		Total	Readily avail.	P_2O_5	K_2O	SO_3	MgO
Green	60	7.5	<0.2	3.0	5.5	2.6	3.4
Green/ Food	60	11	0.6	3.8	8.0	3.4	3.4

Nutrient Supply from Composts

- The available field experimental data indicate that green compost supplies only very low amounts of crop available N and that inorganic fertiliser N application rates should not be changed for the next crop grown.
- In the case of green/food compost, the available experimental data indicate that around 5% of the total N applied is available to the next crop grown (irrespective of application timing).
- Following the repeated use of green and green/food composts long-term soil N supply will be increased.
- As little work has been done on the availability of compost phosphate to crops, it is appropriate to extrapolate from work on livestock manures and sewage sludge which suggests that around 50% of the phosphate will be available to the next crop grown, with the remainder released slowly over the crop rotation.
- Around 80% of compost potash is in a soluble form and is readily available for crop uptake.
- Composts also supply useful quantities of sulphur and magnesium, although there are no data on availability to the next crop grown.
- Composts also have a small liming value that can balance the acidifying effects of inorganic fertiliser N additions to soils.

Total nutrients

- This is the total quantity of **NPKS** present in all forms.
- Nutrient balance sheet systems will commonly use the total PK content of organic manures to calculate balances between cropping seasons.

Potentially available nutrients

- The quantity of nutrients present that is potentially available for plant uptake by the first crop following application.
- The N can be estimated by measuring the ammonium-N content of the fertiliser.
- For **poultry manures**, part of the available N is in the form of uric acid-N.
- Bulky organic manures such as **FYM** contain low quantities of available N. Losses of N from autumn/early winter applications of these materials will be much lower than for materials higher in ammonium-N.
- For P and K (and for N where analysis is not carried out), the quantity of potentially available nutrient is estimated by taking a fixed percentage of the total nutrient content depending on the manure type (see RB209).

Organic nutrients

- Nutrients in organic form are only slowly available and that will not usually be available for uptake by the first crop following application.
- These nutrients will become available in following years.
- Organic manures can contain small, though useful, quantities of sulphur.
- Regular applications of bulky organic manures can improve the structure and water holding capacity of soils but the amount that can be applied in one year/application is limited for land that is in a Nitrate Vulnerable Zone (the majority of England and Wales).

Sewage Sludges

- Sewage sludges or biosolids are good sources of N and P for application to soil but are not permitted for use on most horticultural crops under Assured Produce.
- They do not contain any useful quantities of potash.
- Sludge cakes treated with lime have a useful liming value.
- Sewage sludges can contain Potentially Toxic Elements (PTE's - e.g. zinc, copper, nickel, cadmium, lead, mercury, chromium).
- Limits for PTE's may differ depending on situation and soil ph.
- Refer to crop protocols for edible crops and the Biosolids Assurance Scheme.

Lime

- Maintenance of a satisfactory pH in the soil or growing medium is important to achieve optimum availability of plant nutrients.

- Lime recommendations for field-grown crops are intended to raise the pH of the surface 15 cm of soil.

- Where cultivations are deeper, or acidity occurs below 15 cm (eg for top fruit) the quantity of lime should be increased proportionately.

- Lime should be applied well before sowing or planting out because it takes several months to correct acidity.

- For arable crops, field vegetables and flower crop the target pH when liming is 6.5.

- Liming of soils to pH 7.0 and above reduces the risk of clubroot in Brassicas.

- Light soils receiving high rates of nitrogen will develop acidity relatively quickly.

- For grass & fruit crops target is 6.0. Mineral soils in glasshouses are usually kept at around pH 6.0-6.5

<u>pH values below which growth on mineral soil may be adversely affected:</u>

pH	Crop
Mint	6.6
Celery	6.3
Lettuce	6.1
Peas	5.9
Asparagus	5.9
Spinach	5.8
Carrot	5.7
Onion	5.7
Brussels sprouts	5.7
Cauliflower	5.6
Sweetcorn	5.5
Cabbage	5.4
Swedes/turnips/parsnip	5.4
Rhubarb	5.4
Parsley/chicory	5.1

Optimum pH for field-grown nursery stock

Species	Optimum soil pH
Rhododendron, Calluna,Erica,Picea	4.4-5.5
Acer, Quercus, Betula, Rosa multiflora	5.5-6.5
Syringa, Sorbus, Rosa laxa: Liqustrum, Salix	6.5-7.0

- Most liming materials are slow acting, but this depends on the type and size grade of the lime.
- All liming materials will have a Neutralising Value (NV) which indicates the strength of the material.
- NV is expressed as the percentage liming effect compared to pure calcium oxide (CaO). In practice, however, the hardness of the lime and the particle size will determine how quickly it neutralises acidity so two types of lime could have the same NV but one could raise pH much more quickly than the other.
- The full effect of a single lime application to a field will not be seen for 6 to 12 months after application.

Types of lime:

- Ground chalk / ground (magnesium) limestone (NV c.50-55)
- Hydrated lime (NV c.70)
- Burnt lime (NV c.80, rarely used now)
- Sewage sludge

Lime recommendations from soil pH (t/ha lime needed)

Soil pH	SANDS Arable	Grass	LIGHT Arable	Grass	MEDIUM/CLAY Arable	Grass	ORGANIC Arable	Grass
6.5	0	0	0	0	0			
6.4	2	0	2	0	2			
6.3	2	0	3	0	3			
6.2	3	0	4	0	4		0	
6.1	4	0	4	0	5		3	
6.0	4	0	5	0	6	0	4	
5.9	5	2	6	2	6	2	5	
5.8	5	2	6	2	7	2	6	
5.7	6	2	7	3	8	3	7	0
5.6	7	3	8	3	9	4	8	2
5.5	7	3	8	4	10	4	9	3
5.4	8	4	9	4	10	5	10	4
5.3	8	4	10	5	11	5	11	5
5.2	9	5	11	5	12	6	12	5
5.1	10	5	11	6	13	7	13	6
5.0	10	5	12	6	14	7	14	7
4.9	11	6	12	7	14	7	15	7
4.8	11	6	13	7	15	7	16	7
4.7	12	7	14	7	16	7	17	7
4.6	13	7	15	7	17	7	18	7
4.5	13	7	15	7	18	7	19	7
4.4	14	7	16	7	18	7	20	7
4.3	14	7	17	7	19	7	21	7
4.2	15	7	18	7	20	7	22	7
4.1	16	7	18	7	21	7	23	7
4.0	16	7	19	7	22	7	24	7

Arable lime requirement: to achieve pH 6.5
Grass lime requirement: to achieve pH 6.0

The basis of fertiliser recommendations for soil-grown crops

- Most of the crop groups covered in this course are grown in containers or hydroponic systems and not the soil.
- Cut flowers and bulbs and some strawberries are grown in the soil and it is important to understand how fertiliser applications to such crops are calculated. For most nutrients the basis of the decision is recent.
- Soil analysis of the top 15 cm of soil which indicates the amount of any nutrient that is currently available for plant uptake.
- The Soil Index for that nutrient can then be looked up in tables of fertiliser recommendations which will give rates of fertiliser to use. (See AHDB publication - RB209 — Nutrient Management Guide).
- For nitrogen recommendations analysis of the top 15 cm of soil only does not give a meaningful estimate of the amount of nitrogen that the soil is likely to supply because nitrogen is very mobile in the soil as nitrate and there is continual cycling of nitrogen between available and non-available forms.

Soil Nitrogen Supply

Soil Mineral Nitrogen (SMN)

- This is the nitrate-N (N03-N) and ammonium-N (NH4-N) in the soil. Soils can contain varying quantities of these forms of N depending on the recent cropping, organic manure and fertiliser use.

Nitrogen mineralised from organic matter

- Mineralisation results in the conversion of organic N to soil mineral N.
- This source of N can be large on organic or peaty soil, where there is a history of long-term grass, organic manure use or where N-rich leafy crop debris has been incorporated.

Nitrogen from the atmosphere

- Small amounts of N are deposited in rainfall and directly from the atmosphere. Leguminous crops (e.g., peas/beans/clover) can also 'fix' atmospheric nitrogen into a form that can be used directly by crops.

Nitrogen from organic manures

- Most organic manures contain large quantities of nitrogen and other nutrients. Some of this nitrogen is equivalent to fertiliser N the remainder becomes available more slowly.

Fertiliser nitrogen

- Fertiliser nitrogen is used to make up any shortfall in the crop's requirement for nitroge

Basis for decisions on N use

- The nitrogen requirement of a crop is the amount of nitrogen that is economically justified under given economic conditions, this depends on:

The crop requirement for N

- The amount of N that the soil can supply for crop uptake Fertiliser costs and the likely value of the crop produce

Assessing the Soil Nitrogen Supply (SNS)

- **SNS** is the amount of nitrogen **(kg/ha N)** in the soil **that becomes available** for uptake by the crop from establishment to the end of the growing season, taking account of nitrogen losses.
- Research has shown that there is a close relationship between the measured amount of SNS within the crop rooting depth and the amount of nitrogen taken up by the crop in the absence of applied N fertiliser. The SNS is not the same as but includes Soil Mineral Nitrogen (SMN)

SNS = SMN+estimate of total crop N+estimate of mineralisable N

where:

- Soil Mineral Nitrogen (kg/ha N) is the nitrate-N plus ammonium-N content of the soil within the potential rooting depth of the crop, allowing for N losses.
- Total crop nitrogen (kg/ha N) is the total content of N in the crop when sampling for SMN is carried out.
- Mineralisable nitrogen (kg/ha N) is the estimated amount of N which becomes available for crop uptake from mineralisation of soil organic matter and crop debris during the season.

The SNS varies from field to field and season to season so must be assessed each year, the main factors affecting it are:

- N residues from fertilisers and manures used on the previous crop
- the use of organic manures for the last crop and previous seasons
- the soil type and soil organic matter content
- losses of N by leaching and other processes (winter rainfall amount is important)
- nitrogen made available for crop uptake from mineralisation of soil organic matter and crop debris during the growing season.
- The amount of nitrogen leached will depend of amount of nitrate-N in the soil at the start of the winter, the soil type and the amount of water draining through the soil (the excess winter rainfall)

Excess winter rainfall(mm) = rainfall between field capacity and end of drainage evapotranspiration

Because of regional and seasonal differences separate SNS Index tables are given for three different rainfall situations:

1. Up to 600 mm annual rainfall (50-150 mm excess winter rainfall)
2. 600-700 mm annual rainfall (150-250 mm excess winter rainfall)
3. Over 700 mm annual rainfall (over 250 mm excess winter rainfall)

The SNS Index System

Nitrogen recommendations are based on 7 SNS Indices and each Index is defined in terms of a quantity of SNS in kg/ha N.

This means that the SNS Index can be determined using field specific information without sampling and analysis for Soil Mineral Nitrogen (SMN).

A nitrogen recommendation is obtained by determining the SNS Index of a field and then referring to the appropriate crop table for the selected Index level.

See page 20, section 1 of RB209 and the tables for SNS for different rainfall areas — pages 10-1 1 of section 4 of RB209 (Arable Crops).

NB The SNS Index system is not applicable to long-term grass or fruit crops and RB209 contains no fertiliser recommendations for horticultural crops other than vegetables and bulbs.

Calculating the amount of fertiliser to apply

- The content of each nutrient in a fertiliser is given as a percentage.
- Therefore 100 kg of a 20:10:10 NPK compound fertiliser contains 20 kg of nitrogen, 10 kg of phosphate and 10 kg of potash.
- The amount of product to apply per hectare is calculated:

Rate of fertiliser product (kg/ha) = nutrient application rate (kg/ha) x 100

(Divided)

percent nutrient in fertiliser