Module 3

PLANT NUTRIENTS AND THE BASIS FOR CHOICE OF FERTILISERS FOR THE MAIN HORTICULTURAL CROPS

BEDDING/POT PLANTS - NUTRITIONAL TECHNIQUES

Liquid Feeding

- Production of bedding and pot plants on short timescale.
- Low rate of base fertiliser topped up with liquid feeding.
  - Strength, frequency, and ratio of nutrients can easily be changed.
  - Liquid feeding sometimes used to supplement low-rate use of CRF.

Controlled Release Fertilisers

- Production based on use of CRF granules usually incorporated into medium at time of manufacture.
- Type of product and rate based on crops and the production period.
- Short-term crops such as summer bedding (6 weeks).
- Longer term pot plants & bedding crops over-wintered then CRF can be of particular benefit.
- Useful for giving extra shelf life to plants after despatch.

GROWING MEDIA INGREDIENTS FOR POT/BEDDING PLANTS

Reduced peat media with 10-30% of other materials added used to comply with multiple retailer environmental policies. Additions improve the air/water ratio but may require modifications to the irrigation regime. One of the multiple retailers sells a range of bedding in coir-based modules to avoid the use of peat.

Seedlings and plugs

- Growers usually buy in plugs - specialist producers in UK or The Netherlands.
- Young plants need to be fed little and often, at a low EC rate.
- The growing medium usually only has a low rate of base fertiliser, e.g., 0.5kg/m ^{3}.
- Growing in small units needs careful management of water and feed.

Pots and trays

- Once seedlings or plugs have been potted into pots or trays liquid feeds of different ratios may be used according to the stage of production.

- Move away from the traditional polystyrene (for environmental reasons) and plants are now sold in mesh modules in recyclable plastic

KEY CROPS

Summer Bedding/Patio Plants

- Numerous varieties / cultivars, normally split into three growing regimes:
  Cool (5-10 ^{0}C), warm (10-15^{0}C) and hot (15-18^0 C).
- Normally very short-term 8-12 weeks depending on the time of the year and temperature regime.
- Most potted in spring and sold between April and June.
- Many need no further feed then the base in the growing medium with occasional liquid feeds.

Primulas and Pansies (winter bedding)

- Sown in May — July and transplanted 5-6 weeks later.
- Sold in the autumn or over-wintered to be sold in flower in the spring.
- Do not require high levels of feed, roots sensitive to high salt levels.
- pH should be maintained between 5.5-6.0.
- Chlorosis is common, as iron becomes unavailable when the pH is high and/or there is waterlogging of the substrate.

Poinsettia

- Potted around July for sale over the Christmas period.
- Growing medium with a good AFP is essential, pH of around 6.0.
- Usually grown with a liquid feeding system on 'ebb and flow' benches.
- Substrate structure must allow good capillary movement of feed solution.
- Poinsettias suffer from molybdenum deficiency.
- Avoided by adding sodium or ammonium molybdate to the feed and by avoiding low pH in the medium.
- Calcium deficiency may occur, causing bract browning, especially if humidity levels are high.

Cyclamen

- Winter pot plant, sold particularly over Christmas.
- Medium with 25% bark best for good drainage and help prevent root diseases.
- Sown Feb - April at 15-18^0 C, germination up to 4 weeks and then transplanted at 8 weeks.
- If CRF not used then Cyclamen are typically fed with 2:1:1 feed until the bud's form, then 1:1:1 until the flowers form, finally 1:1:2 as the flowers develop.

Orchids

- Orchids need a very well drained substrate so are usually grown in 100% bark.
- Produced in 2 stages — warm to develop the foliage and then cool for flowering.

Other pot plants

- Pot chrysanthemum and Begonia are usually produced in 13cm pots with capillary watering/feeding.
- Most are on benches with automated movement/spacing as the crop develops.

NURSERY STOCK

- Hardy Ornamental Nursery Stock (HONS) a wide range of plant species grown for outdoor planting.
- HONS is produced for retail (Garden Centre or multiple) or amenity markets (via landscapers).
- Production systems tend to be larger scale but less intensive.
- Large crop diversity it is harder to manipulate fertiliser application to specific crop requirements.
- HONS nurseries become increasingly specialised then greater control over fertiliser application.
- The sector mostly relies on bought-in mixes in semi bulk bags.
- Increasing trend in the UK for nursery stock to be grown in polythene tunnels and glasshouses to reduce winter losses.

Controlled Release Fertilisers

- HONS production in the UK is predominantly based on the use of CRF as
- Usually incorporated into the growing medium at the mixing stage.
- Ensure all CRF is evenly mixed throughout the batch.
- Rate of application adjusted according to growing system, particularly the irrigation system (lower rates on sub-irrigation systems like sand beds) and the level of base fertiliser used.
- Alternative to incorporation at mixing CRF can be applied to each pot during the potting process.
- Known as 'dibbling'. CRF is usually dropped into the hole made for the plant before the plant is inserted.
- The correct amount of CRF is applied through a calibrated dispenser.
- Where accurate controlled release is guaranteed then this is an accurate method and allows the rate to be varied for each species being potted.
- CRF can be applied to the pot surface this can promote the growth of liverwort and requires overhead irrigation to be effective.
- CRFs are manufactured to ensure that fertiliser is released over specified periods of time, example in 5-6-, 8-9-, 12-14- and 16–18-month formulations.
- Choice will depend on the growing time for the crop.
- Crops likely to be sold within a few months of potting will only need a short-term CRF; crops grown over a two-year period (e.g., large specimen or slow growing species) will require a longer term product
- Suppliers provide variations to meet expected changes in crop demand at different potting times and for different species, for example, 'fast start' and 'slow start' formulations.

Other fertilisers

- CRFs not so widely used in other parts of Europe. Mechanised systems in countries like The Netherlands mean the use of liquid feed is more widespread.
- Many growers will not use exclusively CRFs, often a low rate of base fertiliser is also added. Usually a low level of N, P and K sufficient to maintain plants through the early stages following potting. (Typical rate 0.5 - 1.0 kg/cu m).
    - Calcium nitrate may be added to counteract nitrogen immobilisation in mixes containing bark or wood-fibre.
- For peat-based mixes lime is needed depending on the desired pH for the crops being grown. The target pH for general HONS species is usually 5.5 and for ericaceous species around 4.5.
- If CRF becomes exhausted before the plants are sold or potted on then it may be necessary to add additional fertiliser. Usually done by applying a top dressing or liquid feeding. Top dressing with solid fertiliser must be done in good time to allow for the nutrients to be washed into the growing medium.
    - Plugs of controlled release fertiliser can also be inserted into pots to prolong nutrient release but this is expensive. Foliar feeding can be used to green up plants short of fertiliser.
- CRFs still the mainstay in HONS production in the UK. Provides relatively precise fertiliser application with minimum further management and low risk to the environment. In return for these advantages the costs are quite high.

KEY CROPS:

Main crops produced by container HONS growers include:

evergreen & deciduous shrubs, conifers, ornamental grasses, ornamental trees, fruit trees, climbers, alpines, herbaceous, perennials, ericaceous plants (e.g. Rhododendron)

Propagation plugs:

- Cuttings should not be exposed to high levels of feed this can damage new growth.
- Once rooting has occurred feed requirement will increase quickly.
- Plugs and cuttings are normally maintained by use of liquid feed.
- Mini CRF granules are available for plug trays.
- Important to use mini granules in plugs to ensure that each plug receives fertiliser.
- Larger granules for older plants, when mixed at appropriate rates, would not be well distributed in every cell, leading to poor uniformity.
- Typical growing medium in propagation is 50:50% peat: bark to provide adequate drainage and AFP for rooting.
- Perlite can be used and coir also useful for propagation because it has high air capacity.

Liners

- The 'liner' phase of growth is that between plugs and final potting and is often carried out under protection.
- Liners (8-10cm pots) often grown in a 75:25% peat: bark or peat: Woodfibre mix, particularly ericaceous species.
- CRFs are used in liners and supplemented with liquid feed when needed.

Finished plants

- From liner stage plants typically potted into 1, 2 or 3 litre pots until final sale.
- The mix is normally the same as for the liners although CRF with a longer release period may be used if plants are likely to be kept on the nursery for longer periods of time.
- Plants over-wintered out-doors will need a more free-draining mix than those under protection.

Ericaceous plants

- Ericaceous HONS includes Rhododendron, Camellia, Pieris, Magnolia, Azalea, Erica, and Calluna.
- Acid loving plants will require less lime and lower growing pH between 4.5 - 5.5.
- Ericaceous plants have finer roots and benefit more from the use of bark because it buffers against peaks in nutrient levels.
- Some species (e.g. Camellia) are more sensitive to phosphate levels than non-ericaceous crops.

Other crops

- Alpines tend to be grown with more bark than standard HONS mixes.
- This is to recreate their natural growing conditions with open growing media.
- Herbaceous plants and ornamental grasses tend to be fast growing and sometimes a fertiliser with a lower N content and higher K content is used to avoid excessive leafy growth, especially for autumn potted crops.
- Container trees may be field grown to start with and then transferred to containers and grown in a similar mix to the shrubs described earlier.

PRODUCTION SYSTEMS

- HONS producers still rely on overhead irrigation.
- Use of CRFs helps to minimise losses of nutrients by leaching,
- Extra fertiliser may be needed where heavy irrigation or rainfall has leached out existing nutrient reserves.
- Lower fertiliser rates can be used in capillary systems, such as sand beds.
- These systems use water more efficiently.
- EC levels can rise where fertiliser is not leached through and may be necessary to flush through the plants with overhead irrigation on to prevent salt build up.
- Increase in HONS production under glass or polythene in recent years to produce plants for spring sales and reduce losses in wet winter

CUT FLOWERS

- Most cut flowers are soil grown, either under protection or outdoors.
- Main flower crops in UK now are glasshouse AYR Chrysanthemum, Lilies and Alstroemeria, outdoor crops such as Stocks, Sunflowers and Sweet William.

Base dressing

- Most cut flower need adequate base fertiliser before planting out.
- In some cases, it is not possible to fertilise after this stage example, Antirrhinums are very sensitive to high EC levels and quality is seriously reduced if fertiliser is added during growth.
- 'Straight' or compound fertilisers can be used.
- When deciding on the best fertiliser to use, it is most important to get the nitrogen application rate correct.
- Response to phosphate and potash will usually be less than the nitrogen response and in many cases P and K will only be applied for maintenance purposes.
- Potassium should be applied in the autumn, as a sulphate rather than as a chloride where possible.
- It is beneficial to place phosphorous in bands close to the transplants at the time of planting out.

Top dressing

- Top dressings of fertiliser used to supplement base fertiliser where necessary.
- A proportion of the N may be applied as a top-dressing following crop establishment.
- This will help to reduce N leaching and to avoid damage to young root systems through high EC levels.

Liquid feed

- Liquid feeds are generally used to apply extra nutrients and rectify deficiency.
- In some crops, such as cut flowers under glass, liquid feeds are applied on a regular basis, often at each watering.
- This gives more precise control over nutrition levels.

Blocking Substrate

- Cut flower transplants are often raised in peat blocks prior to planting out.
- The blocks commonly consist of a mix of sphagnum and sedge peat with a base dressing incorporated.
- Module production may also involve supplementary liquid feeding.

Field Production of Dry Bulbs and Bulb Flowers

- Bulbous species used production include Narcissus, Tulipa, Anemone coronaria, Crocosmia, Liatris and Gladiolus.
- A key factor in nutrition of bulbs is the significant quantity of stored carbohydrate held within each bulb.
- Nutritional strategies will depend upon the length of time the bulbs are under cultivation and the production system.
- Example, bulbs used for flower production are usually a one-year crop; the bulbs will be discarded following harvesting.
- Serious deficiencies are unlikely to occur in this one season due to the resources within the bulb.
- Dry bulb production often requires crops to be in the ground for two years before lifting.
- Deficiencies are more likely to become apparent in these crops during year two as bulb reserves become depleted.
- Care should be taken to avoid high EC levels; all bulbous ornamentals are susceptible to root damage through high salt concentrations in soil or containers used for forcing.

Bulb Forcing

- Forcing substrates generally peat-based mixes, with reduced peat being used.
- They contain a low level of base fertiliser as the level to avoid any root damage.
- Supplementary nutrients supplied through liquid feeding during glasshouse phase.
- Not all forced crops require fertilisers.
- Example, tulips benefit from low levels of calcium nitrate in the irrigation water once a week, there is no evidence to suggest that daffodils benefit at all from fertilisation during the glasshouse stage.
- Lilies have a higher nutrient requirement and require a base fertiliser in the trays plus liquid feeding.
- Growing percentage of tulips are now forced in systems with water and no substrate at all.

PROTECTED SALAD CROPS (SOUSUBSTRATE GROWN)

- Main difference between edible crops and ornamental crops is the yield of foliage/fruit is important and the cosmetic appearance of the plant less so.
- To achieve high yields even sub-optimal levels of nutrients may become critical.
- Flavour and chemical content of the harvested crop are also important, and these may be manipulated through nutritional management of the crop e.g. high potassium feeds for tomatoes or the use of sodium chloride for celery.
- There is more regular monitoring of nutrient levels in the substrates for salad crops and more data on optimum nutrient levels in the leaves.

Propagation

- Seeds sown in blocks or modules, peat for soil grown and synthetic media for hydroponic crops.
- Blocking substrates include a percentage of sedge peat so the blocks hold together have a lower AFP than other peat growing media.
- Base fertiliser dressing included in substrate if the young plants are held for longer, liquid feeding may be needed.
- pH of 5.5-6.5 is standard, with low nutrient levels (*EC not above ADAS Index 2*) and a low ammonium-N level (not > 50 mg/l).
- Substrates with an organic fertiliser base are available for growers of organic salads.
- Care needs to be taken in the storage of growing media containing organic nitrogen sources because of the potential release of damaging levels of nutrients, particularly ammonium and nitrate.

Soil grown crops

- Apart from organic crops, where production in the soil is a requirement of certification in the UK, lettuce, herbs, celery, aubergines, and cherry tomatoes are the main crops
- **Lettuce** is sensitive to high conductivity; soil EC level must be checked before planting and soil flooded if necessary to reduce the salt level. Lettuce also sensitive to calcium deficiency ('Tip burn') if the plants are not actively transpiring e.g., in humid conditions or a sudden change to very bright weather in the spring.
- **Celery** sensitive to boron deficiency, especially on sandy soils with a pH above 6.5. A soil analysis before planting will determine if the B level is low and either a soil or liquid application of boron can be applied if necessary.
- **Cherry tomatoes** are grown at a high conductivity as this increases fruit dry matter and improves the flavour.
- Adequate potassium levels are important for fruit quality and affect the acid content of fruit and the flavour.

Grow bag crops

- Commonly still used by amateur gardeners, few commercial crops are grown in growbags.
- Growing medium is usually peat-based and should be limed to pH 5.5 - 6.5 (depending on the water hardness) and the plants are liquid fed once the base fertiliser has been used up.
- Other organic materials, such as wood waste and coir, are being increasingly used.

Pot grown crops

- Main pot-grown edible crops are 9cm and 13cm edible herbs, grown primarily for supermarket sales.
- Short-term crop so a bedding plant type substrate is used, with liquid feeding as necessary once the plants are established.
- Plants are grown on benches with recirculated feed which checked regularly as build-up of chloride and sulphate tends to occur over time, so occasionally the feed must be started from fresh water again.
- Pressure to produce such crops organically, so organic base fertiliser and feed may be needed.
- The problem with organic fertilisers is the unpredictable release of nitrogen.

PROTECTED SALAD CROPS • HYDROPONIC SYSTEMS

Introduction

Hydroponics the technique of crop production in solutions containing all nutrients essential for plant growth, both major elements and minor (trace) elements.

- Plants may be rooted into an inert growing medium (or substrate), such as sand, gravel, perlite, polyurethane foam, or mineral fibre (rockwool or glass wool), to which the complete nutrient solution is applied.
- Rockwool (stone wool) is the most common material used.
- Increasing use of non-synthetic media such as coir and wood waste, mainly for cost reasons but also for environmental reasons.
- Excess nutrient solution may then be re-circulated to the plants or allowed to drain from the system.
- Alternatively, the plants' roots may be bathed in nutrient solution in aerated tanks or in a thin film of re-circulating solution in sloping channels.
- The latter technique is known as the Nutrient Film Technique (NFT).
- Potential problem with hydroponics is solubility of oxygen in water is very low and decreases with increasing solution temperature. The rate of diffusion of oxygen through still water is also very low.
- NFT provided a breakthrough because the thin film of water in NFT systems is better aerated, both because the oxygen has a shorter distance to diffuse and there is more turbulence as the solution flows down the channel.
- The system also lends itself to the use of modern, cheaper materials, such as plastics.

The potential benefits of hydroponic productions systems are:

- Precise control of root environment to maximise yield and quality.
- Optimum control of moisture availability, aeration, temperature, nutrient supply, and osmotic potential.
- Independence from site restrictions, such as imposed by adverse soil types.
- The avoidance of soil-borne pests, diseases, and weeds, without sterilisation.

The potential disadvantages of this systems are:

- Risks of acute crop problems in the event of equipment failure, power failure or poor management.
- High capital and running costs, which can normally only be justified for intensive, high value protected crops.
- Problems of maintenance and aftercare by consumers of hydroponically grown containerised plants e.g. pot plants.
- The risk of rapid disease spread in re-circulating systems and need for stricter hygiene.
- Problems where water quality or composition varies.
- Occasional problems associated with the formulation of some fertilisers used, particularly potassium nitrate, which have resulted in contamination and blocking of the system and resulting crop

problems. The problem may relate to the type or amount of anti-caking agent added to the fertiliser, which can provide a carbohydrate source for moulds such as Trichoderma, blocking the irrigation system.

Water supplies

- Adequate supply of clean, disease-free water of suitable chemical composition is required, both to meet short-term, peak requirements and annual needs.
- Nutrient content of the water supply will govern the composition of the fertiliser concentrate added, according to the crop grown, and a full analysis of the water supply is the first requirement to produce a suitable nutrient addition recipe.
- Hardness of water will dictate need for acidification or pH control.
- Water supplies high in non-nutrient ions, which accumulate in recirculating systems. Examples sodium and chlorides.
- Some borehole supplies high in iron, which oxidises when exposed to air and can causes serious problems with blocking of irrigation nozzles, without proper treatment.
- Occasionally nutrient elements such as boron, commonly found in treated river water supplies, having originated from detergents, may be present in such quantities as to accumulate to toxic levels in re-circulating solutions.
- This is especially so where complete, proprietary nutrient mixes are used, rather than those made up from individual components on site.
- It is also possible for other elements to rise to toxic levels from sources within these systems.
- An example is of zinc, from galvanised or brass fittings used in pipework.
- The acidified nutrient solution used is quite corrosive and dissolves the zinc in these cases.
- Only suitable rigid plastic fittings and pipework should be used for hydroponic crops.
- Major nutrients, such as calcium and sulphur (as sulphates) may be present at such high levels in the water supply that they accumulate in re-circulating systems.
- Whilst these may not be directly toxic, their accumulation may cause imbalances with other nutrients.
- Since the most common method of controlling the strength of the nutrient solution is by measuring its electrical conductivity, the contribution from these accumulated salts to the EC can lead to a reduced input, and subsequent deficiency, of other nutrients.
- Rooting volume of hydroponic crops is very low, compared to those in soil, very frequent irrigation of crops in non-re-circulated, "run to waste" systems is needed under peak radiation, summer conditions.
- May be several times per hour, or up to 30 times per day.
- An efficient and accurate irrigation system is a requirement.
- Irrigation frequency control needs to relate to the transpiration rate of the plants at the time.
- The major factor in determining this is the amount of solar radiation.
- A benefit of re-circulating systems, such as NFT, is that water input is easily controlled through a simple float valve arrangement, which responds directly to the use of water by the crop.
- Another benefit is that the use of water, and associated nutrients, is substantially lower, around a third less, than in run to waste systems.
- This has both cost and environmental benefits.

Acidification of water supplies

BEWARE: SAFETY WARNING!

- Concentrated nitric and phosphoric acids are highly corrosive and must be handled with care and precautions.
- Always add acid to water, never add water to acid, as this may cause splash-back of acid.
- Wear eye protection, rubber gloves and protective clothing.
- Use a siphon pump when handling concentrated acid.
- The hardness of water, as described by its bicarbonate content, determines the amount of acidification needed, if any, to reduce the pH to levels which are optimum for nutrient uptake.
- Areas of the country where water supplies are derived from chalk strata, as the Lea Valley, Sussex and Hampshire, bicarbonate levels are moderate to high.
- These supplies need the addition of corresponding amounts of acid to neutralise them.
- Normally nitric acid, phosphoric acid or mixtures of the two are used.
- These also supply nitrate and phosphate, which needs to be considered when producing a feed recipe.
- Normally bicarbonate is present as the calcium salt, so hard waters need lower addition of calcium.
- In soft water areas, such as Wales, Cornwall and the northwest, water supplies come from igneous rocks such as granite, bicarbonate and calcium levels may be very low. Little acid is needed as the water has virtually no buffering capacity.
- Nitrate and phosphate must all be added from fertilisers.
- In these areas there is a danger that solution pH levels may fall too low, after the addition of fertilisers.
- Fertilisers containing ammonium will reduce pH for instance.
- Since calcium levels are low, there is a greater need for calcium addition to soft water.
- Commercial grades of calcium nitrate, the most common calcium salt used, contain up to 1% ammonium, however.
- Its use may cause reduced pH and calcium uptake problems.
- In such circumstances alternative calcium salts, such as calcium chloride, are to be preferred and have resulted in reduced calcium related problems, such as blossom end rot in tomatoes.
- Water supplies in some areas may vary over time and this causes difficulties.
- Problems can also occur in hard water areas, if growers switch to using reservoir supplies which may have been obtained from rainwater draining from glasshouse roofs, i.e. very 'soft'.
- In hard water areas there is some advantage in acidifying the water supply before the addition of fertiliser.

- This allows the carbon dioxide, which is produced by neutralising the bicarbonate with acid, to evolve from solution.
- Helps to stabilise the resultant solution ph. If the acid is added at the same time as the fertiliser, the C02 may not be evolved until the solution is exposed to the air at the irrigation dripper point.
- This will cause the pH to rise, which is not desirable nutritionally and may also cause blockage of the dripper with precipitated salts.
- If water supplies are acidified, a proportion of the bicarbonate should be left unnaturalised to allow for final adjustment when nutrients are added. Otherwise, the pH may plummet, with further addition of acid.
- Nitric acid is normally used for water acidification or mixtures of nitric and phosphoric acid, which helps to avoid excessive nitrate levels in the final solution with very hard water requiring a high acid addition, where nitric acid is used alone.
- The phosphoric acid will also supply some or all the crop requirement for phosphate, depending on the amount used.

Nutrient addition

- Concentrated nutrient stock solutions are made up are then diluted into the irrigation water on application.
- This addition may be by direct injection into water stream or by addition to the water in a mixing tank.
- Plain water is never applied to hydroponic crops, nutrients are always added.
- The composition of the stock solutions is calculated, using a simple computer programme, by reference to the raw water analysis and the nutrient target levels required in the applied feed for the crop.
- The recipe needs to take account of the hardness of the water.
- Also account for the varying contribution of individual nutrients to the conductivity of the diluted solution, this is the usual mechanism used to control nutrient input.
- Concentrated stock solutions cannot be mixed because of the risk of precipitation of some elements, particularly calcium and phosphorus.
- The stock solutions should be split between two tanks, normally referred to as Tank A and Tank B.
- Acid is added separately from a third tank or by direct injection, if needed.
- Normal to add a small amount of acid to the nutrient tank containing trace elements, to help solubility.
- Tank A normally contains calcium and half of the potassium requirement.
- Tank B contains potassium, magnesium, phosphorus, and trace elements.
- The acid addition may be of nitric acid, phosphoric acid, or a mixture of the two. In hard water areas the acid mix is commonly two parts nitric to one-part phosphoric acid.
- Trace elements are usually added as individual salts or complete mixes are available (but with provisos about adjustments for the water supply as previously mentioned).
- Iron is always added in chelated form to maintain it in solution.
- The usual form is as EDTA, which is the cheapest source and should be effective if pH control is adequate

Nutrient control

- After determining the recipe for chosen crop to give desired nutrient balance, actual nutrient addition is normally controlled by monitoring conductivity of the applied solution, usually in the mixing tank.
- One problem with EC based control is that all nutrient levels go up, or down, if EC setpoints are changed, unless recipes are also changed at the same time.
- In practice, crops are much' less sensitive to variations in nutrient levels than might be supposed, but this situation is not ideal and potentially wasteful.
- One way around this is to use constant nutrient levels, which are achieved by proportional injection of nutrients on a dilution basis and use a separate conductivity control system by the addition of common salt i.e., sodium chloride.
- This technique has been used successfully for tomato crops for several years, but surprisingly has not been widely adopted by growers.
- High conductivity feeds can be used to apply controlled osmotic stress to plants.
- This approach can be used to regulate growth or fruit composition and flavour. In tomatoes, for instance, high conductivity feeds result in reduced fruit size, but increased dry matter and enhanced flavour.
- Control of pH by acid addition occurs at the same time as nutrient input unless water has been pre-dosed with acid.
- Even then, final pH control is affected at this stage.
- Both pH and EC sensors need regular calibration for accurate control.
- Since pH sensors are relatively delicate, a dual control system with a backup sensor is recommended, to avoid incorrect acid dosing.
- Modern irrigation computers have several alarm features.
- These can detect low flow rates in the case of pump failure, filter blockage or failed solenoid valves; high flow rates in the case of leaks; incorrect pH or EC control; or running out of nutrients in stock tanks, as examples.
- Alarm parameters should be set close enough to pick up problems at an early stage, but without constant callouts to site.
- Complete analysis of applied nutrient solutions should be carried out from time to time, to check the operation of the system and after any changes to the recipe have been made.
- Care should be taken in interpreting the analysis of samples taken from the substrate, e.g., rockwool slab, or the drain from it, as the composition may be affected by watering practice (under or over-watering), as well as the recipe.
- In the case of nutrient deficiency symptoms being observed, leaf analysis may be helpful as the symptoms may be induced by uptake problems rather than supply in the feed solution.
- Nutrient levels will accumulate with reduced drainage from slabs. The slab or drain conductivity will indicate the adequacy of watering, a high increase over the applied feed EC indicating under-watering and a small rise, over-watering.

Target nutrient levels

- Crops will vary in nutrient requirements in terms of nutrient balance and overall solution strength (conductivity).
- Advice needs to be sought for individual crops as an example, typical figures for tomatoes are given below.
- These are for the main cropping period in the summer.
- Higher EC feeds may be used to achieve growth control early in the season.

Element	**Applied Feed (mg/l)**
pH	5.5
EC (at 20^0 C)	2.8 – 2.4
Nitrate-N	150-175
Ammonium-N	< 5
Phosphorus	30
Potassium	350-400
Magnesium	50-75
Calcium	175 - 200
Iron	3.00
Manganese	0.75
Copper	0.15
Zinc	1.00
Boron	0.50
Molybdenum	0.05

A reduction based on solar radiation measurement is commonly practised.

Calculation of nutrient content in molar units

- The above feed contents are expressed in mg/l or ppm (parts per million).
- In Holland and some other countries, they are expressed in molar terms.
- These are as mmol.l - l (millimols per litre) or, in the case of trace elements, prnol.l-l (micromols per litre). There are 1,000 pmol in a mmol, as there are 1,000 pg in 1 mg.
- A molar solution would contain the atomic weight of the element dissolved in a litre of water.
- The translation from molar content to mg/l can be made by reference to the atomic weight of the element.
- Whilst this may not need to be considered on an everyday basis, it is useful for referring to Dutch data on nutrient composition recommendations or plant tissue analyses, particularly for what may be considered minor crops in the UK.

E**xamples:**

Potassium, atomic weight = 39.

A 10 mmol.l -l solution = 10 x 39 = 390 mg/l.

Phosphorus, atomic weight = 31.

A 30 mg/l solution = 30 / 31 = 1 .0 mmol.l-l

Zinc, atomic weight = 65.

A 1 mg/l solution = 1 / 65 x 1,000 = 15 pmol.l-l

(Note the multiplication by 1, OOO for the conversion for zinc, to gmol.l-l).

STRAWBERRIES GROWN IN BAGS/TROUGHS

- Strawberries now being grown in soil-less systems to avoid soilborne disease problems and improve fruit quality and ease of picking.
- Principles of nutrition like those of protected crops except that liquid feed is applied at higher volumes so there is always a percentage of run-off.
- Structure of the substrate in the bag must therefore be free draining to avoid waterlogging, especially for longer term ever bearer crops.
- Coarse grades of peat traditionally used for bags coir is becoming more popular due good drainage properties and being easier to re-use bags for a second crop.
- The grade/structure of the coir and its resilience to decomposing during use is particularly important if bags are to be used for more than one crop.
- Two main types of crops traditionally June fruiting crop and longer-fruiting 'ever bearer' crop, which is harvested from later summer into autumn.

Bags usually contain only a low level of base fertiliser

(e.g., 0.75 kg/m ^{3} of PG Mix) and lime if needed to achieve a pH of 5.5 -5.8.

Water Quality

- Water analysis taken before the final feed mix is recommended.
- Probable that water will supply some of the nutrients and contribute to total conductivity.
- Important bicarbonate level is determined.
- A level of bicarbonate above 200 mg/l may mean that acid is added to the mix using nitric acid.
- This will add nitrogen to the feed which must be considered.
- Where the level of bicarbonate is between 100 - 200 mg/l it is possible for feed to be acidified using fertilisers in the mix such as Urea Phosphate.

Conductivity

- Important conductivity readings are taken daily from feed at drippers & drainage water from bag.
- Readings taken at the same time each day using a portable conductivity meter.
- Readings recorded for reference and as part of assured produce records.
- During harvest control of conductivity is important because of effect on fruit firmness and flavour.
- in hot bright conditions it may be necessary to lower conductivity because the plants will need more water.

Fertigation regimes

- Type of feed used depends on the stage of growth — for the vegetative phase a higher N feed is common, switching to a higher K feed at fruiting.

- Most growers make up feeds from 'straight' fertilisers.
- It is important to monitor the pH of water and feed and use appropriate iron chelate to ensure good iron availability.