Module 1

THE SOIL OR CONTAINER GROWING MEDIUM IN RELATION TO PLANT NUTRITION

What is the function of the soil or growing media?

- Soil or growing medium determines the rooting environment of a plant.
- This environment has a blend of **physical, chemical, and biological properties,** which influence root growth and interact with each other.
- Most substrates are dynamic systems, not constant, only pure hydroponic systems allow ultimate control of the chemical environment around the plant roots.
- The main difference between soil growing and container growing is that in the former the root system is not confined; hence a greater volume of substrate can be explored for water and nutrient uptake and the physical and chemical properties are therefore less critical than for a containerised plant
- Soil-grown plants may also have a greater ability to form associations with soil organisms such as **mycorrhizae** (which enhance nutrient availability) than container grown plants.

The main functions of the substrate are:

- To provide anchorage for the plant.
- To provide adequate air spaces to allow root respiration
- To hold sufficient available water for the plant
- To hold sufficient available plant nutrients

Biological properties of the substrate are important because microbes are involved in nutrient cycling. The balance between beneficial and pathogenic organisms will affect plant health and the types of soil organisms present (e.g., nematodes, protozoa, actinomycetes, fungi and bacteria) also influence soil fertility and plant growth.

Physical aspects of the substrate

- The physical properties of the soil/substrate are determined by the size and shape of the particles it is composed of and how they interlock.
- The larger gaps between particles are filled with air and the smaller gaps are filled with water, so larger particles with larger spaces hold more air and less water than a substrate with smaller particles and small inter-spaces.
- Some materials also have 'internal' porosity because they hold water/air within the actual particles as well as between particles.
- The physical nature of a substrate is determined by analysis of particle size (i.e., % by weight of particles in each size category).

Soil Texture

- For soil the various fractions are described as **clay (C), silt (Z) & sand (S)**

< 0.002 mm	**Clay (C)**	**Sticky**
0.002 – 0.06 mm	**Silt (Z)**	**Silky**
0.06 – 2.0 mm	**Sand (S)**	**Gritty**

Fractions over 2 mm are classified as 'gravel'.

NB This is the classification used in the UK; other systems apply in different countries.

- The percentage of each of these particles determines the texture of the soil, as denoted by the 'texture triangle'
  - **ZCL = 'silty clay loam'**

- Soils formed on chalk or limestone usually contain natural calcium carbonate (lime) and are denoted with the prefix 'calc.'
- Soil texture can be determined by hand texturing if a particle size analysis is not available, i.e., from the feel of moist soil.
- Sandy soils are more freely draining and hold onto nutrients less well than clay soils.
- Clay soils have a greater 'buffering capacity' as the clay particles have a large surface area with exchange sites that hold nutrients.

Typical AWC values for different textures are (% by volume or mm/10cms depth):

	Topsoil	Subsoil
Sand	8	5
Loamy sand	12	9
Sandy loam	17	15
Sandy silt loam	19	17
Silt loam	22	21
Clay loam	18	15
Sandy clay loam	17	15
Silty clay loam	18	15
Clay	18	15
Sandy clay	17	15
Silty clay	18	15
Peats	35	35

Available water capacity (AWC)

- The AWC of a soil is the amount of water held against gravity that is also available for uptake by plant roots.
- Silty soils contain more available water than clays, which hold a lot of water too tightly for plant use.

Soil Structure

- Soil texture describes the basic building blocks of a soil, the way the individual soil particles are aggregated determines the structure of a soil and this strongly influences how water moves through the soil profile.

- Poor soil structure or drainage conditions are likely to reduce the ability of plant roots to utilise nutrients that are in the soil. Examination of the soil to I metre depth with spade and/or auger is necessary to assess soil structure and drainage condition.

Soil compaction

- Compact soils will restrict the rooting volume and may limit the yield potential and nutrient requirement.
- Nutrients are used inefficiently in these conditions.
- Compaction can be identified by examining the soil and root structure.
- When the soil is broken by hand, large, dense, angular soil units (peds) with few micropores are signs of compaction.
- Few roots or roots growing horizontally are also indicative.

Poor drainage

- Wet or waterlogged soils will cause poor root development and reduced yields.
- Generally grey soil colours (gleying) indicate poor drainage; orange mottled soil colours indicate intermittent poor drainage.
- Wet soils will encourage losses of gaseous N through denitrification.
- There is extra emphasis on soil management in river catchments where water quality is a problem (Catchment Sensitive Farming scheme) and in Source Protection Zones around drinking water boreholes.

Soil types and soil maps

- The physical characteristics of a soil are used to classify which soil series it belongs to.
- Knowledge of the local soil series is helpful as it gives an idea of its natural water holding capacity, drainage status and fertility.
- Soil series are named after the first place that soil type was recorded and are described according to the nature of the soil in the different soil 'horizons', this is usually closely related to the geology of the area, e.g. sandstone, river gravel, chalk downs.
- The Soil Survey of England and Wales have mapped most of England and Wales (except urban areas) at 1:250,000 Ref: www.landis.org.uk.
- Some soil types are more vulnerable to leaching of nutrients such as nitrogen and both inorganic fertiliser and manure use must take account of this, particularly in vulnerable areas, e.g., Nitrate Vulnerable Zones.

Soil Organic Matter

- The organic fraction of soil is what makes it a living environment and distinguishes it from unweather rocks and sediments.
- The organic material in soils provides food for soil micro-organisms, ranging from bacteria and fungi to nematodes, mites, springtails etc. and larger organisms such as earthworms, molluscs, and mammals.
- Microbial biodiversity is very important for maintaining nutrient availability for plants because without microbes many of the plant nutrients are not available for root uptake.
- The organic fraction of soil is also important for carbon sequestration (it is a carbon 'sink') so it has implications for greenhouse gas management.
- Most soils can be improved structurally by the addition of organic matter or 'humus'.
- This helps to stabilise the soil in its structural units, which then allows air to be held between the units and water to drain through the soil profile.
- Adding organic matter improves the water and nutrient holding capacity of soils and the drainage and workability of heavy clay soils. It will also reduce the susceptibility of a soil to erosion.

  It takes time to increase the organic matter status of a soil, repeated applications are required.
- Conversely the organic content can drop very quickly e.g., after permanent pasture is ploughed up, because cultivations activate the soil organisms which break down the humus. A poor soil may only have an organic matter content of about 1%, a fertile soil would have perhaps 5% and peat soils over 20%.
- The organic content of soils is important because it is effectively a store of nutrients that may become available to plants, and it also influences the water holding capacity of the soil.
- Soils with a high organic content) such as fenland peats, do not need much nitrogen fertiliser because nitrogen is continually being released from the organic fraction by microbial activity, however as the organic matter is oxidised the soil depth decreases (e.g., the ground level in Holme Fen, Lincs has dropped by 4 metres since 1852).

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Container growing media and air-filled porosity

When plants are grown in containers soil is not used as the growing medium because of the need for a higher water-holding capacity where the root system is confined to a small volume of substrate. Soil or loam was originally used in containers as in the John Innes mixes, introduced in the 1930s, which consist of loam, peat, and sand. The loam used was not just topsoil but traditionally from turf cut and stacked for some time, so it had a high organic matter content. Reliable sources of loam become difficult to obtain however and there were problems with the need to sterilise the loam (to remove pathogens) and the weight of the containers when transporting plants. Hence in the 1970s 'lightweight' container mixes, consisting of peat and sand became more prevalent. These made standardisation between batches easier, gave better air porosity and allowed more control of pH and nutrient levels.

For container growing media, a particle size analysis can also be carried out, older peats which are more decomposed have smaller particles than younger peats. Peats are classified by their degree of decomposition on the Van Post scale, HI being very young peat and H9 being very humified black sedge peat. Peats are assessed from the colour of the water that is squeezed out of them (clear for HI , dark brown for HI 0).

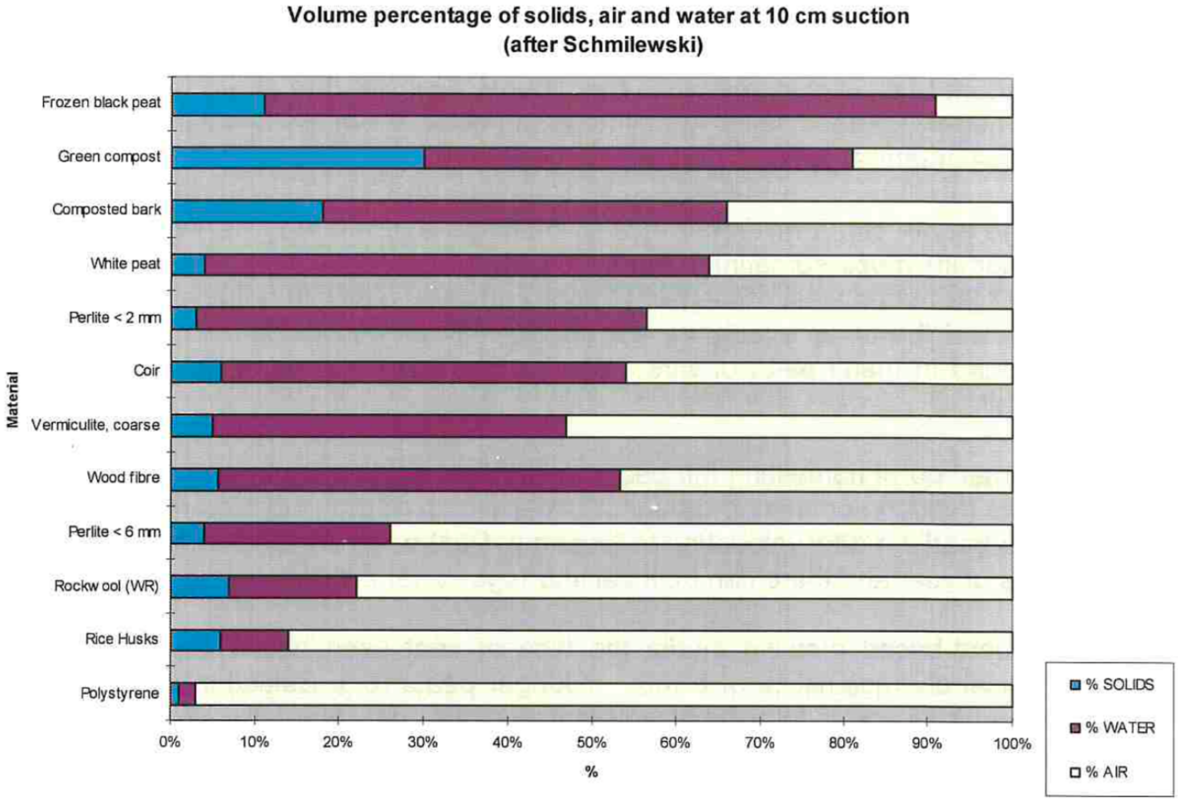
Simplified version of Von Post Scale

Degree of humification	**Scale**	**Class / Examples**
Very Little	1	White Peats
	2	Baltic peat e.g., Latvian
	3	Medium peat
Slight	4	
	5	Irish sphagnum peat
	6	
Moderate	7	Black peat e.g., Lowland sedge peat
	8	
High	9	
	10	

The percentage of 'fines' (<1 mm) is related to the air capacity of the peat. The air and water holding capacities of a growing medium are inter-related, materials with a high ^{c}air filled porosity' (AFP) will, by definition, hold less water. Air filled porosity is measured by displacing the air in the medium with wate

Classification of AFP

AFP Range	Suggested Suitability	Comments
3 – 7%	Short term protected crops in spring seed composts.	Over watering will give anaerobic conditions
7 – 10%	Pot plants (summer) Bedding	Less suitable for overwintering crops
10 – 15%	Pot plants, longer term bedding, nursery stock	Relatively free draining, easiest range to manage
15 – 25%	Winter pot plants Long term nursery stock Orchids Propagation media	Little and often water required



Peats

Peat is a generic term and there are many different types in the world. It forms either in basins where water accumulates or where rainfall is high in upland areas. It is important to distinguish between the different types as the properties of different peats vary hugely, depending on the climate and geology where they were formed, their age and the botanical species they are formed from.

- Sedge peats can form from reeds in marshes e.g., around The Wash in Lincolnshire.
- Sphagnum moss sometimes colonised reed and sedge fens later, particularly in the wetter north and west of the UK.
- There are many different sphagnum species in these bogs and the moss eventually accumulates into a slight dome — 'a raised bog' — e.g., as found in many parts of Eire.
- Blanket bogs are formed in upland areas with high rainfall.

The method of harvesting the peat may influence its structure and quality — peat cut as blocks ('sods') sometimes retains a better structure than 'surface-milled' peat, which is 'vacuumed' up after rotovating to loosen it. Peat harvesting can only take place at drier times of year and there can be local shortages after a series of wet summers.

- For peat-based growing media the type of peat used has a large influence on the physical characteristics of a mix.
- Younger peats (e.g., Baltic/Finnish peat) hold more air and less water than older sphagnum peat and generally have a lower buffering capacity.
- The oldest sedge peats have the highest water holding capacity (e.g., English sedge peat used for blocking composts).
- The colour of the peat is a good guide to the degree of decomposition of the moss that it is formed from.
- So-called 'white' peats are paler in colour. 'Black peat' is used to describe sedge peat in the UK but in other parts of Europe it just means older sphagnum peat compared to the white peats.
- Blending of different peats can be used to create the correct air: water ratio for the crop grown.

Additives to peat such as bark and perlite are used to improve the AFP of a growing medium. Addition of sand to a growing medium adds weight (ballast) but also blocks the pores up, hence reducing AFP. 5 mm grit is recommended where ballast is needed e.g., to stop pots blowing over.

Over the last 20 years there has been more pressure to use alternatives to peat because of the declining areas of certain peat-bog types in the UK and their ecological importance and because peatlands are a carbon sink. Some peatlands are now protected by law against further damage under the EU Habitats Directive. The current government targets are for local authorities to be peat free 2015, amateur gardening by 2020 and professional horticulture by 2030. A Sustainable Growing Media Task Force was set up by Defra to help progress towards these targets. The emphasis currently is on sustainable growing media, not just peat replacement, and a Defra/AHDB project on Responsible Sourcing of Growing Media is focussing on this

Peat alternatives

Commercial growers use peat for two main purposes, as a constituent of growing media and as a soil improver. The use of peat for the latter is decreasing and cannot be advocated because of the many equally suitable peat-free products available for improving soil organic matter status. The replacement of all peat in growing media is less simple and would take much longer to achieve, particularly for more demanding crops such as ericaceous plants.

The major peat alternatives being used now in reduced peat blends are timber industry by-products such as bark and wood-fibre. Coir is also used in blends or alone for protected ornamentals and strawberry bags. In the early days coir was not consistent in quality, with problems of high salt levels in some batches and contamination by pathogens. Some growers trying it were therefore put off by poor results, this emphasises the need for adequate research before growers gain confidence in new growing media. Composted barks, forestry operation by-products and manufactured wood-fibres are all being used successfully in reduced peat media for multiple retailers who demand this. There is also interest in the use of composted green waste in growing media at up to 20-30% of the mix. Only high-quality green compost is suitable (ref: PASIOO and the guidelines produced by the Waste Resources Action Programme, WRAP).

The use of reduced peat and peat-free growing media has implications for management of crops, particularly in relation to irrigation and nutrition.

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Chemical aspects of the substrate

Basic principles

- The aerial parts of a plant typically consist of 90% water and 10% solids.
- Of the dry matter approximately 90% are organic compounds (cellulose, sugars, proteins etc.) and 10% is the mineral component (major and minor nutrients) which are products of photosynthesis.
- Although the minerals only represent a small % of the fresh weight of the plant, they are essential for the various growth processes.
- Plant nutrients are normally applied in fertilisers as salts, which are composed of positively and negatively charged ions, e.g., potassium nitrate (KN03) comprises potassium (K+) cations and nitrate (N03-) anions.
- One of the important mechanisms which helps to regulate the supply of certain nutrients to the plant is the cation (+ve ions) exchange capacity (CEC).
- This is the holding and releasing of these positively charged ions on the negatively charged surfaces of clay, peat or other organic particles.
- Cation exchange capacity therefore influences the fertility of a soil or substrate. Humus has a high CEC, as does vermiculite (a clay mineral).
- Perlite has a very low CEC. Soils or substrates with a high CEC are less susceptible to leaching of nutrients.
- Anions such as nitrate are more readily leached, especially from a free draining substrate.

pH

- The pH of a soil or growing medium is a measure of its acidity or alkalinity and is dependent on the relative concentrations of the hydrogen (H+) and the hydroxyl (OH-) ions in solution.
- At pH 7.0 (neutral') the hydrogen ions balance the hydroxyl ions.
- Where there are more hydrogen ions the material is acid (lower pH) and where there are more hydroxyl ions the material is alkaline (higher pH).
- The pH scale is logarithmic hence pH 5 is ten times as acid as pH 6 and pH 4 is 100 times more acid than pH 6.
- pH is measured with indicator solution, which changes colour according to the hydrogen ion concentration, or with a pH meter when it is measured on a suspension of the material in distilled water.
- The availability of plant nutrients in soil or substrate is strongly influenced by the pH:

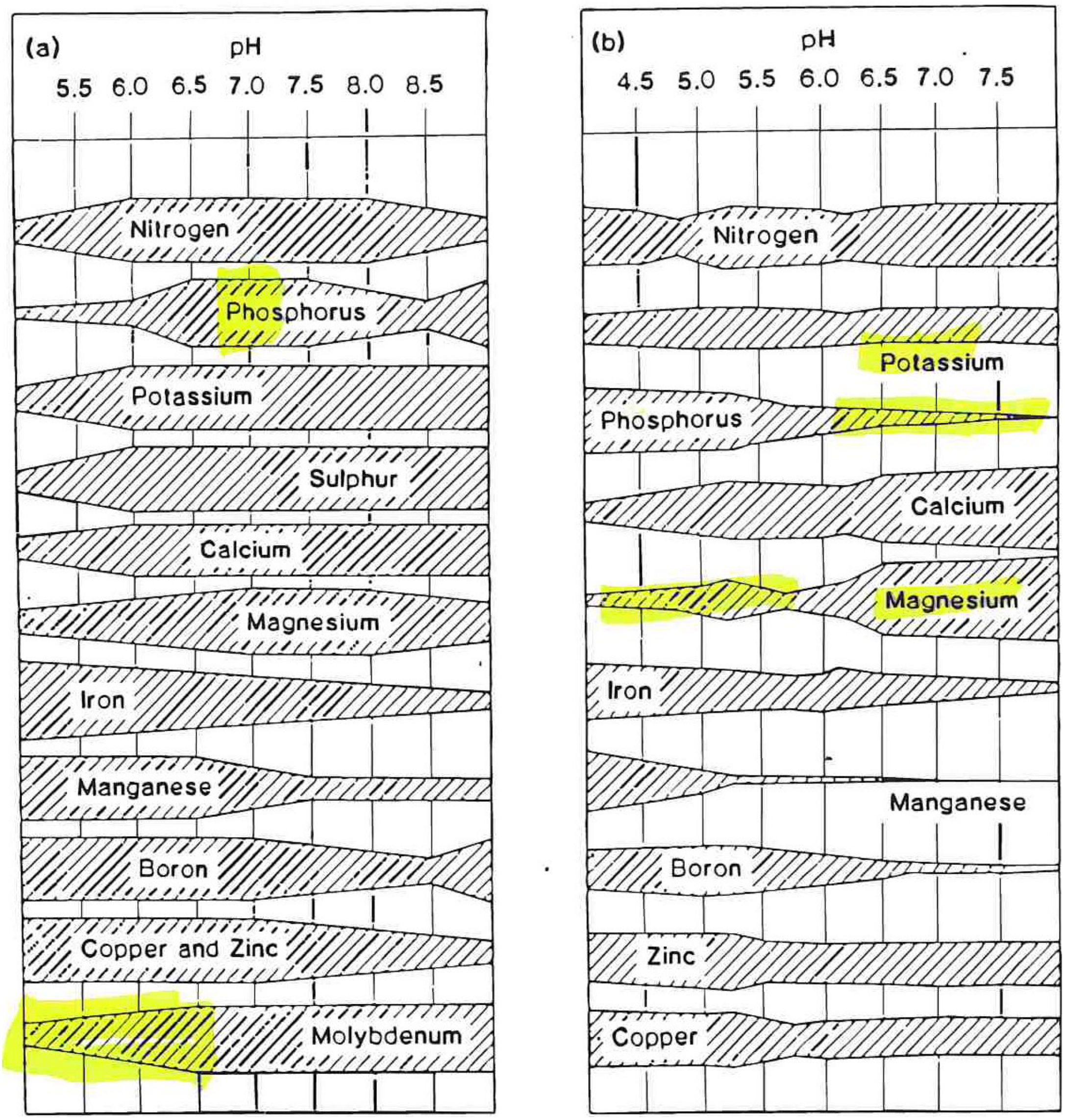


Figure 4.9 Contrasting effects of pH on nutrient availabilities in (a) mineral soils (after Truog 1948) and (b) a typical light-weight potting mix (after Peterson 1981).

- At low pH the hydrogen ions themselves can cause toxicity, but more importantly, acid conditions make the availability of metals such as manganese and aluminium so high that they cause toxicities.
- To maintain a balance, the pH of soils is usually maintained at around 6.0 and for peat-based growing media around 5.5 - 6.0 (although higher pHs are acceptable in mixes containing other materials such as green compost).
- For acid loving plants a pH of around 4.5 - 5.0 is desirable in growing media (<6.0 in so

Lime requirement

- Two materials may have the same pH but different amounts of reserve acidity hence the lime requirement to raise the pH a certain amount will be different.
- Materials with a high lime requirement are said to be well buffered against a change in pH e.g., clayey mineral soil or peat.
- Younger peats need less lime to raise their pH by one pH unit than older peats. A typical lime rate for a peat would be between 1 and 2 kg lime per cubic metre of peat to raise the pH by one unit, e.g., from 4.0 to 5.0.
- For soils the lime requirement is higher for clayey soils compared to sands e.g., to raise the pH of a clay soil by one unit may take 6 t/ha of ground lime, but for a sand it would only need 4.5 t/ha.
- The sand would lose the calcium more rapidly however, due to leaching, so the pH would fall again more quickly.
- It is very important to correct the pH before planting as there needs to be an intimate mix between the lime and the soil/substrate particles for neutralisation of the acidity.
- Applying lime as a top-dressing over a growing container crop is not effective.
- The amount of lime added to a container growing medium must allow for calcium (bicarbonates) that will be added to the substrate in the irrigation water over the life of the crop.
- In hard water (high bicarbonate) areas the pH of a growing medium may rise by one or two pH units in a year, hence a lower starting pH is advised, unless the water is being acidified.
- The main forms of lime used in horticulture are ground chalk (calcium carbonate) and ground magnesium lime (calcium and magnesium carbonate).
- The latter is usually used for container mixes as it supplies magnesium as well as calcium.
- The 'Neutralising Value' of liming materials must be stated, this gives a comparison with pure calcium oxide, e.g., a ground chalk with NV of 50% means it has 50% of the NV of calcium oxide.
- The particle size and hardness of the ground lime determines how quickly it will neutralise the acidity of the soil or growing medium.
- For growing media that do not require neutralisation of acidity, calcium may be added in the form of gypsum (calcium sulphate) but this will raise the conductivity of the mix.
- Similarly, magnesium can be added as kieserite or Epsom Salts (magnesium sulphate).

Reducing pH

- Reducing pH is more difficult than increasing it.
- For soils it is not usually practical, or economic but powdered sulphur is occasionally used. It is not worthwhile however for soils which contain free calcium carbonate.

Nutrient uptake

- Plants absorb nutrients as charged particles (ions) through their root hairs, which are covered by a film of water containing dissolved nutrients.
- This is referred to as the soil solution (or nutrient solution in hydroponic systems).
- The concentration of nutrients found in plant roots is often higher inside the roots than outside so the plant must use energy, from sugars manufactured in the leaves, to absorb nutrients (active transport').
- The plant absorbs ions selectively e.g., if calcium nitrate is added more nitrate ions than calcium ions will be absorbed.
- At low soil temperatures or where the oxygen supply in the soil or sugar supply in the roots is limited, the rate of active nutrient absorption is lower.
- Plants also release ions through their roots, e.g., hydroxyl ions can be released in exchange for nitrate ions.
- Some nutrients are absorbed passively (mass flow) with the water being taken up —for example calcium.
- All nutrients move from the roots of the plant to other parts in special tubes ('xylem'); for passively absorbed nutrients such as calcium the amount taken up is very dependent on how much water is being pulled through the plant in the transpiration stream.
- The rate of plant growth can often be increased by increasing the supply of nutrients, however a balance between nutrients is important e.g., very high potassium levels reduce availability of magnesium.
- Where nutrients are supplied in excess plant growth will be depressed.
- In some situations, nutrient supply is sufficient, but nutrients are not taken up by plants adequately due to other factors.

Examples of poor availability of nutrients:

Calcium deficiency due to high humidity and hence low transpiration.

- Poor supply of P because it is locked up (fixed) in an insoluble form.
- Iron deficiency due to high pH or due to waterlogging damaging fine roots.
- Magnesium deficiency due to soil compaction or drought/irregular water supply.
- Poor uptake due to competition between similar ions e.g., poor uptake of nitrate due to high chloride level or poor uptake of magnesium due to high potassium level.
- Reduced supply of plant available nutrients due to low temperature and/or biological activity in the soil or substrate.

Conductivity

- Electrical conductivity (EC) of a substrate is a measure of the total salts present.
- The soil/substrate is made into a suspension with deionised water and the speed with which an electrical current pass through it determines the EC - more charged ions = higher conductivity.
- Conductivity is usually measured in micro-siemens/cm (pS/cm), it is temperature dependent and usually quoted at 20 degrees centigrade (at 25 degrees a higher reading will be obtained).
- EC meters often measure in milli-siemens/cm (1 MS = 1000 VS)
- The EC is a useful measure of the amount of nutrients or other salts present in a substrate but doesn't identify which salts are present.
- The major contributors to EC are however, nitrate, chloride, sulphate, potassium, and magnesium.
- At high EC the concentration of nutrients may be higher in the solution around the plant roots than inside the roots, so water moves out of the roots by diffusion instead of into the roots.
- This hinders water uptake and may damage the roots, especially young roots/root hairs.
- Thus, a lower EC is required for seedlings and young plants (plus salt sensitive spp., eg. Rhododendron, Azalea).
- A higher EC can be used to control growth or improve fruit flavour (e.g. cherry tomatoes) as it restricts water uptake, however if it is too high plants will be damaged.
- The plant can adapt to a higher EC of the soil solution to some extent by concentrating the nutrient levels in their roots.
- If a crop is suffering from high EC, the usual recommendation is to flood with plain water to try to leach out some of the soluble salts.
- Any drying out of the soil or growing medium will concentrate the salt levels further so should be avoided, as should stress to the plants (use shading if necessary)
- Excessive conductivity (salinity) may occur when:
- Too much fertiliser is applied for the crop –
- Nutrient availability is increased e.g., rapid release of nutrients from controlled release fertilisers in high temperatures.
- Crops are irrigated with water containing salts such as chloride is used (e.g., borehole water)

Examples of sensitivity of different crops to high conductivity:

Very Sensitive	Sensitive	Tolerant	Very tolerant
Azalea Camellia Kalmia Primula	Lettuce Erica Alyssum Antirrhinum Raspberry Strawberry Blueberry	Carnation Chrysanthemum Tomato Pelargonium	Cordyline Yucca Chamaecyparis 'leylandii'

Limiting ECS for container grown plants (1:5 extraction ratio);

Conductivity	Conductivity pS/CM	Interpretation
0	0 – 150	Low EC
1	151 – 300	Max. for growing media for seed usually 200
2	301 – 400	Max. for salt sensitive spp./young plants around 350
3	401 – 500	Possible damage to less vigorous crops
4	501 – 600	Damage possible on most protected
5	601 – 700	Damage possible even to vigorous shrubs and established tomatoes, peppers, carnations
6+	>701	Severe damage likely

Water quality and its influence on plant nutrition

- The main aspect of water quality of concern to horticulturists is the ‘temporary hardness’ of the water (i.e., the carbonate and bicarbonate content).
- The bicarbonate level is also referred to as the ‘alkalinity’ of the water and is due to the rainwater moving through chalk or limestone.
- Hard water will cause blockages in irrigation equipment, it can cause marking on foliage where overhead irrigation is used and it raises the pH of the growing medium over time, which may reduce the availability of certain nutrients.
- Water with a bicarbonate level over 125 mg/l is considered ^{C}hard’ and if the level is over 250 mg/l it may cause problems.
- For example – the mains water from the downs in West Sussex/Hampshire has a bicarbonate level of around 300 – 350 mg/l.
- Alkalinity can be corrected using either strong acids or acidifying water-soluble fertilisers.
- In the UK the standard acid used is or 30% nitric acid but phosphoric acid or sulphuric acid can also be used.
- If nitric acid is used a typical rate of use will also add between 40 and 80 ppm of N to the water, which must be allowed for in liquid feed calculations.
- Use of any acid will increase the conductivity of the water or liquid feed so there may be limitations on the amount that can be used if the water has a high ‘background’ EC already.
- There are Health and Safety rules about the storage and use of acids, which must be complied with.
- Where acidification cannot be used because of the increase in EC it causes (e.g., for carnivorous plants) the only options are to find an alternative water source (e.g., rainwater) or to use reverse osmosis.
- The latter is expensive however.

Other water quality issues are:

- EC of the water, which may be influenced by geology or proximity to the sea, e.g., sulphate in spa areas or chloride from bore holes near the sea.
- Iron content, because when oxidised it can block irrigation equipment and mark foliage. Treatment is usually by aeration and then filtration.
  Boron level, where detergents have increased the B level, e.g., in river waters
- Pathogen levels — e.g., in recirculated waters
- With some elements it is the accumulation in the soil or compost over time which can lead to problems, so the total amount of the water applied to a crop is important, hence longer-term crops are more at risk.

- There are guidelines on water quality parameters but there are large differences in sensitivity between species.
- In general, ericaceous plants and legumes are more sensitive to poor water quality than other species.

Suggested maximum levels for irrigation water:

Electrical conductivity	850 micro siemens (20^0 C) (600 for plugs)
Bicarbonate.	200 mg/l (less for plus)
Nitrate	60 mg/l
Ammonium	10 mg/l
Potassium	100 mg/l
Calcium	120 mg/l
Magnesium	50 mg/l
Sodium	30 mg/l
Chloride	70 mg/l (<50 mg/l for plugs)
Boron	0.5mg/l
Iron	0.4mg/l
Manganese	3.0 mg/l
Zinc	0.3 mg/l
Copper	0.5 mg/l
Molybdenum	0.05 mg/l
Aluminium	2.0 mg/l
Fluoride	1.0 mg/l

Major and Minor Plant Nutrients and their function

The Essential Nutrients

There are 12 mineral elements needed by all plants in addition to the carbon, hydrogen, and oxygen which they obtain from the carbon dioxide in the air (from photosynthesis) and water in the growing medium. The mineral nutrients come from the soil or growing medium, entering plants through their roots. Major nutrients are those needed by the plant in greater quantities and the minor ones, or trace elements, are required in smaller quantities but are no less important.

Major nutrients

Nitrogen (N)
Phosphorus (P)
Potassium (K)
Calcium (Ca)
Magnesium (Mg)

Sulphur (S)

Minor nutrients

Iron (Fe)
Manganese (Mn)
Zinc (Zn)
Copper (Cu)
Boron (B)
Molybdenum (MO)

Functions of nutrients

Nutrient cycles and their behaviour in soils and plants

Nutrients behave in characteristic ways and may occur in different forms. An understanding of these different forms and of the processes involved is important, the Nitrogen cycle.

The Nitrogen Cycle.

The Nitrogen Cycle in soils is a very dynamic process but has great practical implications on modern agriculture/horticulture and prevention of nitrate pollution of watercourses. See separate handout.

Soil organic matter	This is the main 'pool' of nitrogen in the soil but in organic form is not available for plant uptake. Organic matter may be of recent origin (organic manures, crop debris) or much older. A typical arable topsoil may contain 4-8 t/ha of total N.
Microbial biomass	This is the population of living bacteria and other organisms in the soil. They are responsible for the decomposition of organic matter. The size of the microbial biomass will vary depending on soil conditions and the 'food supply'(i.e., organic matter).
Nitrogen fixation	Leguminous plants have symbiotic micro-organisms (e.g., rhizobia) associated with their root systems. These micro-organisms form part of the microbial biomass and 'fix' nitrogen gas from the atmosphere.
Mineralisation	This is the process of organic matter decomposition by the microbial biomass ammonium-N. Temperature, aeration (e.g., cultivation) and moisture are key control factors on the rate of mineralisation.
Nitrification	This is the process of bacterial conversion of ammonium to nitrate-N. Ammonium-N that is not nitrified will be absorbed by the soil as exchangeable ammonium. Nitrification inhibitors (e.g., DCD or dicyanamide) inhibit this conversion - the aim is to keep N in the ammonium form to reduce leaching risk.
Immobilisation ('locking up')	To 'feed' the living microbial biomass, nitrate is absorbed and 'immobilised' by bacteria. As these bacteria die so this nitrogen is mineralised - hence the nitrogen 'cycle'.

Leaching	This is the process of downward movement of nitrate through the soil profile. Nitrate may be leached but still available for crop uptake provided it is within the rooting depth of the crop. Where nitrate is leached below rooting depth it may pollute surface watercourses and aquifers.
Ammonia volatilisation	This is the direct loss of ammonia (NH3) gas. Organic manures are the main source of ammonia volatilisation. Ammonia is very soluble in water and thus losses are quickly reduced if there is close contact of the soil water and ammonia source.
Denitrification	This is the process of chemical reduction of nitrate (N03) to nitrous oxides (NOx) and nitrogen N2). The process requires warmish soils and anaerobic (without oxygen) conditions — waterlogged soils.

Most plants can absorb nitrogen in both the nitrate and ammonium forms. However, ammonium-N is usually rapidly nitrified to nitrate-N, which is the main form absorbed by agricultural crops

Nitrate leaching.

The amount of nitrate leached from soils is influenced by many factors. The most important factors are:

- The amount of nitrogen in the soil. Where there is a lot of nitrate present, the leachate water will have a high concentration of nitrate which will increase the total amount of nitrate leached for a given volume of drainage water. Nitrogen management practices are designed to minimise the concentration of nitrates in soil at any point in time, but especially before times of the year when there is a high risk of leaching. The key principle is to match nitrogen inputs (fertiliser, organic manures) to crop growth patterns.
- Water must drain through the soil before leaching can occur. Hydrologically Effective Rainfall (HER) - also called excess rainfall - is the amount of water that drains through a soil (HER=rainfall minus evapotranspiration between field capacity and the end of drainage). The risk of nitrate leaching is higher in wet than in dry rainfall areas.
- The soil types. Nitrates are more rapidly leached below rooting depth in sandy soils of low available water capacity (AWC) than other silty and clayey soils of higher AWC. Nitrates are more easily leached on shallow soils over rock where rooting depth is limited.

- Cropping. Where a crop is growing on the soil (particularly over-winter), nitrates will be taken up by the crop thus reducing leaching. Evapo-transpiration need will also reduce the HER amount.

The Phosphorus Cycle

Phosphorus is cycled through organic matter in the soil, but this process is less important than fertiliser as a source of P nutrients. P is absorbed by plants as orthophosphate (I-IxP04-). Phosphate anions in the soil are held on or in soil particles in complex associations with calcium, aluminium, and ferric iron. Some soils, particularly some calcareous clay soils, have a high capacity to fix phosphate. Phosphate anions do not leach through mineral soils in the same way as nitrate ions because they become adsorbed or absorbed onto/into soil particles.

Potassium, magnesium, sodium, and calcium cycles

These cations are positively charged and are held on clay particles. The fraction in solution plus that loosely held on clays is termed 'exchangeable' or 'labile' nutrient. Large 'non-exchangeable' reserves of potassium occur in some young clay soils which provide a significant supply into the exchangeable pool. Sandy soils of low clay content have a limited ability to retain these nutrients due to a shortage of (clay) exchange sites. Different nutrients are held on the exchange sites with different strengths. Thus, application of calcium will dislodge sodium - in practice this is reflected in the use of gypsum (a calcium source) to improve saline (sodium saturated) soils and the use of calcium nitrate to 'buffer' coir by displacing sodium ions.

Natural losses of these nutrients will occur on sand soils through leaching. Leaching losses will be higher where high rates of N are used.

The Sulphur Cycle

The Sulphur Cycle is very similar to the Nitrogen Cycle. Sulphur in organic matter is mineralised to sulphate (SOD which may be absorbed by plant roots or leached. Plants used absorb a large part of their sulphur requirement as S02 directly from the atmosphere when pollution levels were higher, but many crops now require sulphur fertiliser.

Elemental sulphur may not be absorbed directly by root or leaf uptake. Elemental sulphur must be oxidised to sulphate by soil bacteria (Thiobacillus) before uptake is possible.

Function of plant nutrients

Nutrient	Function in plant	Behaviour in soil
Nitrogen	Uptake mainly as nitrate (NO_3), but also possible as ammonium (NH_4); used in protein formation. Very mobile in plant.	Large store of N in soil organic matter (2-10 t/ha total N), but not all available for plant uptake. Nitrate is very mobile in soils; ammonium is immobile. Complex N cycle.
Phosphorus	Uptake as orthophosphate (H_xPO_4); used by plants in ATP energy transfer; mobile. Important for root and fruit development	Soil H_xPO_4 held by clay particles and in association with Ca, Al and Fe ions. Very little leaching potential on mineral soils but losses possible by surface runoff. Availability for uptake reduced at very low or very high pHs (<6 or >7).
Potassium	Regulates cell water content and turgor (sugars); important in disease and cold resistance, essential for some enzyme systems. Very mobile.	Occurs as K^+ in soil, and held by clay particles. Some clays can contain large natural reserves (native K<->non exch. K<->exch.K<->solution K. Small leaching losses possible on soils with <5% clay.
Magnesium	Needed for chlorophyll production. Very mobile.	Similar to potassium
Sodium	Needed by some crops (eg carrots, beet)	Similar to potassium. Marine soils are usually rich in sodium.
Sulphur	Uptake as sulphate (SO_4). Important in protein synthesis. Mobile.	Very similar to the N cycle. Reserves of S in organic matter that become available through mineralisation. SO_4 is mobile and will leach.

Calcium	Important for cell wall formation. Very immobile	Large amounts in calcareous soils, naturally low levels in sandy soils.
Iron	Uptake as ferrous (Fe^{2+}) or chelates. Needed for enzyme and chlorophyll production	Soils contain lots of iron but not available. Deficiency likely at high pH & calcareous soils, high organic matter, especially in perennial crops.
Manganese	Uptake as Mn^{2+} Needed for enzyme systems. Fairly mobile.	Low content in sands. High pH and high organic matter can cause crop deficiency.
Boron	Uptake as B^{2+} Needed for cell walls Relatively immobile	Low content on sands. Can leach. High pH/high organic matter can cause crop deficiency. Excess use of boron can cause toxicity
Copper	Uptake as Cu^{2+}. Poor mobility. Needed for enzyme systems and photosynthesis	Mainly occurs as Cu^{2+}. Held on clay surfaces or complexed in organic matter. Low content on sandy soils. Not leached. High organic matter can cause deficiency in crops such as carrots on organic soils.
Zinc	Uptake as Zn^{2+}. Poor mobility. Needed for enzyme systems.	Mainly occurs as Zn^{2+}. Held on exchange surfaces in organic matter. High pH, high P, low organic matter and calcareous soils can cause deficiency (not common in UK but has been recorded in susceptible crops, such as tomatoes, in peat based media and hydroponics). Not leached.
Molybdenum	Uptake as molybdate Fairly mobile. Needed for N reduction enzymes.	Held by clay particles. Acid soils cause Mo deficiency in susceptible crops such as brassicas ('whiptail') and Poinsettia.

4.3 Deficiency and Toxicity Symptoms

Element	Deficiency	Toxicity
N	Retarded growth. Pale leaves, starting with older ones, sometimes purpling.	Dark green leaves, stunted growth
P	Restricted growth, purpling of older leaves, premature leaf-drop in autumn.	Chlorosis of leaves, stunting, esp. P sensitive spp., Fe deficiency.
K	Interveinal/marginal necrosis/chlorosis on older leaves, poor fruit yield/flavour, reduced flowering	Mg deficiency symptoms
Ca	Distortion of growing points, e.g. 'tipburn', blossom end rot, bitter pit, small leaves.	Rare
Mg	Interveinal chlorosis /necrosis on older leaves	Rare
Fe	Interveinal chlorosis or bleaching of youngest leaves.	Mn deficiency
Mn	Interveinal chlorosis, beginning at leaf margins, on younger/middle aged leaves, leaf mottling.	Marginal cupping of younger leaves, dark spotting on leaves, papery bark.
Zn	Rare – small leaves	Fe deficiency
Cu	Rare, distortion of growth in some spp.	Fe deficiency
B	Death of growing points, heart-rot in root crops, mis-shapen fruit	Yellowing of margins of older leaves, interveinal spotting
Mo	Yellow leaf margins, margins of terminal leaves curl up, 'whiptail' in cauliflower.	Rare

Nutrient Incompatibility	
Excessive	*Inhibited*
Nitrogen	Potassium
Ammonium	Calcium, copper
Potassium	Nitrogen, calcium, magnesium
Phosphorus	Copper, iron, zinc, boron
Calcium	Magnesium, boron
Magnesium	Calcium
Sodium	Calcium, potassium, magnesium
Manganese	Iron, molybdenum
Iron	Manganese
Zinc	Manganese, iron
Copper	Manganese, iron, molybdenum

Key to the Typical Symptoms of Various Nutrient Deficiencies

Deficiency symptom	*Deficient nutrient*
The dominant symptom is chlorotic foliage.	
Entire leaf blades are chlorotic	
▼ ➔ Only the lower leaves are chlorotic, followed by necrosis and leaf drop ☚	Nitrogen
▼ ➔ Leaves on all parts of the plant are affected and sometimes have a beige cast ☚	Sulphur
Yellowing of leaves takes the form of interveinal chlorosis	
▼ ➔ Only recently mature or older leaves exhibit interveinal chlorosis ☚	Magnesium
▼ ➔ Only younger leaves exhibit interveinal chlorosis/bleaching. This is the only symptom ☚	Iron
▼ ➔ In addition to interveinal chlorosis on young/middle aged leaves, grey or tan necrotic spots develop in chlorotic areas ☚	Manganese
▼ ➔ While younger leaves have interveinal chlorosis, the tips and margins of leaves remain green, followed by veinal chlorosis and rapid, extensive necrosis of leaf blade ☚	Copper
▼ ➔ Young leaves are very small, sometimes missing leaf blades altogether, and internodes are short, giving a rosette appearance ☚	Zinc
Leaf chlorosis is not the dominant symptom	
Symptoms appear at the base of the plant	
▼ ➔ At first, all leaves are dark green, and then growth is stunted. Purple pigment often develops in leaves, particularly older leaves ☚	Phosphorus
▼ ➔ Margins of older leaves become chlorotic and then burn, or small chlorotic spots progressing to necrosis appear scattered on old leaf blades ☚	Potassium
Symptoms appear at the top of the plant	
▼ ➔ Terminal buds die, giving rise to a witch's broom. Young leaves become very thick, leathery and chlorotic. Rust coloured cracks and corking occur on young stems, petioles and flower stalks. Young leaves are crinkled ☚	Boron
Light green colour or uneven chlorosis/tip-burn of young tissue develops. Root growth is poor, roots are short and thickened ☚	Calcium

Use of Soil/Growing Medium/Leaf analysis

Taking samples

Samples for analysis must be representative.

- Sub-samples from across the area should be taken, usually 25, on a 'W' pattern. Sampling depth is usually normal cultivation depth (15cm) but deeper samples are usually taken for soil mineral nitrogen analysis as N is very mobile in the soil profile.

Growing media:

For unused growing media take sub-samples from across a bulk load or from at least 6 bags for bagged product. Note batch numbers/delivery dates on bags. For a growing medium in use take cores from at least 25 pots across the batch or take whole pots/plugs for young plants in smaller cell sizes.

Leaves:

Take leaves from several plants, sampling the youngest fully expanded leaves only. The number of leaves required will depend on the leaf size and size of batch being sampled.

Water

Run the supply for a few minutes before collecting a sample in a clean plastic bottle, note that the chemical composition of mains or borehole water can vary so sampling at different times of year recommended.

Use of handheld pH and EC meters

Portable pH and conductivity meters are available. These are useful for checking hydroponic solutions and liquid feeds but checking soil or compost is more difficult as the substrate must be mixed with distilled water first. pH is not a problem but where a low ratio of substrate to water (e.g., 1: 1) is used the moisture content of the sample will have a large influence on the concentration of the nutrients in the sample. Meters must be regularly re-calibrated (standard pH and conductivity solutions are available from NRM laboratories for this). Some EC meters are temperature compensated to 25 degrees C, not 20 so the reading will be 10% higher than a laboratory analysis at 20 degrees. When checking the EC of liquid feeds remember to allow for the 'background' EC of the mains water.

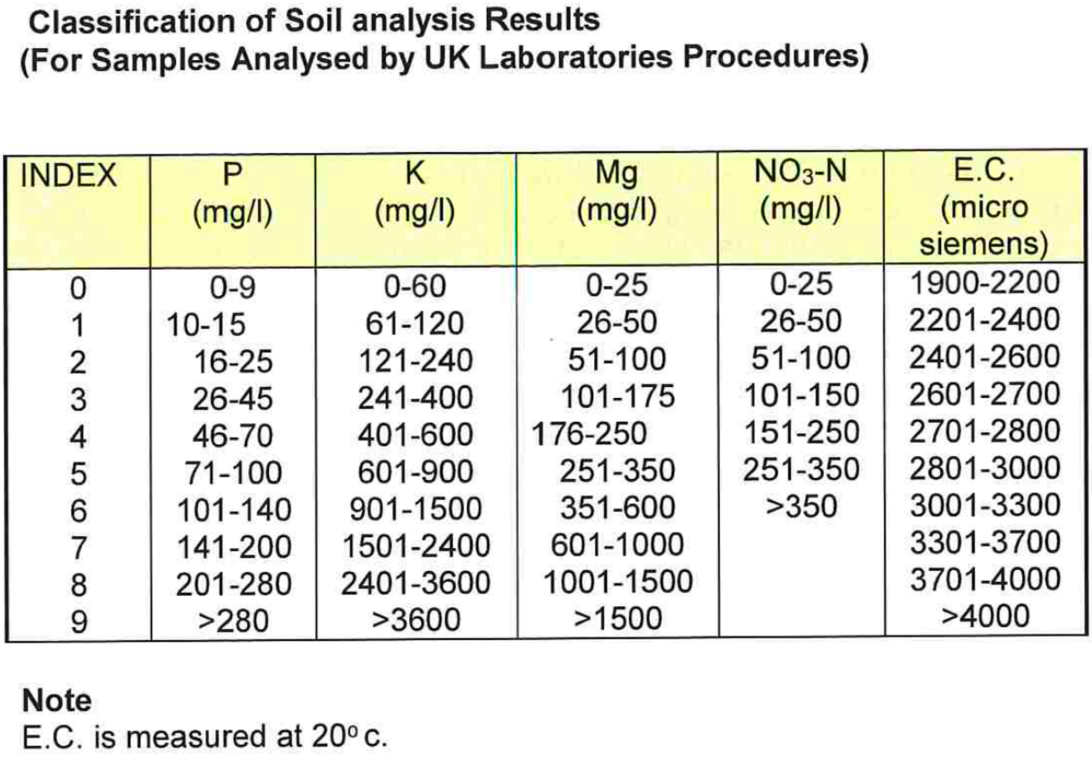
Soil pH can be tested for with soil indicator solution, which turns green in alkaline conditions and orange/red in acid conditions.

Types of analysis

Soils:

Soil samples are dried and ground before extraction to get the elements into solution for analysis. The nutrient levels quoted are usually on a dry weight basis and are given in mg/l or mg/kg. The major nutrients may also be given as an ADAS Index because fertiliser recommendations relate to the Index, not the exact mg/l. A lime requirement (to raise the soil to pH 6.0) may be given based on the pH and soil type.

A routine soil analysis usually includes pH, P, K, Mg, Nitrate-N and conductivity. Trace elements and sulphur may be tested for if necessary.



Classification of Soil analysis Results
(For Samples Analysed by UK Laboratories Procedures)

INDEX	P (mg/l)	K (mg/l)	Mg (mg/l)	NO_3-N (mg/l)	E.C. (micro siemens)
0	0-9	0-60	0-25	0-25	1900-2200
1	10-15	61-120	26-50	26-50	2201-2400
2	16-25	121-240	51-100	51-100	2401-2600
3	26-45	241-400	101-175	101-150	2601-2700
4	46-70	401-600	176-250	151-250	2701-2800
5	71-100	601-900	251-350	251-350	2801-3000
6	101-140	901-1500	351-600	>350	3001-3300
7	141-200	1501-2400	601-1000		3301-3700
8	201-280	2401-3600	1001-1500		3701-4000
9	>280	>3600	>1500		>4000

Note
E.C. is measured at 20^{o} c.

Growing media:

Growing media samples are not dried before extraction. The standard extraction ratio in the UK is I part growing medium to 5 parts water, hence the moisture content of the substrate at sampling will not have a major effect on the results. (Note 1:1.5 or 1:2 is common in other European countries.) The results are quoted on a volume basis so the density of the sample must be determined too. Nutrient levels are quoted in mg/l.

A routine substrate analysis usually includes pH, conductivity, and available levels of: Nitrate-N, Ammonium-N, P, K, Mg, Sulphate, Chloride, Sodium, Calcium, Boron, Copper, Manganese, Zinc and Iron.

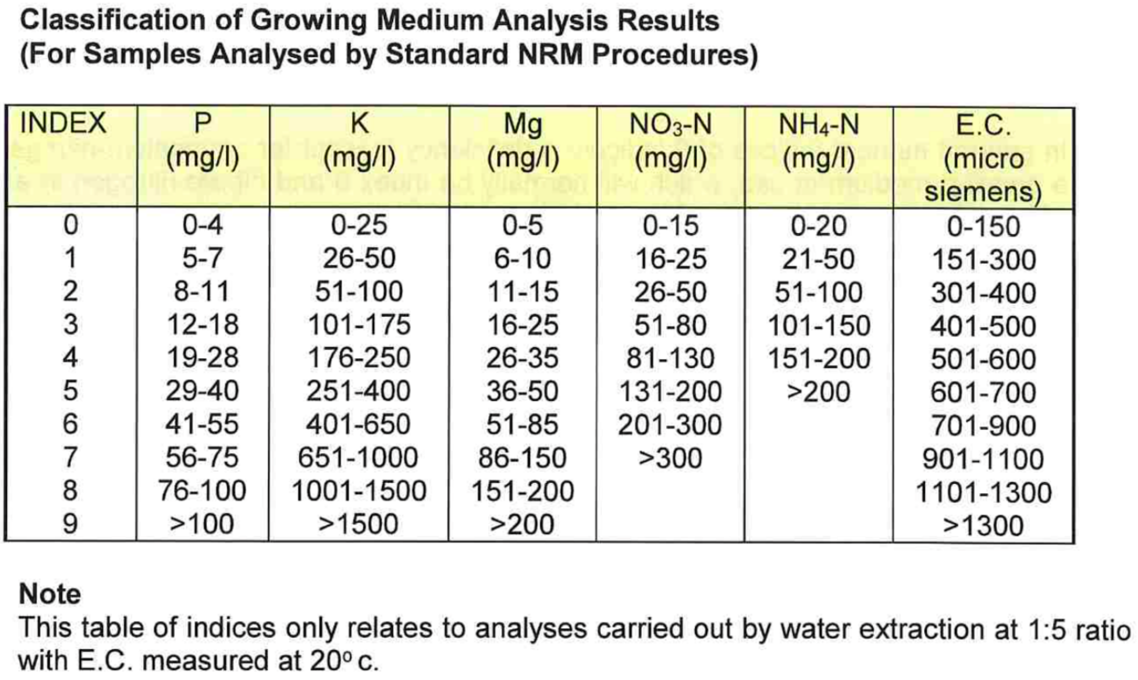
NOTE - THE BREAKDOWN OF MG/L INTO INDICES IS NOT THE SAME FOR

SUBSTRATE ANALYSIS AS FOR SOIL ANALYSIS BECAUSE THE METHOD OF ANALYSIS IS DIFFERENT.

If a substrate has controlled release or slow-release fertiliser incorporated an analysis for available nutrients will only tell you what was available to plants at the time of sampling and may be influenced if heavy rain or irrigation has leached available nutrients just before sampling. If you want to check the rate of controlled release fertiliser in a mix the best way is to do a granule count (assuming you have a figure for number of granules of the CRF per gram). This can only give a general guide; however, you must count granules from many samples or pots to get a statistically valid figure for granules per litre and hence kg/cu m.

Another type of substrate analysis is total water-soluble nutrient analysis where the material is macerated first to break up fertiliser granules. This is useful to check the nutrient reserves in the fertiliser.

Interpretation of growing medium analysis must bear in mind the time of sampling, crop growth stage, growing conditions etc.



Classification of Growing Medium Analysis Results (For Samples Analysed by Standard NRM Procedures)

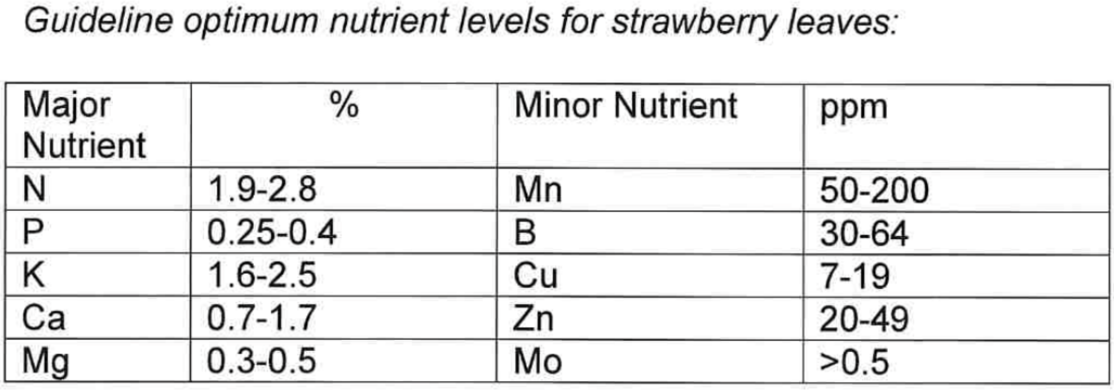
INDEX	P (mg/l)	K (mg/l)	Mg (mg/l)	NO_3-N (mg/l)	NH_4-N (mg/l)	E.C. (micro siemens)
0	0-4	0-25	0-5	0-15	0-20	0-150
1	5-7	26-50	6-10	16-25	21-50	151-300
2	8-11	51-100	11-15	26-50	51-100	301-400
3	12-18	101-175	16-25	51-80	101-150	401-500
4	19-28	176-250	26-35	81-130	151-200	501-600
5	29-40	251-400	36-50	131-200	>200	601-700
6	41-55	401-650	51-85	201-300		701-900
7	56-75	651-1000	86-150	>300		901-1100
8	76-100	1001-1500	151-200			1101-1300
9	>100	>1500	>200			>1300

Note

This table of indices only relates to analyses carried out by water extraction at 1:5 ratio with E.C. measured at 20° c.

Leaf tissue:

Leaf tissue analysis is not used as widely in the UK as in other countries and there is a lack of UK standard data for the wide range of ornamental species grown. There are standards for key crops however (e.g., tomatoes, strawberries, chrysanthemum) but the age of leaf sampled and type of sample (e.g., midrib/petiole of leaf included or not) will affect results. Leaves can be analysed for major and/or trace elements but iron analysis is not useful! on either leaf tissue or soi!!substrate.



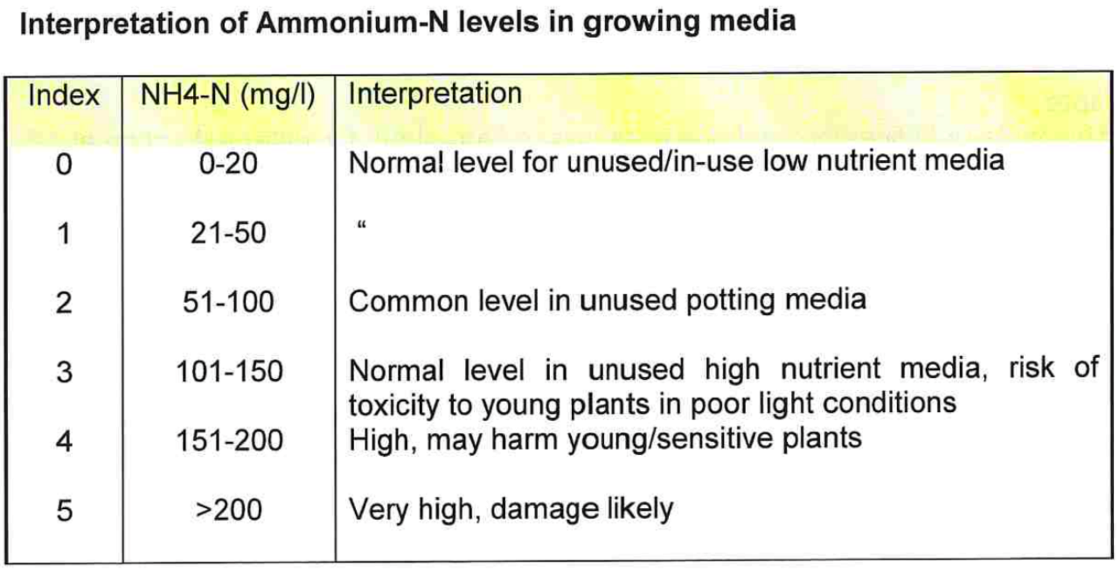
Guideline optimum nutrient levels for strawberry leaves:

Major Nutrient	%	Minor Nutrient	ppm
N	1.9-2.8	Mn	50-200
P	0.25-0.4	B	30-64
K	1.6-2.5	Cu	7-19
Ca	0.7-1.7	Zn	20-49
Mg	0.3-0.5	Mo	>0.5

Interpretation of Analytical Results

When interpreting analyses, it is important to know the background to the samples, when? from where? If samples are being taken to monitor nutrient levels it is useful to compare the results to previous ones, perhaps by plotting key parameters on a graph. If an analysis is for a 'one-off' sample, perhaps to diagnose why growth is poor it must be remembered that it is only a 'snap-shot' and that nutrient levels may change quite rapidly (in nutrient solutions and growing media anyway, soils are more stable nutritionally). For example, the conductivity in a pot may rise rapidly with over-fertilising but the salts will often leach quickly too so by the time a sample is taken the EC may not be as high as it had been.

In general nutrient Indices of 0 indicate a deficiency (except for ammonium-nitrogen in a growing medium in use, which will normally be Index 0 and nitrate-nitrogen in a soil which will often be Index 0). The desirable index for any one nutrient depends on the nutrient, the crop being grown, the system of production and the crop growth stage. Anywhere between Index 1 and 5 may be OK. An Index of 6 or above may indicate an excessive level, although in an unused substrate a high P index is not abnormal, and it will decline with time.



Interpretation of Ammonium-N levels in growing media

Index	NH4-N (mg/l)	Interpretation
0	0-20	Normal level for unused/in-use low nutrient media
1	21-50	“
2	51-100	Common level in unused potting media
3	101-150	Normal level in unused high nutrient media, risk of toxicity to young plants in poor light conditions
4	151-200	High, may harm young/sensitive plants
5	>200	Very high, damage likely

The principles of liquid feeding

Why do we need liquid feeds?

- Plants grown in a relatively small volume of growing medium will soon use up all the available nutrients hence, unless a controlled or slow-release fertiliser has been incorporated, supplementary fertiliser must be applied in either solid or dissolved form.

- For a typical peat growing medium the base fertiliser will only provide about 10% of the total plant's requirements through the life of the crop and supplementary feeding will be required from between 2 and 8 weeks after potting, depending on the mix specification and the crop vigour.

- Top-dressing with solid fertiliser is not always practical hence the use of water-soluble fertilisers once the base dressing incorporated in the substrate/soil has run out is well established in some sectors of horticulture.

- Some sectors e.g., nursery stock, tend to rely more on the use of controlled release fertilisers to provide long-term nutrient supply.

The efficacy of a liquid feeding programme depends on good monitoring of the crop requirements and the feed being applied. It is then possible to have more control over the crop development than can be achieved with controlled release fertilisers, which is why liquid feeding is generally preferred by pot plant growers.

Basic principles:

The type of liquid feed required depends on:

- How long the plant is to be grown for
- How vigorous the plant is and the stage of growth
- The type of irrigation system used
- Water quality

Calcium and magnesium are usually supplied from the lime added to the soil or growing medium but can also be added in liquid feeds, magnesium sometimes needs to be included in the feed to ensure a satisfactory K : Mg ratio is maintained.

Nutrients applied are usually expressed as either mg/l (= parts per million assuming density of 1), e.g., 200 mg/l or 200ppm Nitrogen.

P & K are sometimes expressed as the oxide **(P_2O_5 = P x 2.29 and K_2O = K x 1.2)** you must know whether you are using the **element** or the **oxide** when referring to **P & K.**

The actual amount of nutrient available to a plant will depend on the volume of liquid applied; hence you need to get a whole litre of liquid into a pot to apply 200 mg N if using a 200 mg/l N feed.

In small pots/plugs the volume of water with the feed dissolved in it going into each cell is small so maintaining nutrient levels is more difficult and a constant dilute feed system is preferable to feeding once a week with a more concentrated feed.

The ratio of nutrients applied in the liquid feed should match the plant requirements otherwise deficiencies/toxicities can occur.

Over application of one nutrient could reduce availability of another. Over application of nutrients is also wasteful if the runoff from watering/feeding is not collected and could cause pollution.

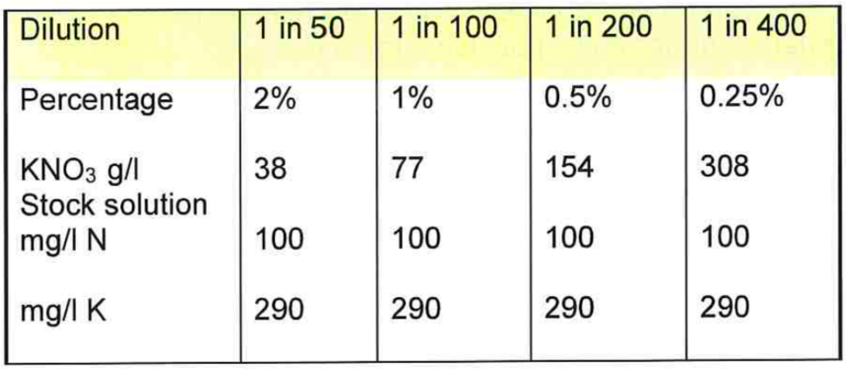
Water high in bicarbonate may need acidifying before adding liquid feed (allow for extra N applied in the acid), otherwise nutrients such as P are less available.

If the water is only moderately hard (170-250 mg/l bicarbonate) liquid feed containing urea phosphate can be used to acidify it and maintain P availability

Making up liquid feeds

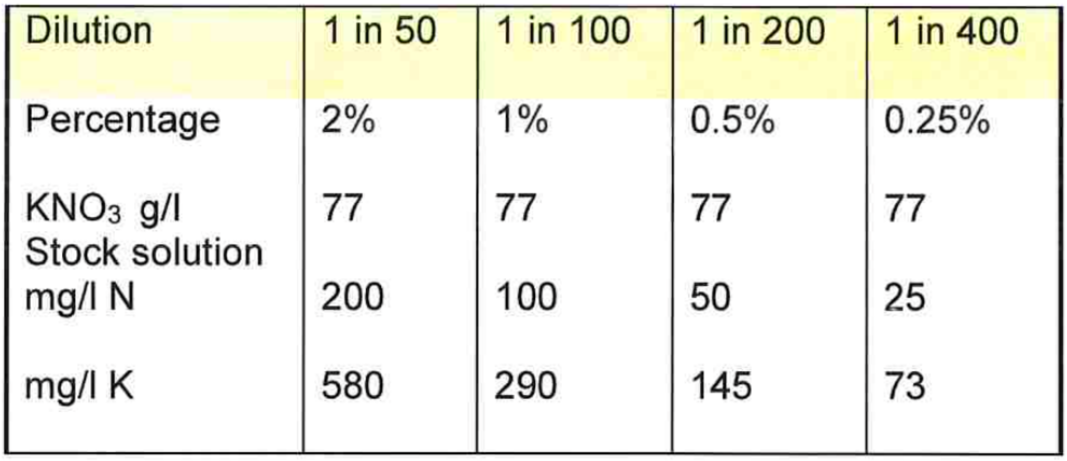
The standard system for making up liquid feeds is to dissolve fertilisers in a smaller volume of water first to make a 'stock solution'. This is then applied through a dilutor to the crop, e.g., at 1% = 1 part stock solution in 100 parts water. In summer a more dilute feed (e.g., 1 in 200) may be used because the crop needs larger volumes of water but in winter less water can be applied otherwise the plants will become waterlogged so a I in 100 feed may be better. Very strong feeds (e.g., 1 in 50 or 2%) must be rinsed off the foliage with plain water to prevent leaf scorch.

Example of use of different stock solutions of potassium nitrate (14% N, 38% K):



Dilution	1 in 50	1 in 100	1 in 200	1 in 400
Percentage	2%	1%	0.5%	0.25%
KNO_3 g/l Stock solution	38	77	154	308
mg/l N	100	100	100	100
mg/l K	290	290	290	290

Example of use of the same stock solution at different dilutions:



Dilution	1 in 50	1 in 100	1 in 200	1 in 400
Percentage	2%	1%	0.5%	0.25%
KNO_3 g/l Stock solution	77	77	77	77
mg/l N	200	100	50	25
mg/l K	580	290	145	73

Equation for calculating fertiliser requirement:

$$\textbf{g/litre stock solution} = \frac{\textbf{mg/l of element x dilution factor* x 100}}{\textbf{1000 x \% of element in fertiliser}}$$

* Dilution stock solution is applied at, (if 1 in 100 figure is 100)

Example:

To make a feed with 200 mg/l N, 30 mg/l P and 150 mg/l K when diluted 1 in 100:

1. Calculate the P first, from MAP

$$\frac{30 \times 100 \times 100}{1000 \times 24.5} = \mathbf{12.2g}$$

This will also supply N (12% N):

12/100 x 12.2 g = 1.5 g in stock solution = 1500 mg=15 mg/l when diluted 1 in 100

2. Calculate the amount of potassium nitrate needed to give 150 mg/l K

$$= \frac{150 \times 100 \times 100}{1000 \times 38}$$

$$= \mathbf{39.5\ g}$$

This will also supply N (14% N):
14/100 x 39.5 g = 5.5 g in stock solution = 5500 mg =55 mg/l in feed at 1 in 100.

3. Calculate how much more N is needed from ammonium nitrate:

N so far = 15 mg/l from MAP + 55 mg/l from KN03 = 70 mg/l,

200 - 70 = 130 mg/l N still needed
Amount of ammonium nitrate needed to supply 130 mg/l N

$$= \frac{130 \times 100 \times 100}{1000 \times 34.5} = 37,$$

The final recipe for stock solution is:

12.2 g/' mono ammonium phosphate (1.22kg in 100 litres)
39.5 g/l potassium nitrate (3.95 kg in 100 litres)
37.7 g/' ammonium nitrate (377 kg in 100 litres)

Checking liquid feeds

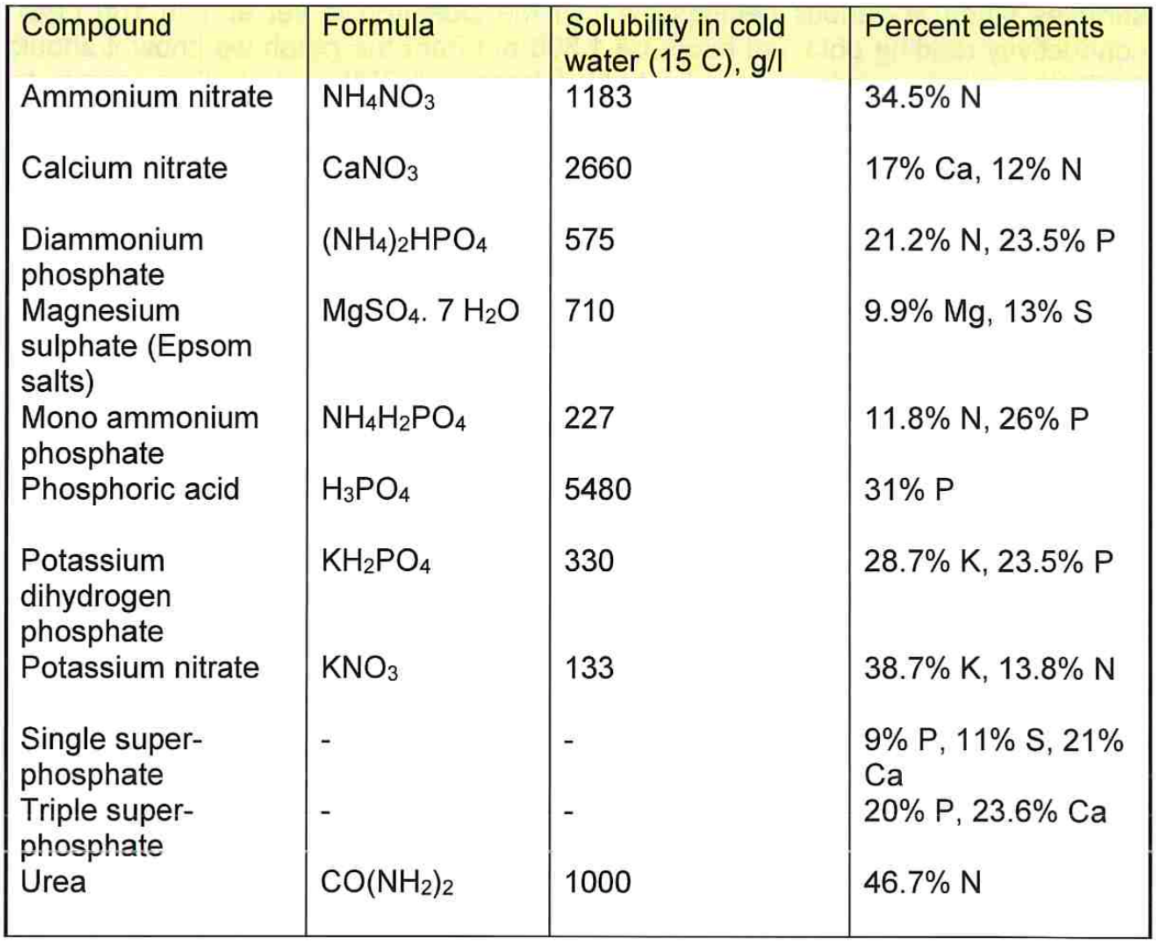
To check that a liquid feed is the right strength measure the conductivity using a hand-held EC meter.

For proprietary feeds the expected EC for a given concentration of feed will be given on the bag but allowance must be made for the 'background' EC of the water.

NOTE

if urea is used as a source of N in a liquid feed its contribution cannot be checked from the conductivity as it is non-ionic so doesn't affect the conductivity.

Compositions of commonly used fertilisers



Compound	Formula	Solubility in cold water (15 C), g/l	Percent elements
Ammonium nitrate	NH_4NO_3	1183	34.5% N
Calcium nitrate	$CaNO_3$	2660	17% Ca, 12% N
Diammonium phosphate	$(NH_4)_2HPO_4$	575	21.2% N, 23.5% P
Magnesium sulphate (Epsom salts)	$MgSO_4 . 7 H_2O$	710	9.9% Mg, 13% S
Mono ammonium phosphate	$NH_4H_2PO_4$	227	11.8% N, 26% P
Phosphoric acid	H_3PO_4	5480	31% P
Potassium dihydrogen phosphate	KH_2PO_4	330	28.7% K, 23.5% P
Potassium nitrate	KNO_3	133	38.7% K, 13.8% N
Single superphosphate	-	-	9% P, 11% S, 21% Ca
Triple superphosphate	-	-	20% P, 23.6% Ca
Urea	$CO(NH_2)_2$	1000	46.7% N

Calibrating a dilutor

Liquid feeds are commonly applied with a dilutor that adds a certain volume of stock solution to the irrigation water as it passed through it.

It is important to calibrate such dilutors regularly:

- Make up a stock solution of the fertiliser containing IOOg/l
- Stir and leave for fertiliser to dissolve completely
- Make up a series of dilutions- 1:50, 1: 100, 1:200 and 1:400
- Measure the conductivity of each of the dilutions and plot them on a graph

Use the curve to set the dilutor to a specific dilution you can then take the stock solution and run it though the dilutor and read the conductivity on samples taken at various settings.

Example:

If the Dosatron is set at 1 in 100 (1%) the conductivity reading obtained might be 1,300 but from the graph we know it should be 1 ,450 the setting needs to be adjusted, perhaps to 1.25% and another sample taken to see if the conductivity is right.

The settings on the Dosatron are used only as indicators and the conductivity readings measure the accurate strength of the feed applied.