FACTSHEET 05/19, a revision of 05/05

AHDB

Nutrition of container-grown hardy nursery stock

Figure 1. Lack of an effective fertiliser strategy can lead to longer production times and, in more extreme cases, plant downgrading and even crop losses

Action points

- **Create clear growing media specifications and review them annually**
- **Implement an effective fertiliser strategy for the crops being grown, based on the range of fertiliser products and delivery systems available, to optimise plant development and maintain crop quality (Figure 1)**
- **Regularly monitor the nutrient status of the growing media used on the nursery and sample leaf tissue from crops as required**
- **Consider using one of the on-site crop monitoring devices summarised in this factsheet to generate real-time information about crop nutrient status**
- **Select several key crops to monitor and build up long-term nutrient management records. Such records will assist in the development of a fertiliser strategy and enable nutrient management benchmarking**
- **Understand irrigation water quality and its effect on nutrient availability. Adjust water alkalinity levels as appropriate**
- **Monitor the nutrient status and level of root development in young plants (seedlings, plug plants and liners) prior to potting on. Manage the level of root activity to coincide with potting on so that plants can immediately access available nutrients in the new growing medium**

Background

The production of uniform, high quality, container-grown hardy nursery stock is essential for the future success of the UK hardy nursery stock industry. Selecting growing media that have physical and nutritional characteristics to match crop needs is vitally important to keep production to schedule and avoid downgrading and wastage. Understanding the nutrient release pattern from fertilisers and plant demands throughout the growing season is also paramount to maintain crop quality, avoid potential leaching of nutrients into the environment and to comply with legislation (Figure 2).

Figure 2. Maintaining crop quality requires an understanding of plant nutrient demand and fertiliser performance, taking account of the nursery production systems employed

Increasingly, industry and retailer quality assurance schemes now assess the environmental impact of nursery production systems and demand evidence-based input data from businesses.

Plant quality and longevity after dispatch are also key attributes and must be maintained through to the final customer in terms of retail shelf life and, ultimately, post-planting performance. Optimal crop nutrition throughout the production process is important to ensure plant quality during the latter stages of the supply chain.

This factsheet provides key practical information for making decisions concerning crop nutrition, including:

- The essential nutrient inputs required for quality plant growth
- Creating growing media specifications and an effective fertiliser strategy
- The types of fertilisers and delivery methods available to achieve optimal crop performance
- The influence of irrigation water alkalinity and growing media pH on nutrient availability
- Guidance on monitoring available nutrients throughout the growing season

Nutrient functions within the plant

It is essential to understand the basic functions of the various elements within the plant, because they contribute to key physiological processes that determine plant quality. Knowledge of the symptoms associated with deficiency or toxicity is also important to be able to take appropriate actions to maintain crop quality (Table 1).

Creating growing media specifications, considerations when drawing up a fertiliser strategy and the benefits of nutrient management benchmarking

Growing media specifications are generally based on historical nursery production information and the technical support of the growing media manufacturer. To arrive at the optimal specification there are several factors that must be considered:

- Crop requirements (such as duration of production, growth stage, plant species, plant vigour, etc.)
- Crop production systems in use (use of protected structures, irrigation systems employed, type of standing beds, etc.)
- Supplementary fertiliser practices adopted
- Irrigation water quality, in terms of alkalinity
- Customer requirements and specification agreements

Any growing medium specification should cover the starting pH and electrical conductivity (EC) levels (a measure of the total salts in solution in the medium), the physical constituents used and their particle sizes and the fertilisers incorporated and rates used.

An effective fertiliser strategy should commence with the nutrient content of the growing medium and aim to match nutrient availability with plant demand throughout the production process. The need for supplementary fertilisers will be determined by several factors, including the type and rate of any previous fertiliser used, the crop species grown, cropping duration, the production systems employed, prevailing weather conditions experienced and the agreed customer specifications (Figure 3). Any extra fertiliser should ideally be applied to a schedule, but reactive applications may be required in response to prolonged periods of wet weather or slow customer demand, for example, to prevent such issues affecting crop quality.

Figure 3. The need for supplementary fertilisers will be determined by crop needs, cropping duration, the production systems employed, prevailing weather conditions and any agreed specifications

Table 1. Essential plant nutrients, their function within the plant and known symptoms of deficiency or toxicity

Nutrient	Function in plant	Deficiency symptoms	Toxicity symptoms
Nitrogen (N) Uptake mainly as nitrate, but also possible as ammonium	Protein formation	Deficiency causes poor plant growth and a general yellowing of leaves, commencing with the oldest leaves, which can become red and abscise	High levels of nitrogen lead to soft, lush, blue/green, disease-susceptible growth
Phosphorus (P)	Energy transfer from photosynthesis, root and shoot tip development and flower initiation	Low levels result in general stunting of growth, purpling of older leaves and interveinal chlorosis in some species	Excess can lead to chlorosis in the youngest plant tissue. Ericaceous species are particularly sensitive
Potassium (K)	Regulation of cell water content, sugar transfer via the phloem vessels	Insufficient levels result in middle-aged leaves expressing marginal chlorosis and necrosis	High levels of potassium depress magnesium uptake and lead to apparent deficiency
Magnesium (Mg)	Chlorophyll production	Magnesium deficiency results in interveinal chlorosis of oldest leaves	High levels of magnesium may induce calcium deficiency
Calcium (Ca)	Cell wall formation and cell division	Lack of calcium results in the loss of growing points and collapse and browning of new plant tissue (often linked to high humidity levels)	Toxicity symptoms seldom seen
Sulphur (S)	Constituent of amino acids, proteins and vitamins	Low levels cause a general yellowing of plants, similar to that seen with nitrogen deficiency	Toxicity symptoms seldom seen
Iron (Fe)	Enzyme and chlorophyll production	Iron deficiency results in severe interveinal chlorosis of the youngest leaves (can be associated with high pH and poor root development)	Excessive levels of iron lead to associated manganese accumulation
Boron (B)	Closely related to calcium assimilation in cells	Insufficient levels lead to leaf thickening and downward curling; leaves may become chlorotic, with necrotic spots and lack of apical dominance	High levels of boron cause marginal leaf necrosis on older leaves and can result in flower abortion
Manganese (Mn)	Enzyme systems, especially those associated with nitrogen metabolism	Lack of manganese causes mottled 'star' like chlorosis of younger to middle-aged leaves (often linked to high pH)	Excessive levels can cause spotting on older leaves and papery bark (exacerbated by low pH)
Copper (Cu)	Enzyme systems and photosynthesis	Deficiency results in stunting and reddening of leaves; roots may also be poorly developed	High levels will slow growth; new leaves can be pale green and older leaves can develop necrotic margins
Molybdenum (Mo)	Nitrate reduction enzymes	Low levels of molybdenum result in narrow strap-like leaves (usually related to low pH)	Toxicity symptoms seldom seen
Zinc (Zn)	Closely related to phosphorus metabolism	Lack of zinc causes pale, stunted growth	Excessive levels lead to stunted chlorotic growth (sometimes noted on plants under galvanised gutters in structures)

pH levels refer to growing media pH.

See the ***AHDB Crop walkers' guide – Hardy nursery stock*** for a range of deficiency images.

Fertiliser performance and crop development can be subsequently monitored by regular analysis of the growing medium and leaf tissue. The records generated will enable benchmarking of key crops to optimise initial fertiliser rates, determine application timings of additional fertiliser and provide a better understanding of crop nutrient demand throughout the growing season.

Nutrient delivery and types of available fertiliser

There are five methods of nutrient delivery to the crop using a range of fertiliser products. These methods can be used individually, in combination or sequentially.

Base fertilisers

Base fertilisers can be conventional, crystalline, inorganic fertilisers, such as the compound fertiliser 14-16-18 TE (the 'TE' indicating a suite of trace elements accompanying the nitrogen, phosphorus and potassium), or slower release, organic fertilisers, such as 7-7-9, which is based on processed organic residues. There is now also a range of fertilisers that contain nitrogen in the form of methylene urea (38–39% N), which – while not wholly 'organic' – slows down initial release and availability of nitrogen to the crop.

A base fertiliser would normally be added to the physical constituents of a growing medium at the time of production, along with lime and a wetting agent. Typically, such fertilisers are only intended to last four to six weeks and can be easily leached from the growing medium by excessive irrigation or high rainfall after potting, prior to the plants developing an active root system within the new medium. Where used, they are often regarded as a source of short-term nutrients to crops, to which controlled release fertiliser products are added or water soluble fertilisers are applied sequentially afterwards, to supply nutrients over a longer time period.

Base fertiliser is normally added to the growing medium at a rate of 0.5–1.5 kg/m^3. The amount added will vary according to crop species and time of year of potting; for example, lower levels are required for salt-sensitive crops and for autumn potting schedules.

The effectiveness of the inclusion of any base fertiliser depends on the rate of root establishment of the plant following potting. There is considerable merit in pre-conditioning young plants into active root growth prior to potting on, by applying water soluble fertilisers to the plants in advance. Fertilisers, such as 10-52-10, can be used to create a stock solution at a rate of 1 kg/10 L of water and applied for two to three weeks, at 1 in 100, at every watering via a water-powered proportional dilutor to liners and plug plants, ahead of potting on to stimulate root activity.

When moving away from growing media based on peat, there is likely to be a need for additional nitrogen fertiliser. This is because of the potential immobilisation of nitrogen as a result of increased microbial activity in alternative media based on bark and wood fibre. Originally, ammonium nitrate (34.5% N) was used, but the availability of this form of nitrogen to horticulture is now severely limited. Other forms of additional nitrogen that can be used include calcium nitrate (18% N), calcium ammonium nitrate (27% N) and urea (46% N). Note the differing percentage of nitrogen levels in the various forms of supplementary nitrogen; allowance should be made for this when changing source. The nitrogen 'draw-down requirements' of all new physical ingredients used in growing media must be determined ahead of their commercial adoption.

Conversely, growing media containing green compost can contain significant amounts of slower release nutrients; hence, a lower rate of controlled release fertiliser may be satisfactory.

Controlled release fertilisers (CRFs)

For many years, CRFs have been used as the standard method of longer-term fertiliser delivery to a wide range of container-grown hardy nursery stock crops. These products are granulated fertilisers, coated in a resin or polymer that allows moisture to slowly penetrate the coating (Figure 4). The encapsulated fertiliser is then dissolved and diffuses into the growing medium. Generally CRF is added to the physical constituents of a growing medium at the time of production, along with lime, a wetting agent and sometimes a base fertiliser.

It is important to note that fertiliser release will commence as soon as the CRF granules have absorbed moisture, which they will do once the sealed product bag is opened. Fertiliser manufacturers normally state that once mixed into the growing medium, the medium should be used within 14–21 days to avoid accumulation of fertiliser salts from the initial release, which could damage plant roots and lead to nutrient leaching from the medium at first irrigation.

CRFs have different longevities, ranging from three or four months to 18 months, depending upon the thickness of the coating material. Prevailing temperatures also

Figure 4. Different fertiliser products and formulations for use in container-grown hardy nursery stock production. From left to right: prills, granules, powder and pellets

influence the rate of fertiliser release. Product longevities are determined under laboratory conditions, either at a constant temperature of 21°C or 25°C. While these tests are important to provide guidance on the relative release pattern of the different products, they do not always readily translate to commercial production conditions. For example, there is often a considerable difference in growing media temperature between containers situated on the southern facing edge of a production bed and those in the centre of the bed, which can affect uniform fertiliser release across the whole crop. However, coating technologies are constantly evolving; for example, some products have secondary coats to prevent initial release from the granules, to help reduce the impact of such conditions.

In terms of the CRF product required and the rate at which it should be incorporated into the growing medium, several factors must be considered:

- The plant species grown and its relative vigour or salt sensitivity
- The stage of production, propagation through to potting on established plants
- Time of potting; spring/summer versus autumn/winter
- Production timescale in terms of time to next potting or marketing
- Cropping systems used, including the use of protective structures and the type of irrigation system employed

Generic recommendations for the use of CRFs are provided in Table 2.

As well as incorporation, CRFs can also be dispensed or 'dibbled' into the growing medium at potting. With this technique, the desired amount of fertiliser is dispensed into each container at the base of the drilled planting hole during machine potting (Figure 5). This approach allows changes in fertiliser rates to be made more easily. Dibbling also permits a 10–20% reduction in the rate of fertiliser applied, relative to incorporation during production of the growing medium. Furthermore, when coupled with careful water management and good nursery hygiene, dibbling helps to reduce the development of moss and liverwort on the surface of the growing medium.

Figure 5. A CRF dispenser can deliver a measured amount of fertiliser into the base of the drilled planting hole when machine potting

Table 2. Generic recommendations for the use of different CRF types in growing media

Typical use	CRF type	Rate range (kg/m^3)	Comments
Propagation in cell trays	Mini granules	0.5–1.0	Very difficult to achieve good distribution the smaller the plug tray cell size
Spring-potted, very short-term perennials	Mini granules or very short-term depending upon container size	1.0–2.5	Very short-term equates to three to five month type products. Lower rates for protected crops
Herbaceous perennials including alpines, heathers and herbs	Short-term	1.0–3.0	Short-term equates to five to six month type products. Lower rates for protected crops. Consider the use of 'dibble' application for subjects such as heathers
General shrubs, including climbers, conifers and shrubs liners	Medium-term	2.0–4.5	Medium-term equates to eight to nine month type products. Consider using species-specific CRF where available
Trees, shrubs and long-term crops	Long-term	2.0–6.0	Long-term equates to 12 to 18 month type products. Use lower rates if supplementary fertilisers are to be used

Several products now offer a range of ratios of major nutrients within each longevity type. For example, 'fast-start' blends with more nitrogen and 'high K' blends with less nitrogen and more potassium, where excessive leafy growth is unwanted (for example, with herbaceous plants).

Always refer to the manufacturer's technical literature and recommended CRF rates.

Reduced CRF rates are recommended for young plants/liners and for autumn potting.

For specific situations that may require additional fertiliser release or prolonged longevity, there can be merit in blending CRF products from different manufacturers to achieve the desired result.

Most CRF products now contain trace elements, negating the need for the separate incorporation of fritted trace elements for most crops.

Slow release fertilisers

Slow release fertilisers, which can be fully or partially derived from organic materials, all rely on the microbial mineralisation process to convert the organic source of nutrients to a mineral equivalent that can then be taken up by plants. The mineralisation process is determined by the presence of a microbial population (or the speed at which a population can develop to meet the nutrient demands of the plant), the correct moisture level and sufficient temperatures to allow the microbial population to flourish.

Traditionally, when applied to soils, such fertilisers have performed satisfactorily because the mineralisation process is driven by the presence of complex microbial populations and there is a sufficiently large nutrient buffer in the soil to overcome any short falls. In growing media made up of relatively inert materials, the mineralisation process may be slow and unreliable in terms of meeting plant requirements for mineral elements. Even adding such fertilisers to peat-based growing media can be problematic because, while some of the microbes required are present, others have to build up and incomplete mineralisation can lead to the accumulation of toxic amounts of specific elements.

As a result, such fertilisers are normally used as top-dressings, the aim being to gradually supply mineral elements to maintain plant growth. Although a number of products contain a range of nutrients, some can contain high levels of a single element, such as nitrogen, so correct product selection is important.

Water soluble fertilisers

Such fertilisers are normally dissolved in water to make a stock solution and are then applied through a water-powered proportional dilutor at a set dilution ratio to the crop (Figure 6). Straight fertilisers, such as calcium nitrate, or compound fertilisers, such as 18-10-18, can be applied in this manner.

Water soluble fertilisers allow greater control of plant growth than a CRF-based system. They may also be employed where the CRF within the growing media is running out; for example, if plants are kept on the nursery longer than anticipated, or where excessive leaching of nutrients has occurred and immediate nutrition is required.

Water soluble fertilisers containing different ratios of nutrients can also be used to help manipulate growth. For example, a high nitrogen, water soluble fertiliser, used carefully during the growing season, can provide a timely boost to crop growth and colour. Similarly, the delivery of a high phosphate, water soluble fertiliser to young plant material prior to potting on will speed up establishment (Table 3).

Figure 6. Typical water-powered proportional dilutor used for the application of water soluble fertilisers to crops

Table 3. Example water soluble fertilisers for shrubs and herbaceous crops and suggested growth stage at application

General fertiliser ratio ($N-P_2O_5-K_2O$)	Growth stage at application
1-1-1	Young plant establishment, when phosphorus demand is higher
3-1-3 or 4-1-4	Vegetative growth stage during spring/summer
3-1-6	Lower nitrogen/higher potassium fertiliser for flowering or during the later stages of growth in late summer/autumn

Fertiliser strategies based on the application of water soluble fertilisers are better suited to crops grown under protection, where the environment can be controlled; long periods of rainfall can be problematic, leaching out nutrients and negating opportunities to replace them. The suitability of water soluble fertilisers is also determined by the efficiency of the irrigation system employed on the nursery – overhead systems are usually less efficient than drip irrigation, for example.

Overhead application of a dilute fertiliser solution can also exacerbate liverwort and moss development on the surface of the growing medium and on production beds and pathways. Plants grown solely with water soluble fertilisers will also have very little retail shelf life once they leave the nursery and regular application of fertiliser ceases.

With any type of water soluble fertiliser, the concentration of nutrients applied can be varied, either by adjusting the strength of the stock solution, or – more commonly – by adjusting the injected dilution ratio on the water-powered proportional dilutor.

Specialist fertilisers are also available for use with hard or soft irrigation water; the former containing phosphate in a form more available at higher pHs and the latter supplying extra calcium.

Supplementary fertiliser applications

Where nutrient levels are low because the CRF is running out or where excessive leaching of nutrients has occurred over winter and it is not practical to apply a water soluble fertiliser, plants can be top-dressed in the early spring using short-term CRFs or compound fertilisers. Fertilisers can be applied manually or via an applicator that automatically dispenses a set amount of fertiliser onto the growing medium surface of each container (Figure 7).

Short-term CRFs

Supplementary feeding with a short-term CRF, either top-dressed loosely onto the surface of the growing medium or by the use of CRF plugs (clusters of prills) inserted into the growing medium, is more expensive than the other options, but useful for long-term/high-value crops that may not be sold until later in the year. Top-dressing should be carried out during March to allow sufficient time for nutrient release to take effect.

Compound fertilisers

Top-dressing with a powder or granular inorganic, compound fertiliser will supply nutrients for up to six weeks and, if the growing medium surface is moist, nutrients will rapidly become available to the plant. Nutrient release from organic-based fertilisers is usually slower and will take a little longer.

It is important to distribute the fertiliser evenly, while avoiding placement immediately around the stems of plants because this can cause damage (Figure 8). If production beds are located in exposed areas and plants are prone to being blown over, then any loose fertiliser application may be lost to the crop. As with the overhead application of water soluble fertilisers, nutrient application directly to the growing medium surface can encourage liverwort and moss growth.

Figure 7. A typical top-dressing applicator for use with container-grown crops

Figure 8. Application of a fertiliser top-dressing to the surface of the growing medium, avoiding contact with the stem base

Foliar fertilisers

For some crops it may be worth considering the use of a foliar fertiliser to boost crop performance, particularly ahead of any re-potting operations. Several proprietary foliar fertilisers are available, but some crops, like *Camellia* or *Rhododendron*, have leaves that are too waxy to absorb such fertilisers. Some foliar fertilisers can be tank mixed with routine fungicide applications; product labels and manufacturer's technical recommendations should be checked before doing so.

A summary of the types of fertiliser products available for use in the production of hardy nursery stock can be found on the AHDB website at **ahdb.org.uk/knowledge-library**

Factors affecting nutrient availability in the growing medium

Irrigation water alkalinity

Having detailed knowledge of the quality of the irrigation water applied to crops on the nursery is important, especially the alkalinity level of the water. Alkalinity is a measure of the bicarbonate content of water and can be categorised from very soft (0–50 ppm bicarbonate) to extremely hard (over 300 ppm). Pure rainwater has very low alkalinity, whereas mains or groundwater that has percolated through limestone or chalk geology will be saturated with carbonates to the extent that plants are lime washed at each irrigation. Higher levels of irrigation water alkalinity increase the risk of the growing medium pH rising over time and this will, with the exception of molybdenum, limit the availability of trace elements to the plants.

Acid treatment to adjust irrigation water alkalinity

Where the alkalinity of irrigation water is above 200 ppm bicarbonate, it is worth considering treatment to reduce the level (Table 4). Treating irrigation water with strong mineral acids, such as nitric acid (60%), to reduce the alkalinity to 60–90 ppm residual bicarbonate will avoid pH changes in the growing medium (Figure 9). However, the injection of nitric acid will also mean that the applied irrigation water will have a nitrate loading of around 40–50 ppm nitrogen, which may require other fertiliser treatments to be modified as a result.

Other strong acids, such as phosphoric acid, can be used to reduce the alkalinity of water. Citric acid may be used where the water alkalinity is less than 200 ppm. Several water soluble fertilisers are available that contain urea phosphate, which is extremely acidic, to reduce the alkalinity of the water supply.

Note that, where rainwater is used as the main source of irrigation water, it may be necessary to supplement the crop with calcium and magnesium. This is because, apart from the limestone added to the growing medium and the limited level of magnesium in some fertilisers, the water supply is often the usual source of both elements. Additional calcium and magnesium can be supplied using water soluble fertilisers, or within the growing medium via the addition of materials such as gypsum or kieserite.

Table 4. Water type categorisation and suggested treatment methods

Water type	Alkalinity (ppm or mg/l)	Need for treatment	Possible method of treatment
Very soft	0–50	Worth considering	Addition of extra calcium to the growing medium
Soft	51–125	None	None
Hard	126–200	Worth considering	Acidifying water soluble fertilisers or mild acid
Very hard	201–300	Yes	Blend water or inject strong acids
Extremely hard	>301	Yes	Blend water, inject strong acids. Find alternative source if possible for ericaceous crops/propagation

Figure 9. Automatic acid dosing equipment and acid storage to adjust irrigation water alkalinity

Growing media pH

The availability of nutrients in growing media varies with pH and many nutrients are available to plants at the required level only within certain pH ranges. As a guide, for most peat-based growing media, a starting pH of 5.0–5.5 is preferred for general shrubs and 4.5–5.0 for ericaceous species. Some *Malus* and *Prunus* fruit tree species require a higher pH than general shrubs (5.5–6.0 is recommended) to avoid bark splitting (Table 5).

A pH below 4.5–5.0 for non-ericaceous plants will cause problems associated with insufficient calcium and excess availability of trace elements such as iron, manganese and zinc, causing toxicity. If the pH is too high – that is, greater than 6.0–6.5 – many nutrients, particularly iron (Figure 10), manganese and phosphorus, become less available.

Many of the emerging peat replacement materials such as bark, coir and green compost all have initial pH's above 7.0. However, unlike peat which has a relatively high buffering capacity these new materials have low buffering capacities and hence their ultimate influence on the pH of media mixes is very limited.

Table 5. Desired pH ranges by cropping groups

Cropping group	pH range*	Comments
Ericaceous	4.5–5.0	Plants are generally inefficient at taking up iron, but are sensitive to high levels of available phosphorus
General nursery stock	5.0–5.5	Adequate for most species
Malus and *Prunus* species	5.5–6.0	These plants are subject to manganese accumulation at lower pHs and this can lead to bark splitting

*For peat-based growing media using the 1:5 water extraction analysis method.

Note that where peat is replaced in the growing media, only the peat fraction requires lime; above 50% peat replacement, alternative sources of calcium and magnesium are required.

Figure 10. Severe induced iron deficiency in *Hydrangea*

Monitoring crop nutrition

An awareness of the various symptoms of plant nutrient deficiency and toxicity is important so that appropriate corrective actions can be undertaken. However, by the time symptoms are visually obvious, crop quality can already be affected and it can take longer for corrective measures to take effect. Routinely monitoring the growing media via sample analysis at external laboratories can highlight potential problems at an earlier stage and minimise downgrading and crop losses. As part of AHDB-funded project HNS 193 ***Nutrient management in hardy nursery stock***, several real-time, hand-held monitoring devices were assessed for their practical application on nurseries. The potential of these devices is summarised in this factsheet.

Growing media analysis for nutrient status

Analysis of both freshly delivered growing media and the media from growing crops is useful to monitor pH and general nutrient status, particularly for crops included in any nutrient management benchmarking, new plant species in cultivation, or following changes to growing media specifications. A minimal monitoring programme for spring-potted, overwintered, container-grown nursery stock should be based on pH and nutrient analysis in mid-summer (available water soluble nutrient analysis), early autumn (total water soluble nutrient analysis) and late winter/early spring (total water soluble nutrient analysis).

For protected crops, for which nutrient levels may fluctuate, and for salt sensitive species, a strategy based on more frequent growing media analysis may be necessary; for example, at monthly or six week intervals, particularly for the EC level. This can be especially pertinent where capillary irrigation systems are used because salts may gradually build up in the growing medium and within capillary matting. The overall nutrient status of a growing medium can be broadly determined from the EC (Table 6). UK analytical laboratories usually express EC in microsiemens (µS) per centimetre. Millisiemens (mS) per metre is also sometimes quoted (100 µS/cm = 10 mS/m). Care must be taken when comparing analysis results from laboratories that use different analytical methods.

Table 6. Maximum suggested electrical conductivity levels by crop type

Crop type	Maximum EC µS/cm*
Salt-sensitive young plants – ericaceous rooted cuttings, plug plants and liners	150
Other young plants – liners, bare-root herbaceous plants, alpines	300
Established herbaceous plants and shrubs	400
Vigorous shrubs and trees	500

*Suggested levels for peat-based growing media, using the 1:5 water extraction analysis method.

Monitoring available nutrients

To obtain an indication of available water soluble nutrient levels within the growing medium, analytical laboratories use a water extraction method (peat-based media only). Where CRFs are used the analysis will only measure the nutrients in solution at the time of sampling, if nutrient release from the CRF granules is balanced by crop uptake, only low levels will be detected.

Similarly, where greater slower release nutrient sources are present – for example, in a medium containing green compost – this will underestimate the potentially available nutrients. Hence different chemical extractants, rather than water, are more appropriate.

Monitoring remaining CRF nutrients

Total water soluble nutrient analysis (analysis of a macerated sample of the growing medium), can be more helpful at certain times of year because it provides information on the percentage of original nutrients still contained within the CRF granules. This can be particularly useful to assess total nutrient levels before the winter period and prior to supplementary fertiliser applications in spring.

Leaf tissue analysis for nutrient status

Leaf tissue analysis can be useful to diagnose nutritional disorders, particularly suspected trace element deficiencies/toxicities for which growing media analysis is not so easy to interpret, and to collect long-term data from key crops for benchmarking. A general range of values for each element is provided in Factsheet 10/16 ***Sampling methodologies and analysis interpretation for growers of hardy nursery stock***, along with useful references to further information to aid value interpretation. Such values should still be tempered in relation to the season, crop species in question and the growing conditions experienced.

Use of on-site crop monitoring devices

Hand-held devices for measuring growing media pH and EC are useful for problem diagnosis, monitoring new crops or batches of growing media and to check whether or not supplementary fertilisers need to be applied. However, AHDB-funded project HNS 193 identified several new devices, including an iPhone application, which showed potential for monitoring the nutrient status of a crop in real-time, with equipment output being correlated to leaf tissue nitrogen levels determined via laboratory analysis. A device for measuring growing media EC was also linked to leaf tissue analysis results.

There are several important points to remember when using the devices summarised in this factsheet:

- Select and mark a typical plant within the crop from which to take sequential readings
- Dedicate one person to undertake the assessments and try to take readings at the same time of day at each recording
- In terms of plant assessments, it is difficult to obtain chlorophyll readings from conifers, the leaf colour measuring device should not be used on variegated plant species and sap-based devices require fleshy sample leaves
- Clearly label samples to be sent away to analytical laboratories
- Note any crop trimming, irrigation events or water soluble fertiliser applications that may have taken place earlier in the day if using EC measurements

Note that device output is specific to the recording site only; it is not advisable to use data from other sites.

During the first year of monitoring using these devices, laboratory analysis will also be required to correlate against the crop values recorded.

Leaf chlorophyll sensing

The sensor within the atLEAF+ device measures two specific light reflectance levels and gives an output in the range 0–100. Correlation of the device output to leaf tissue nitrogen levels can be mapped over time (Figure 11).

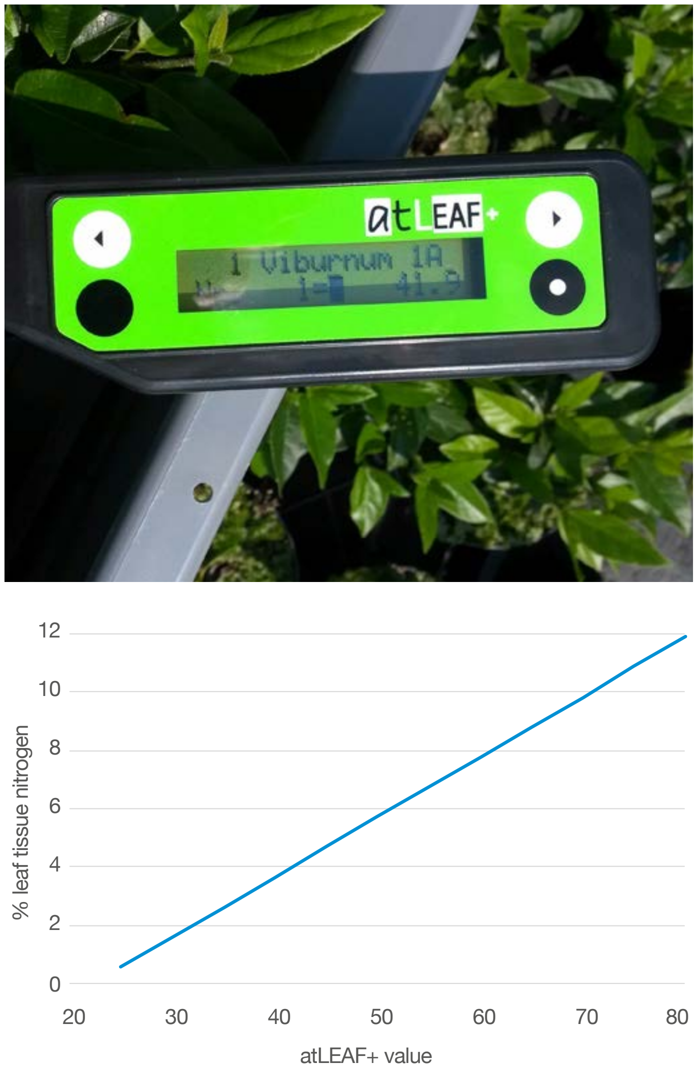

Figure 11. The atLEAF+ leaf chlorophyll measuring device and the correlation between the device output and leaf tissue nitrogen levels for *Tradescantia*

Leaf colour assessment

FieldScout GreenIndex is an iPhone application that uses the phone's in-built camera and a colour calibration board to assess leaf colour. It allocates a 'dark green colour index' of 0–1. As with the atLEAF+ device, correlation of the device output to leaf tissue nitrogen levels can be mapped over time (Figure 12).

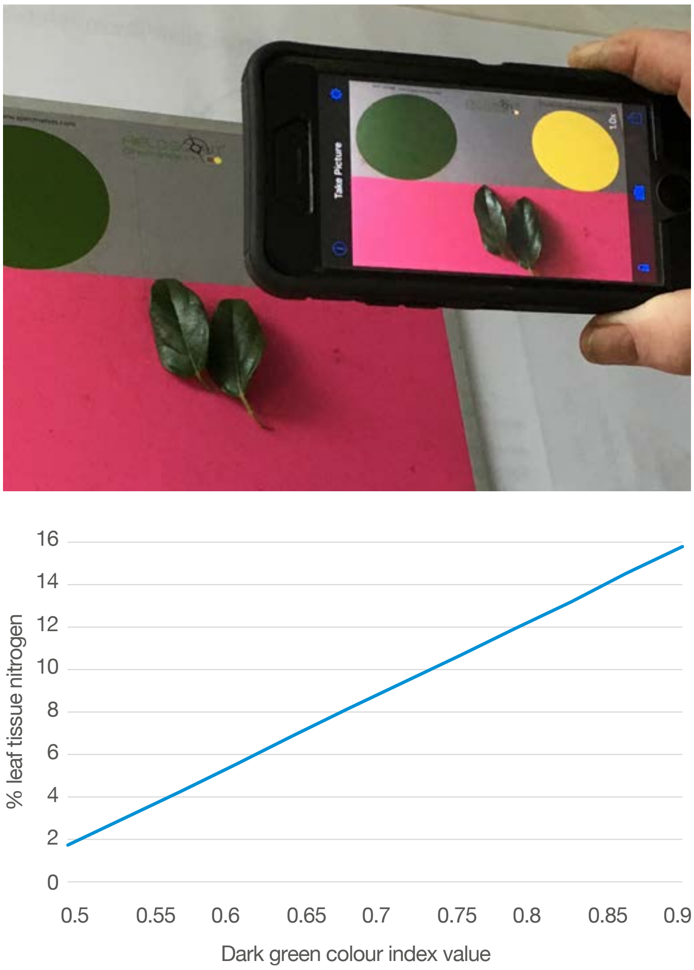

Figure 12. The FieldScout GreenIndex iPhone application in use and the correlation between the device output and leaf tissue nitrogen levels for *Tradescantia*

Leaf sap testing

A nitrate strip test and LAQUAtwin nitrate device can both be used to directly measure nitrogen levels in leaf sap (Figure 13). A garlic press should be used to extract sap from a selected fleshy leaf (it is not easy to obtain leaf sap from some plant species). Both devices show leaf nitrate nitrogen content only, not total nitrogen as calculated via laboratory leaf tissue analysis. Coloured plant sap can affect the reading obtained.

Figure 13. Nitrate strip test and LAQUAtwin nitrate sensor

Measuring growing media electrical conductivity

The Decagon ProCheck device and GS3 sensor provide an EC reading of the growing medium (Figure 14). The growing medium should be assessed prior to any water soluble fertiliser application or irrigation event and before crop trimming (where scheduled) because such actions can affect results. Taking multiple readings from the growing medium will help to minimise random output from CRF granules. Bear in mind that the background EC of the irrigation water used on the nursery may provide higher readings than those generated by laboratory analysis.

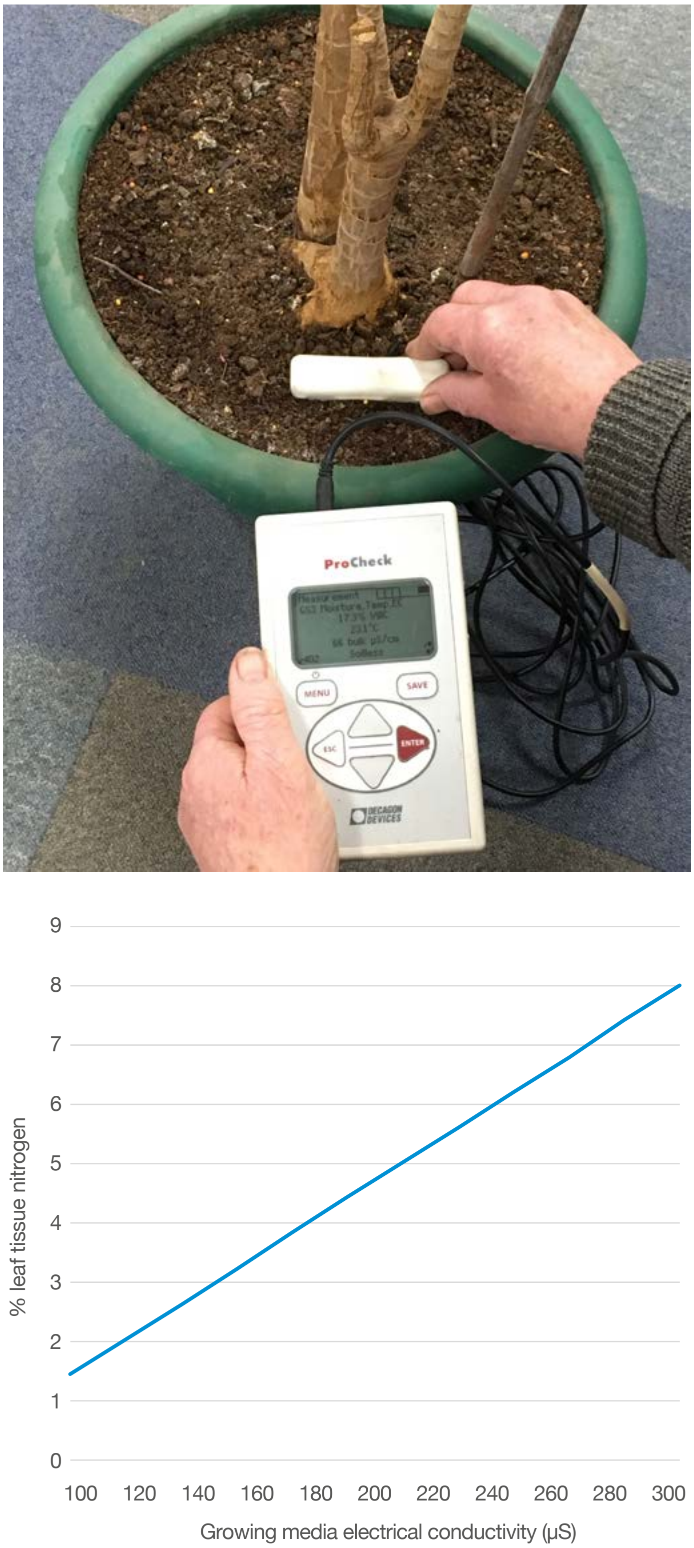

Figure 14. The Decagon ProCheck and GS3 sensor and the correlation between growing media EC and leaf tissue nitrogen levels for *Buddleia*

Authors

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List of UK laboratories offering analytical services and suppliers of the on-site monitoring devices

UK laboratories

Anglian Soil Analysis
www.angliansoil.co.uk

Eurofins UK
www.eurofins.co.uk

NRM Ltd
www.nrm.uk.com

Yara
www.yara.co.uk

On-site monitoring devices

atLEAF+ device
www.atleaf.com

Decagon ProCheck and GS3 sensor
www.decagon.com

FieldScout GreenIndex application
www.specmeters.com

LAQUAtwin nitrate device
www.horiba.com

Nitrate strip test
www.merckmillipore.com/gb

Further information

AHDB Horticulture factsheets and publications

Factsheet 13/18 ***Calibrating a water-powered proportional dilutor***

Factsheet 17/17 ***Measuring and improving the performance of overhead irrigation for container-grown crops***

Factsheet 10/16 ***Sampling methodologies and analysis interpretation for growers of hardy nursery stock***

Crop walkers' guide – Hardy nursery stock

AHDB Horticulture grower summaries and reports

HNS 193 ***Nutrient management in hardy nursery stock***

HNS 189 ***Study to review and improve nutrient management in container-grown hardy nursery stock***

HNS 96a and 96 ***Investigations into the controlled release fertiliser requirements of heathers***

HNS 95 ***Investigation into the controlled release fertiliser requirements of climbers***

HNS 43a–f ***Investigations into the controlled release fertiliser requirements of container-grown nursery stock and herbaceous perennials***

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Acknowledgements

Thanks go to Susie Holmes, Susie Holmes Consulting and Andrew Hewson, ADAS, the original authors of Factsheet 05/05 ***Nutrition of container-grown hardy nursery stock***.

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