FACTSHEET 10/16

Hardy Nursery Stock

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Sampling methodologies and analysis interpretation for growers of hardy nursery stock

This factsheet provides background information about the various types of chemical analyses available, guidance on how water, substrate and leaf tissue samples should be collected and managed to ensure accuracy of the results obtained, and offers assistance with the interpretation of the laboratory analysis results generated for each of the sample types.

Figure 1. A typical selection of healthy container-grown hardy nursery stock

Action points

- Sample nursery irrigation water annually as a minimum
- Provide training for, and have the same person, sampling the selected crop(s)
- To achieve the most useful data set for the nursery, select from crops that are regularly grown and likely to remain core business lines and/or high value crops with nutritional issues (indicator crops)
- Analyse, and keep bagged reference samples of substrate mixes used for the indicator crop(s); samples should be stored somewhere dark and cool to prevent deterioration
- Select sample timings each year to reflect the stages of plant growth from potting onwards
- Once the laboratory is selected and the analytical methods established, use them consistently to permit interpretation and comparison of the results over time
- Set up a simple database or spreadsheet system for managing and storing the results
- Annually review the results with an external FACTS qualified consultant, representative or specialist to help make future decisions on substrate mix changes and nutrient feeding regimes.

Introduction

Regular analysis of irrigation water, regardless of source, is important and should be undertaken at least annually if not every six months or more frequently to keep track of variations in the chemical content of the water. Analysis results can then be used to determine the need for some kind of remedial treatment, such as acidification, or to fine-tune nutritional programmes.

Monitoring crop performance consecutively over a number of seasons, via substrate and leaf tissue analysis, helps to refine substrate mixes and nutritional programmes in relation to plant growth and quality, seasonal changes in the weather and the fertiliser types and rates adopted. Monitoring is also essential to keep track of how crops are developing in relation to customer specifications and demands.

At the present time, the easiest way to monitor plant performance in relation to substrate inputs is by the use of samples sent to a laboratory for the appropriate analysis. Ongoing work supported by AHDB Horticulture (project HNS 193) may in future permit on-site measurements to supplement or replace the need for laboratory analysis of samples but, at the time of writing, the techniques summarised within this factsheet are still the most reliable and easy to benchmark against existing data for crops.

All analysis results are only as good as the original sample submitted. The methodology involved in taking the samples and the need to exclude specific materials that may impact on the results are critical. Once the samples have been submitted to the laboratory, the techniques used are standard, well defined and documented.

Types of available analysis

The three common analytical procedures covered in this factsheet include:

(a) Irrigation water analysis and analysis of water containing soluble fertiliser

(b) Substrate analysis, either as received (available water soluble nutrient analysis) or ground (total water soluble nutrient analysis) to release any residual nutrients from the coated fertiliser

(c) Leaf tissue analysis.

The methods used to analyse irrigation water, water containing soluble fertiliser and leaf tissue are common across many countries; however, the substrate analysis methodology varies depending upon the country where the analysis was undertaken. Laboratories in the UK have adopted the pan-European standard of analysis that was developed over 12 years ago and involves extraction using water at a 1 volume of substrate to 5 volumes of distilled water ratio. The results of this analysis are expressed as milligrams/litre (mg/l), based on the measurement of the density of the material as received and cannot be directly compared to the method many Dutch laboratories use. In the case of the latter method, samples are based on a pre-determined moisture content and an analysis extraction using water at 1 volume of substrate to 1.5 volumes of distilled water ratio, and the results are expressed in millimoles (mmol) of the element. In this factsheet, all the information on substrate analysis will relate to the UK adopted method for which there are large amounts of data from which to make interpretations.

Irrigation water analysis and analysis of water containing soluble fertiliser

Irrigation water quality varies hugely depending upon its source. There are a number of basic criteria to consider with all water sources, of which the most important one is the alkalinity, or 'liminess' (bicarbonate content) of the water (Figure 2). Other important criteria include the boron, chloride, fluoride (where reported) and sulphate contents, which are all reported as mg/l. Depending upon where the irrigation water is sourced, other criteria that may also need to be considered include the iron content (which may be present in the rocks above and surrounding some groundwater sources) and the presence of chemical contaminants such as residual herbicides, for which a specific analysis is required.

Figure 2. Limescale deposits on the leaves of *Choisya ternata*

Note that the pH of water is not flagged as an important criteria for consideration, this is because it can be artificially raised in 'potable' (drinking water) supplies to avoid metal pipework damage and because the other criteria are much more significant, in terms of their effects on the substrate and associated plant growth.

By law, all water utility companies have to undertake regular analysis of all the water sources they are responsible for, and for all potable sources; a request for the annual analysis summary can be made from anyone drawing water in a specific area. The analysis not only includes information on the alkalinity and mineral element content of the water, but it also covers a massive suite of chemical residue analyses including several herbicide active ingredients, such as 2,4-D, as water companies constantly monitor water resources to observe the movement of long-term persistent chemicals in the environment. However, most water companies will have several sources for their mains water supply, and are not required to notify businesses when they switch between them, so it cannot be assumed that mains water has the same chemical composition all year round. If other water sources, such as rainwater or river water are used, these are likely to be very different chemically from the mains water so should also be analysed at least once a year.

Analysis of irrigation water containing soluble fertiliser can be useful to check the nutrient levels actually being applied. If proprietary fertiliser products are used, however, it may be sufficient just to check the electrical conductivity (EC) with a handheld meter because the manufacturers of these feeds usually state an expected EC for the feed when used at a particular dilution (Figure 3). It is important to remember that the 'background' EC of the water needs to be added to the stated figure.

Figure 3. Handheld electrical conductivity meters are often sufficient to provide an indication of the nutrient levels contained within a liquid feed

Substrate analysis

In the UK, substrate samples submitted for analysis first have their fresh density measured and later reported in grams/litre (g/l). This is because the volume taken for analysis is measured as a weight based on the fresh density figure, and all results are calculated back to allow for the fresh density of the sample. The sample is then extracted using five times the volume of distilled water. This technique was originally developed by the Fisons Quality Assurance Laboratory and hence the old name given to it was the 'Fisons Extraction Method'. The only modification since, is that the extraction is undertaken using a 1:5 ratio rather than the 1:6 ratio originally used. The use of a large volume of water was simply to negate the initial moisture content of the sample; the sample being fully 'swamped' by the extraction volume and hence differences in moisture content of samples were not important. The Dutch 1:1.5 method of extraction does the opposite, and assumes the sample moisture content is important so that samples are equilibrated to an initial moisture content before extraction. This takes more time than the UK method.

In both cases, there are limitations, impacting on the end results, in terms of the extractant being water only. Water is a very weak extractant compared to other chemical solutions used, such as saturated calcium sulphate or dilute mineral acids such as nitric or hydrochloric acid. However, the aim of the method is to gauge those elements that are in the root environment and could be easily taken up by plant roots, either by being swept into the plant as part of the transpiration stream or actively absorbed across the root membrane based on differential concentration gradients.

For those elements in the substrate solution that are unattached ions, such as nitrate-N, or chloride, then the results obtained are often good reflections of their availability. However, for other elements such as phosphorus, which may be bound up with calcium as a relatively slowly available form of the element, then the analysis may simply be an indication of their presence or absence. The only way this apparent anomaly can be dealt with is by carefully considering the make-up of the substrate and also by having a sufficiently large database of results to become familiar with trends in the results. Similarly for copper, results often indicate <0.06mg/l, all this means is that the value is below the detection level, but, more importantly, it should also be realised that copper is strongly bound to organic matter such that a simple water extraction will tend to underestimate the available copper.

For substrates containing controlled release fertiliser (CRF) granules, the available water soluble nutrient analysis will only detect the nutrients that have been released from the granules and are present in the substrate solution at the time of sampling. If the plants have recently been irrigated and/or nutrient release is in balance with nutrient uptake, the analysis of a substrate containing CRF may indicate a low level of nutrients, hence a 'one-off' analysis is less useful than regular sampling. An alternative method is to grind up the sample to release the reserves of nutrients left within the granules (total water soluble nutrient analysis). This may be useful to check how long the CRF will last before additional feeding is required or to check the rate of CRF originally incorporated into the substrate (alongside a granule count).

Leaf tissue analysis

Leaf samples are a useful guide to the history of what the plant has been exposed to and has accumulated. The analysis follows the drying of the sample in an oven, the sample is then ground up and strong mineral acids (such as a mixture of nitric and sulphuric acids) are used to extract the mineral elements. All the mineral components in the tissue are released and the filtered extract measured accordingly. The major elements are reported as percentages, the minor elements as milligrams/kilogram (mg/kg).

Sampling methodologies

Sampling irrigation water and water containing soluble fertiliser

Any water sample needs to be at least 200ml in volume and should always be collected into a clean plastic bottle, securely sealed and labelled (Figure 4). If the sample cannot be sent off within 12 hours, it should be stored in a cool, dark place. Warm, light conditions may encourage algal growth and this can distort the analysis results.

If acid is used to reduce the alkalinity of the irrigation water, it is important to submit a fresh sample of both the untreated and the treated water for comparison and ensure that the fresh water is from the same source as that being treated with the acid, and for instance not an adjacent tap, which may be fed from another source.

When sampling water containing soluble fertiliser, ensure the dilutor equipment is allowed to run for a short while to make sure the liquid feed solution collected from the tap is a representative sample of that being applied to crops.

Figure 4. Taking a water sample from the irrigation system

Sampling substrate

When sampling from container-grown plants, substrate should not be taken from the top 2cm or the bottom 3cm of the root ball if at all possible. Substrate samples from these areas can distort the results due to the respective build-up or leaching of nutrients from the areas. When sampling, it is best to have a small clean bucket for the substrate sample and to move around the whole crop area sampling from a representative number of individual plants throughout the whole area. Remove the pot from each plant selected and take a pinch sample of the substrate from the side of the root ball, within the region specified (Figure 5). Sample from at least 10–20 pots if they are one litre in size. Slightly fewer pots are needed the larger the pot size is, but the target is to end up with at least a one litre sample of substrate. For smaller plants, such as plugs or liners, it may be necessary to take all of the substrate from an individual cell or pot, mix the collected samples together and then sub-sample from it. The latter technique should also be used when sampling substrate containing CRF that has been applied by 'dibbling' directly into the planting hole, rather than having the CRF mixed into the whole substrate.

If there are good and poor areas of crop that need to be compared, samples from both areas should be taken, labelled 'good' and 'poor', and submitted as individual samples. The crop or area where the samples were taken from should be recorded and a notice placed up within the sampled crop/area to indicate that the plants should not be moved without permission. If required, consider taking an image of the plants at sampling, too. In the case of crops grown using CRF, bear in mind that if plant growth has been poor for some time (and particularly if the crop has been grown under protection), nutrient levels can build up to high levels within the substrate as the fertiliser granules will continue to release nutrients.

Substrate samples should be sent off in a labelled, strong, sealed plastic bag to prevent rupture during transit. If samples cannot be sent off immediately to the laboratory, store the filled bags in a dark, cool place. In the case of bagged reference samples kept on the nursery, be aware that if the substrate is moist and contains CRF, the fertiliser granules will continue to release nutrients, such that the readily available nutrients will be significantly elevated.

Figure 5. Sampling substrate from container-grown hardy nursery stock

Guidance on how to download and use the Layar app to access the video functionality associated with Figures 5 and 7 can be found at the end of this factsheet. For those who are unable to access the software go to horticulture.ahdb.org.uk/sampling-methodologies-and-analysis-interpretation-growers-hns to view the two video guides on substrate and leaf tissue sampling.

Sampling leaf tissue

For routine monitoring of crops, leaf samples should be collected across a range of at least 20 plants within a crop and should be made up of fully expanded mature leaves, avoiding the youngest or oldest leaves (Figure 7). For a leaf sample to yield meaningful results, at least half a litre of leaves are required, otherwise there will be insufficient dry matter, once drying has taken place.

Where there are specific visual symptoms on the leaves that need to be analysed, these leaves may be collected but they should, if possible, be submitted with a sample of leaves not showing the symptoms for comparison. Figure 6 indicates the areas of the plant where specific nutritional problems may be expressed in terms of visual symptoms and this may help in making a decision on the sample taken for analysis.

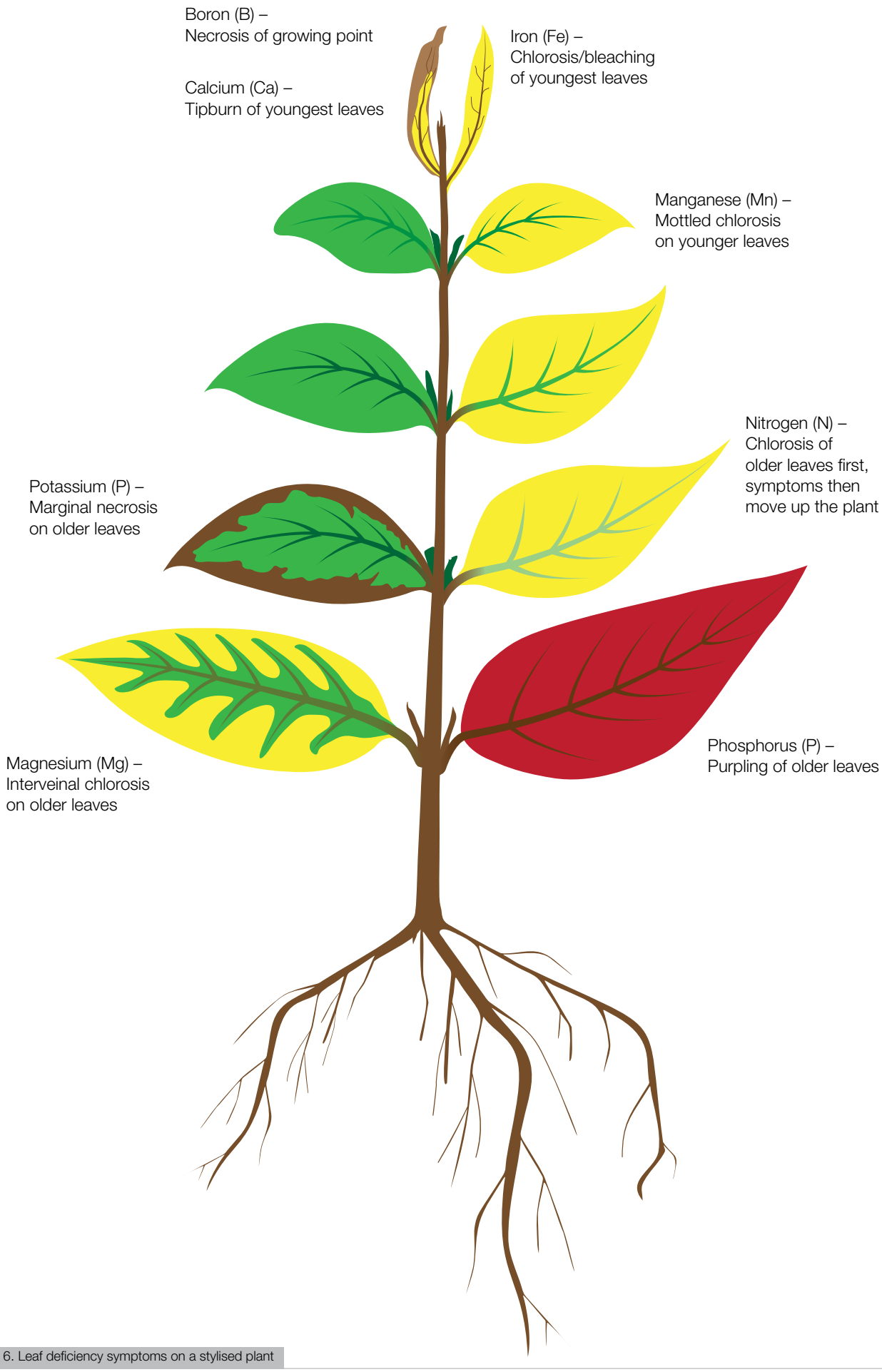

Figure 6. Leaf deficiency symptoms on a stylised plant

Figure 7. Collecting suitable leaves from a crop for leaf analysis

Leaf samples should be sent off to the laboratory promptly; if necessary, they should be stored in a cool place prior to dispatch. In the case of suspected iron deficiency, leaf tissue analysis does not usually provide a reliable result, however, symptoms of iron deficiency are generally characteristic (Figure 8) and normally easy to recognise on the plant and may be diagnosed from other circumstantial evidence such as substrate waterlogging, resulting in fine root loss, and/or high substrate pH levels.


Figure 8. Iron deficiency symptoms on pulmonaria

Routine sampling

In the case of routine sampling, it is important to give careful consideration to the indicator crops to be sampled on the nursery. Where large blocks of a specific crop are grown year on year, these could be used as indicator crops across the nursery each year. Where significantly different rates of CRFs are used in the substrate mixes across the nursery for different cropping groups, representative crops should be selected from these to act as the indicator crops.

Costs of analysis

As an approximate guide, the analysis costs for a medium-sized, single site nursery are presented below (based on 2016 cost figures):

- Irrigation water analysis (including analysis of water containing soluble fertiliser), allowing for four samples per year: £100–£150
- Substrate analysis of three distinct substrate mixes routinely monitored to provide benchmarking, allowing for six samples per mix over 18 months: £360
- Leaf tissue analysis of three representative indicator crops in three substrate mixes, allowing for four samples per crop over 18 months: £360
- Total cost: approximately £820–£870.

As part of AHDB Horticulture-funded project HNS 193, the use of on-nursery equipment and techniques for the assessment of the health and wellbeing of crops are being compared and contrasted with samples collected and sent for laboratory analysis.

Analysis interpretation

Irrigation water

Table 1 summarises the highest, average and lowest criteria and element values from a number of actual irrigation water analyses and provides the maximum suggested value for each criteria or element. The important criteria for consideration from the analysis are covered in more depth in the following sections.

Alkalinity interpretation

Water types can be categorised based upon their alkalinity (bicarbonate content), these are listed in Table 2, along with the suggested treatment methods for irrigation water. As mentioned previously, it is the alkalinity of the water that is important not the water pH, because it is the bicarbonate content of the water that causes the pH rise in substrates over time and also results in deposits on leaves (Figure 2) and on irrigation application equipment.

While soft water (such as rainwater or mains water from the granite rock areas of the North West and the South West of England) may appear to be desirable in terms of its low alkalinity, the water type can present its own unique problem in terms of calcium availability to the plant. This is because irrigation water is one of the main sources of readily available calcium, to such an extent that, in very soft water areas, a supplementary source of calcium may actually be needed.

Table 1. Highest, average and lowest criteria and element values from a number of actual irrigation water analyses* and the maximum suggested value for each parameter in ideal circumstances

Criteria, element and unit of measurement															
	Alkalinity as HCO_3	Conductivity (EC)	NO_3-N	P	K	Mg	Ca	Na	Cl	SO_4	B	Fe	Cu	Mn	Zn
Value	mg/l	µS/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Highest	387	1810	172	93	157	46	159	98	53	234	25	2.5	46	2.5	0.3
Average	171	631	19	18	25	18	70	30	26	81	2	0.5	3	0.2	0.1
Lowest	0.1	42	0.1	0.1	1	0.1	1	4	0.6	3	0	0	0	0	0
Suggested maximum	250[1]	850[2]	60	30	100	50	120[3]	40	70[4]	200	1	0.4	0.5	3	0.3

Based on a database of UK growers. [1]200 for ericaceous plants and propagation/plug plants. [2]650 for propagation/plug plants. [3]Minimum of 40 preferred. [4]50 for propagation/plug plants.

Table 2. 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 substrate
Soft	51–125	No	None
Hard	126–200	Worth considering	Acidifying liquid feeds or mild acid
Very hard	201–300	Yes	Blend water or inject strong acids
Extremely hard	301 and over	Yes	Blend water, inject strong acids. Find alternative water source if possible for ericaceous crops/propagation

Treatment of water with only moderate alkalinity can be achieved by the use of acidifying water soluble fertilisers that are formulated around compounds such as urea phosphate, or via the injection of mild acids such as citric acid. More extreme alkalinity requires the injection of strong mineral acids such as nitric or phosphoric acid (Figure 9).

The important thing to consider when using an acid, is what will it contribute to the treated water; with nitric acid, for example, there will be an increase in the nitrate-N available to the crop and, additionally, there will be more available calcium. Nitric acid injection therefore results in the crop receiving a low level feed of calcium nitrate continuously.

The analysis results presented in Table 3 illustrate the effects of water acidification, in this case with a mixture of nitric and phosphoric acids. The alkalinity of the borehole water is 255mg/l, and the background conductivity is 649µS/cm. Once treated, the alkalinity is reduced to 91mg/l (soft) but the result is a significant increase in the nitrate-N (9.7 to 117mg/l) and the phosphate from 0.8 to 20mg/l. Therefore, when this water is applied to crops, there is a constant feed of nitrogen and phosphorus, which has been supplemented in this particular case with some potassium, to give an N:P:K liquid feed.

Figure 9. A typical automated acid injection system on a nursery (top) and associated acid storage (bottom)

Table 3. Water analysis of irrigation water from a borehole water source and following treatment with acids

Criteria, element and unit of measurement							
	Alkalinity as HCO_3	Conductivity (EC)	NO_3-N	P	K	Mg	Ca
Water source	mg/l	µS/cm	mg/l	mg/l	mg/l	mg/l	mg/l
Borehole	255	649	9.7	0.8	0.4	2.2	158
Acid treated	91	1374	117	20	17	12	143

Element interpretation

As stated previously, the other criteria to consider when interpreting irrigation water analyses include the boron, chloride, fluoride, sulphate and iron levels. High levels of boron may indicate industrial contamination of the water source. Chloride and sulphate are not required in great quantities by plants, but both will add to the overall conductivity of irrigation water. The presence of large quantities of chloride (along with sodium) may indicate salinity issues with the water source. High iron levels can cause precipitation in irrigation equipment or leave a deposit on foliage, while fluoride can lead to problems in crops such as cordylines. The suggested maximum levels of each can be found in Table 1, the suggested maximum level of fluoride, which isn't listed in the table, is 1mg/l.

Substrate

Interpreting 'one-off' analyses is particularly difficult, especially for substrates containing CRF as the release of nutrients from these products is temperature dependent. The time of sampling and interval since the last irrigation or rainfall event can also affect the results. Plotting the electrical conductivity (EC) over time with fortnightly or monthly sampling is much more useful. In a hard water area, this is also useful to check that the substrate pH is not rising too quickly.

Available water soluble nutrient analysis interpretation

As referred to previously, the available water soluble nutrient analysis provides a good indication of the levels of the freely available elements, the process, however, does not extract elements such as phosphorus and calcium easily. Table 4 summarises the suggested desirable range of the key criteria and elements. (Note the levels of water soluble trace elements are not easy to interpret and have therefore not been included).

When interpreting substrate available nutrient analysis results, the first parameters to note are the pH (as this determines nutrient availability) and the EC (because this is a measure of the total water soluble salts/nutrients present).

The pH of peat-based substrates should be in the range of 4.5–5.5 for acid loving (ericaceous) species, such as azalea and rhododendron or 5.5–6.5 for general nursery stock species. For media containing green compost or loam, a higher pH is acceptable because nutrient availability extends over a greater pH range, therefore a pH up to 7.5 for a mix containing green compost is not usually a problem, although it would be for a peat mix (Figure 10).

The EC level should be interpreted taking into account the nutrients that are contributing to it and the crop in question. For example, an EC of 500 for vigorous nursery stock, which is mostly due to the presence of nitrate and potassium ions is probably fine, but an EC of 500 with low nitrate and high chloride or sulphate is not desirable. High chloride levels not only damage plant roots but they will also hinder uptake of nitrate. An EC of 500 for young plants or salt sensitive species would also not be suitable as both groups are susceptible to root damage if the EC is too high (this often then leads to the establishment of root pathogens). The effects of high EC will be exacerbated if the substrate is kept dry (because this concentrates the salts), so keeping the substrate moist as well as flushing with plain water to leach out salts is recommended.

Figure 10. pH induced leaf chlorosis on the upper leaves of hydrangea

Table 4. Substrate available water soluble nutrient analysis interpretation

Criteria/ element	Unit of measurement	Suggested desirable range*
pH	pH units	4.5–7.5 (Dependent upon species and growing medium, 4.5–5.5 for ericaceous species)
Electrical conductivity (EC)	µS/cm	70–600 (Dependent upon species and stage of production: 70–300 for young plants/liners, 100–500 for general nursery stock and 300–600 for vigorous species in larger container sizes)
Nitrate-N	mg/l	50–200 (Dependent upon species and age of plant)
Ammonium-N	mg/l	Maximum of 100 (50 for young plants)
Phosphorus	mg/l	5–30 (Maximum of 18 for phosphate sensitive plants)
Potassium	mg/l	50–300 (Dependent upon species and stage of growth)
Magnesium	mg/l	15–150
Calcium	mg/l	20–100
Sodium	mg/l	Maximum of 50
Chloride	mg/l	Maximum of 150 (80 for chloride sensitive species/propagation)
Sulphate	mg/l	Maximum of 500 (depending on other 'salt' levels present). Can be higher with some specific borehole water sources, where drilled into gypsum rock deposits (2,000)

**Desirable ranges based on analysis using the 1:5 water extraction method.*

Although plants take up nitrogen in both the nitrate and ammonium form, most species prefer the nitrogen supply to be predominantly in the nitrate form as high levels of ammonium are toxic. Ammonium toxicity causes direct root damage and calcium deficiency due to reduced uptake of calcium. Fertilisers containing nitrogen in the organic or ammonium form carry a risk of ammonium build-up in the substrate if the microbial conversion of this to nitrate is not fast enough. Young plants and/or those being grown when light levels are low are particularly at risk.

For media based on peat, most of the calcium and magnesium required by the plant is provided by the liming material used and actual deficiencies are rare (Figure 11), however, for non-peat mixes, alternative sources of these elements may be needed and the levels of each need to be monitored.

The ratio between nutrients can also be important, for example potassium and magnesium are similar sized ions, hence a high level of potassium may hinder uptake of magnesium. Coir-based substrates will have naturally high potassium levels initially but these will fall during use.

Extraction via water tends to underestimate the trace element levels in a substrate, therefore the levels reported in a standard available water soluble nutrient analyses are not very meaningful, unless unusually high levels are found.

Figure 11. Classic magnesium deficiency symptoms, interveinal chlorosis of the older leaves

Total water soluble nutrient analysis interpretation

Where the substrate contains a CRF fertiliser, it is often useful to request the laboratory to undertake a ground total water soluble nutrient analysis too. This means that the sample, as well as being analysed as received, is also ground up to crush the CRF granules. The result provides an indication of the reserves of fertiliser still remaining in the granules, permitting a judgement to be made as to whether some form of fertiliser top dressing, liquid feeding or insertion of CRF tablets will be necessary to enhance the container life of the plant.

From the analysis results, the ammonium and nitrate nitrogen figures can be added together (some laboratory reports include this as a 'total nitrogen' figure) and compared with the expected level from the rate of fertiliser used, with the caveat that it's not generally possible to obtain 100% recovery. For example, an unused substrate containing 3g/l of a CRF with 15% N would have a theoretical nitrogen level of 450mg/l in a total water soluble nutrient analysis (there will also be nitrogen from any base fertiliser added and a little from the peat too). For longer-term crops, samples can be taken at the end of the winter to estimate the proportion of the nutrients that are left in the CRF granules and, therefore, the likelihood that supply will be sufficient for the spring flush of new growth.

Impact of the sampling methodology on the analysis results obtained

Table 5 highlights the importance of taking the substrate sample from the appropriate position on the root ball to ensure the accuracy and consistency of the results obtained. Samples were taken from 9cm liner pots, the peat-based substrate contained no controlled release fertiliser, just a base fertiliser. The table shows the general difference in the results obtained between the zones, the middle zone is where the main root activity was taking place. Note the accumulation of sulphate at the top of the root ball and its impact on the substrate EC relative to the other zones.

Table 5. Substrate analysis results from different zones in the root ball within the container

Criteria, element and unit of measurement														
	pH	Conductivity (EC)	NO_3-N	NH_4-N	P	K	Mg	Ca	SO_4	B	Fe	Cu	Mn	Zn
Sample position in container		µS/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Top	5.9	376	60	9	47	71	70	169	603	0.07	0.64	0.04	0.32	0.23
Middle	5.9	243	51	13	30	42	38	95	305	0.05	0.60	0.03	0.16	0.15
Bottom	6.1	188	33	11	17	58	18	44	236	0.07	0.04	0.04	0.07	0.13

Leaf tissue

The range of published leaf tissue analysis data has always been limited. The reference publications listed in the 'Further information' section of this factsheet are the most helpful and easily available. While the results they quote provide good initial guidance, there is no substitute to collecting good and poor samples from individual nurseries to build up a specific database (Figure 12).

Such results however, must still be tempered in relation to the season and the growing conditions experienced. Table 6 summarises the highest, average and lowest element values from a number of actual leaf analyses of different, woody plant species as a guide.

When interpreting leaf analyses, it must be remembered that the nutrient levels expressed relate to nutrient uptake in the past, not the present. It is always useful to also undertake a substrate analysis as a cross reference as this will highlight any underlying issues that could be affecting nutrient uptake, such as a high substrate pH level. Leaf tissue analysis is most useful when a database for a particular crop or cultivar on the nursery has been built up over a number of years of analyses.

Figure 12. Leaf samples taken from plants showing a specific nutritional deficiency (left) alongside a healthy plant (right) to provide comparative results

Table 6. Highest, average and lowest element values from a number of actual leaf tissue analyses* from a range of different woody plant species

	Element and unit of measurement										
	N	P	K	Mg	Ca	Cl	Mn	Cu	Zn	Mo	B
Value	%	%	%	%	%	%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Highest	6	1	3	1	4	1	875	320	180	7	47
Average	3	0.5	2	0.5	1.5	0.5	155	35	35	1.5	24
Lowest	2	0.2	0.8	0.2	0.7	0.01	44	1	11	0.2	13

**Based on a database of UK growers.*

List of UK laboratories offering analytical services

Anglian Soil Analysis, One Way Street, Sutterton, Boston, Lincolnshire PE 20 2JQ, angliansoil.co.uk

Eurofins UK, i54 Business Park, Valiant Way, Wolverhampton WV9 5GB, eurofins.co.uk

NRM Ltd, Coopers Bridge, Braziers Lane, Bracknell, Berkshire RG42 6NS, nrm.uk.com

Yara, Harvest House, Europarc, Grimsby, Lincolnshire DN37 9TZ, yara.co.uk/crop-nutrition/Tools-and-Services/analytical-services

Further information

AHDB Horticulture factsheets and publications

Factsheet 15/06: 'Water quality for the irrigation of ornamental crops'.

Factsheet 05/05: 'Nutrition of container-grown hardy nursery stock'.

AHDB Horticulture grower summaries and reports

HNS 193: 'Nutrient management in hardy nursery stock (NutrHONS)'.

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

Other publications

Fertilisation guide for nursery crops. T. Aendekerk. Research Station for Nursery Stock, Boskoop, The Netherlands, 1997. (Not currently in circulation as a translated publication from the Dutch original).

Media and mixes for container-grown plants. A.C. Blunt. Unwin Hayman, 1988.

Plant analysis handbook II. A practical sampling, preparation, analysis and interpretation guide. H. Mills and J. B. Jones. MicroMacro Publishing, 1996.

Acknowledgements

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How to download and use the Layar app

To access the video functionality associated with Figures 5 and 7, the Layar app needs to be downloaded and used.

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5. How to use the Layar video guide: https://youtu.be/ZR4eSmmPCxg

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If you want more information about AHDB Horticulture, or are interested in joining our associate scheme, you can contact us in the following ways...

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