FACTSHEET 05/17

Precision scheduling of irrigation in the production of container-grown hardy nursery stock in various growing media

Figure 1. Overhead irrigation on a commercial nursery using rotoframe type nozzles

This factsheet provides practical recommendations for the efficient irrigation of container-grown hardy nursery stock in order to optimise water use and maintain plant quality in peat-based, peat-reduced and peat-free growing media and to minimise the risk of potential nutrient leaching from crops. This factsheet should be read in conjunction with updated AHDB Horticulture Factsheets 18/17 (on which this builds), and 17/17.

Action points

Optimising irrigation water application

- **Regularly inspect and maintain irrigation systems to ensure they are performing according to the manufacturer's recommendations; as required, take the opportunity to improve the system design and hardware (Figure 1)**
- **Measure volumes of water delivered over a set period of time by different nozzles or emitters used on the nursery to ensure output is uniform and appropriate (as outlined in Factsheet 17/17)**
- **Install water meters so that the volumes of water applied over the season to different crops can be measured and recorded**

Irrigation scheduling

- **Consider some form of irrigation scheduling, whether it's via the monitoring of plant and container weights, an estimate of evapotranspiration, or the use of moisture sensors to more accurately apply irrigation**
- **When using estimates of evapotranspiration to schedule irrigation, ensure that species specific crop coefficients are updated regularly to maintain precision**
- **When using a moisture sensor to schedule irrigation, ensure that it's calibrated for each growing medium and that it's inserted correctly to ensure accuracy**

HORTICULTURE

- **Fit a rain gauge to the irrigation controller to interrupt the irrigation sequence during rainfall**

Growing media management

- **Ensure that container sizes, growing media and crop water requirements are similar in each irrigation block to make it easier to apply a standard amount of irrigation water**
- **Identify the upper and lower target plant and container weights for each medium and species so that a suitable irrigation period can be determined**
- **Measure the duration of irrigation needed to achieve less than 5% run-through at the lower irrigation set point for each medium, and reduce the irrigation duration for peat-free media by approximately 30-50% compared to peat-based media to prevent over-watering**
- **The irrigation duration for peat-reduced growing media can be similar to peat-based media, but may need to be reduced with some crops in order to minimise run-through**

Background

More efficient water use is vital to the future success of any horticultural business. Around 80% of all hardy nursery stock (HNS) produced in England and Wales is reliant on some form of irrigation. HNS nurseries used an estimated 25 million m^3 of water in 2005; however, this was considered to be one of the wettest in the last 35 years and other estimates place the volume nearer to 50 million m^3. Thus, the HNS sector is a major user of water. Coupled with this, 75% of all HNS nurseries lay within regions where competition for limited water supplies is increasing and 40% are in areas classified by the Environment Agency as being either 'over abstracted' or 'over licensed'. Abstraction rates in these areas are already unsustainable and are predicted to rise by a further 30% by 2050. A large proportion of HNS nurseries also rely on mains water, which will become increasingly expensive and can be constrained during drought periods.

Significant legislative drivers, such as the Water Framework Directive and the Nitrates Directive, will place increasing pressure on businesses to reduce the environmental impact of intensive horticultural production. As part of the Abstraction Licence Reform, trickle/drip irrigation will no longer be exempt from legislation designed to safeguard resources and limit damage to the environment. In future, all drip irrigation will require an abstraction licence and there must also be a demonstrable need for, and an efficient use of, irrigation water before time-limited abstraction licences are renewed.

Achieving the 'good status' for water quality set out in the Water Framework Directive is proving to be a challenge in the UK and elsewhere, and so there is also increasing pressure on the agriculture and horticulture industries to minimise the impacts of intensive production systems on both surface and ground water quality. In 2015, only 17% of the water-bodies in England were classified as being of 'good ecological and chemical status' under new standards set down by the Water Framework Directive and most rivers, lakes, coastal and ground waters in England will still not meet legally binding EU water pollution targets by 2021 – six years after the initial deadline.

Diffuse water pollution comes from many sources that may be small individually but damaging collectively. Agriculture and horticulture aren't the only causes of these problems, but they do contribute around 50-60% of nitrates, 20-30% of phosphorus and 75% of the sediment getting into water sources.

More guidance is needed to help the majority of HNS nurseries to implement and maintain water-saving irrigation strategies that also optimise plant quality and minimise the sector's environmental impact. This factsheet is the latest in a series dealing with irrigation scheduling and water use efficiency in the production of container-grown HNS.

Plant responses to under- and over-watering

All growers recognise plant responses to under-watering, and they know that some HNS species are particularly sensitive to over-wet media, but plant responses to over-watering are often more subtle than those to drying and can be easily overlooked. Plant losses from over-watering are difficult to separate from those resulting from uneven irrigation and so few growers fully appreciate the effect that over-watering can have on plant losses over-winter, in the spring and during the growing season.

Over-watering can lead to limited oxygen availability (hypoxia) in the growing media due to the replacement of air spaces with water. Low oxygen concentrations and the accumulation of carbon dioxide (from root respiration) limit root water uptake in over-wet media. Even short-term hypoxia can result in the death of root hairs and smaller roots where the majority of water and nutrients are absorbed. The reduced size and functionality of the root system due to over-watering episodes can predispose plants to wilting during periods of high evaporative demand, and lower resilience, so that losses due to pathogens are likely to increase (Figure 2).

Figure 2. The physical consequences of over-watering container-grown hardy nursery stock (centre two plants)

Optimising irrigation

The first step towards optimising irrigation water use efficiency is to ensure that irrigation systems are well designed and appropriate for their intended use, are operating within the prescribed range of pressures, are free from leaks and are maintained regularly. Take the opportunity to improve the system design and hardware in irrigation blocks whenever possible. Whichever method of irrigation delivery is used, it is essential to know how much, and how uniformly, water is being applied. The practical steps needed to achieve this are described in AHDB Horticulture Factsheet 17/17 and include how to calculate how much irrigation water is being applied to a crop and how to measure and interpret water application rate and the uniformity of distribution.

Once irrigation delivery has been optimised, accurate scheduling of irrigation requires knowledge of crop water use at different growth stages, and how this varies on a day-to-day basis and under the environmental conditions in different parts of the nursery. Estimating the water use of different species at different ages, in different media and container sizes, under different growing conditions at different production sites under varying environmental conditions is a significant challenge for all HNS growers. However, in order to maintain optimum growing media moisture contents and availabilities, accurate estimates of plant water use are essential. Fortunately, a range of tools is now available to help with this task, but it is likely that a combination of approaches will be needed on a typical container-grown ornamentals nursery.

Knowing when to resume irrigation following rain events to maintain the optimum growing medium moisture availability is also difficult, but improved practice could significantly lower leaching of fertilisers and pesticides, and reduce plant losses as a consequence.

Influence of different media on water availability

Recent research and commercial experience has shown that growing HNS species in media based on coir, pine bark, wood fibre and other materials can be just as successful in terms of the resulting plant growth and quality compared to plants produced in peat-based media. There are potential advantages from using peat-reduced and peat-free media which are not currently being exploited fully due to concerns about how best to manage irrigation and fertiliser regimes. For example, rooting is often improved in better draining media, while the drier surface reduces moss and liverwort growth, which could help to reduce the labour costs associated with the preparation of plants prior to dispatch.

The impact of over-watering on crop losses and plant quality is likely to be lower when using peat-reduced and peat-free media, as are losses due to root death caused by over-wet media during winter.

Most growers acknowledge that irrigation and nutrient regimes will need to be modified when using peat-reduced and peat-free media. The relatively poor water holding capacity of most peat-free alternatives will necessitate more frequent irrigation events, but over-watering must be avoided to minimise run-through of water and dissolved fertilisers and limit environmental pollution.

Run-through can be measured by collecting the volume of water that leaches from a representative group of containers (six to ten is ideal) following a typical irrigation event. Saucers can be used to capture run-through (Figure 3) but if the volume of water applied means that these are likely to overflow, using plastic bags within larger containers placed underneath the containers to capture the water will ensure more accurate results (the method is described in more detail in AHDB Horticulture Factsheet 18/17).

Water holding capacities can be 30-50% less in peat-free media mixes relative to peat-reduced or peat-based ones, and so more frequent irrigations of shorter duration are required. Incorporation of wetting agents into these mixes may help to improve water retention and uptake.

The need to irrigate commercial crops is often judged by visual assessment. The colour of peat changes from dark to light brown when dry, but with peat-free or even peat-reduced media, the top layer tends to dry out very quickly (increasingly so, the higher the percentage of peat replacement). As a result, peat-free or peat-reduced media are often over-watered, as they appear to be drying out when in fact the lower layers still contain sufficient moisture. This may require some adjustment on the part of nursery staff accustomed to a quick visual check of the surface of the medium when assessing irrigation needs. The drier surface of peat-free and peat-reduced media should, in fact, help to limit evaporative losses and improve media water availability.

Figure 3. Capturing run-through from a container-grown nursery stock trial using *Ribes*

Tools to help inform irrigation decision making

The purpose of irrigation to container-grown plants is to promote healthy shoot and root growth and optimise aesthetic appeal at the point of dispatch and during retail by ensuring that growing medium water availability is maintained within an optimum range. Rather than trying to maintain the moisture level at container capacity it is more usual to allow a degree of drying, but growers need to know 'how dry is too dry'. In this factsheet, the optimum growing medium moisture content is defined as one that supports good, healthy growth and allows plants to transpire freely while avoiding over-wet conditions so that leaching of fertiliser is minimised or eliminated, and excessive media drying that would limit plant quality is averted.

The optimum volumetric substrate moisture content (VSMC) will differ between species but, as shown in Figure 4, the range of values is between container capacity and the VSMC at which the plant begins to perceive and respond to limited water availability (a-b). Lower VSMCs can be used to implement deficit irrigation strategies to control plant growth and improve visual appeal, as explained in Factsheet 18/17.

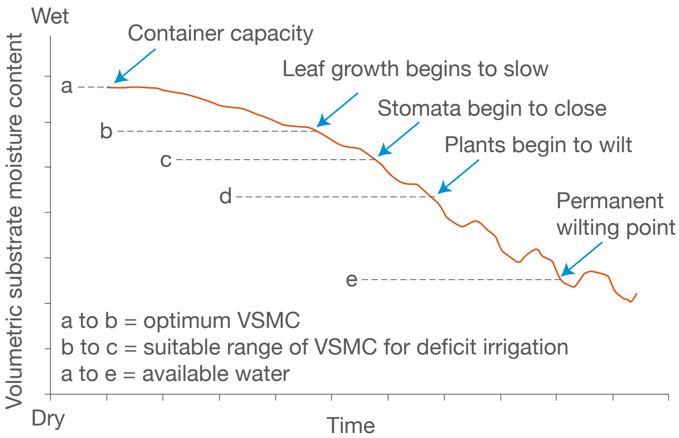

Figure 4. Optimum volumetric substrate moisture content for a standard commercial growing medium

Maintaining the optimum media moisture content for tens or hundreds of varieties on a typical container nursery is challenging enough but is complicated further by the effects of the UK's changeable weather on plant water use. Nevertheless, this can be achieved with effective irrigation scheduling using several different approaches, either alone or in combination. Although some irrigation decisions are still based on experience and intuition, the techniques and approaches described in reports and factsheets from several AHDB Horticulture-funded projects offer more effective ways to optimise irrigation scheduling on a typical HNS nursery. These approaches are explained in the following sections, and practical guidelines on how to implement them on the nursery are provided in the section after.

Gravimetric estimates of plant water loss

The simplest way to work out the duration and frequency of irrigation events is to measure plant water loss over a given time. Weighing representative plants and containers at intervals throughout the day using an electronic balance (Figure 5) can provide accurate data on rates of weight loss (plant water loss) that can be used to optimise irrigation regimes.

Figure 5. A container-grown rose being monitored using a simple electronic balance

Measuring water loss over several hours, at different times during the day, at different growth stages and during different weather conditions will give more accurate data than simply measuring water loss over a few hours. Weighing lysimeters are available commercially that enable several plants to be measured continuously but these systems are unlikely to be cost-effective for most HNS nurseries.

In order to be able to replace the volume of water lost via evapotranspiration using this approach, the volume of water delivered per unit time by the irrigation system must be known – guidelines on how to measure application rate and uniformity of distribution are provided in AHDB Horticulture Factsheet 17/17.

Scheduling irrigation using crop coefficients and estimates of evapotranspiration

Irrigation can be scheduled using estimates of evaporative demand combined with crop coefficients to calculate the volume of water lost by a plant (actual evapotranspiration), and therefore the volume of water needed to be supplied by irrigation. One advantage of this approach is that irrigation can be scheduled for many different crops from just a few measures of daily evaporative demand across the nursery, provided that the relevant crop coefficients are known. The capital cost incurred using this approach is, therefore, likely to be less that that associated with purchasing several moisture sensors used either with hand-held meters or data loggers with telemetry.

For container-grown crops, the most accurate way of determining crop coefficients is to measure weight (water) loss directly over a period of 24 hours and divide this value by the number of degree hours recorded over the same period. The number of degree hours will be higher on sunny, windy days than on cloudy, cool or calm days. The resulting crop coefficient (grams of water lost per degree hour) can then be used in conjunction with daily estimates of potential evapotranspiration to estimate plant water loss over a given period. Provided the crop coefficient is recalculated regularly to account for increases in canopy leaf area, irrigation can be scheduled very effectively.

An example calculation of a crop coefficient for a given variety over a 24 hour period is given in the section entitled 'Practical tips on how to optimise irrigation scheduling on the nursery'.

A drawback with this approach is that in order to update crop coefficients, the repeated weighing of several plants of each species must be carried out regularly and this is not always feasible in commercial production systems. Other, proxy measures of plant water use based on easily measurable plant variables such as estimated canopy area, leaf area index, plant height or canopy spread may be used, but this approach carries more risk and care is needed to ensure that irrigation is scheduled effectively.

Irrigation scheduling in response to evaporative demand is already being practiced by a few HNS nurseries. Evaposensors (Figure 6) and evapometers can be used to estimate accumulated degree hours and combined with crop coefficients to inform irrigation scheduling. It is important that there is sufficient water in the evaposensor reservoir to ensure that the ‘wet’ leaf doesn’t dry out.

Figure 6. Evaposensor in use on a commercial nursery

Degree hours can be used in conjunction with crop coefficients but there are difficulties with this approach and it can be time consuming. It is often more straightforward to use accumulated degree hours in conjunction with plant and container weights or measurements of media water content to identify the value at which a target weight or moisture content is reached. By linking the evaposensor to an irrigation controller, irrigation can be applied automatically once the accumulated degree hours reach the target value.

Monitoring growing media moisture contents

A range of sensors is available to measure growing media moisture levels, see Figure 7 and the section ‘Equipment for controlling irrigation' in Factsheet 18/17. The most widely used are moisture sensors that use an electromagnetic field to measure the relative permittivity of the surrounding medium. The sensor supplies a waveform to the sensor prongs that changes according to the dielectric potential of the material. The dielectric value is then converted to growing medium water content by a calibration equation specific to the medium being used.

Adjusting the duration and frequency of irrigation events to maintain moisture contents within pre-determined thresholds is a very effective scheduling tool that has delivered significant water savings, good commercial yields and improvements in quality in many horticultural sectors.

Several moisture sensors are commercially available and ‘spot’ measurements can be made with a sensor and a meter, or continuous readings can be taken if a data logger is used. The relatively low cost of the moisture sensors combined with improved and cost-effective telemetry options now makes remote access of near real time media moisture contents economically viable for many nurseries. However, care must be taken when using moisture sensors to ensure that reliable and accurate measurements of media moisture contents are made.

Figure 7. Examples of various growing media moisture sensors (note some have been lifted from the media to show the various designs available)

Automated precision irrigation

Some systems described in the previous sections can be linked directly to solenoid valves or commercial irrigation equipment so that irrigation is triggered automatically once a pre-determined value of daily evapotranspiration or growing medium moisture content is reached (Figure 8). Work in other sectors using drip irrigation has shown that this type of precision irrigation delivers improvements in marketable yields and consistency of produce quality, in addition to significant improvements in resource use efficiency and environmental sustainability. However, these benefits are more difficult to achieve using overhead systems since only 20-40% of the water applied is retained within the containers and inefficient systems typically misplace between 50 and 80% of the water applied. The use of a gantry overhead irrigation system greatly increases irrigation uniformity, and seems to offer several advantages over conventional overhead systems. However, the large capital investment needed for this approach means that gantry systems will not be commercially viable for most medium- and small-scale HNS businesses.

Practical tips on how to optimise irrigation scheduling on the nursery

Some of the approaches described previously are already being practiced either individually or in combination by a few progressive HNS businesses. The choice of approach will depend on many factors including the size of the nursery, site topography, availability of skilled labour, the range of plant species grown, the source and quality of irrigation water, the method of irrigation delivery, market specifications and so on.

Measuring plant water loss using an electronic balance

It is important to weigh several plants at each time, from different positions within the bed or growing area, so that an average value of water loss over a given time for the crop can be calculated. Inexpensive, battery powered electronic balances are widely available. The choice of balance will depend on the range of container sizes and the size of plants grown. The electronic balance must be stable and placed on a flat surface.

Figure 8. Evapotranspiration monitoring equipment linked to irrigation control panels

First of all, ensure that the crop has been well irrigated and the containers are at capacity; this is probably best achieved by hand-watering labelled containers at different positions within the bed and waiting for 30 minutes for excess water to drain through. A sample size of between six and ten representative plants in containers will provide accurate results. If possible, the same group of plants should be weighed on each occasion, so that consistent results are obtained. Placing these plants in containers of a different colour means that they can be located easily and quickly by different members of staff. Note the time (T1), then weigh and record individual plant and container weights, and replace carefully on to upturned saucers to prevent any water uptake from below. Re-weigh plants in the same order after a set period of time (T2); three to four hours is normally sufficient. Subtracting the weight at T2 from that at T1 will give the weight/volume of water lost during the measurement time, and from that the volume of water lost per hour can be calculated (remembering that 1g of water is equivalent to 1ml or 0.001L).

For example, if the average container and plant weight at T1 was 1,800g, and fell to 1,400g at T2 four hours later, the average rate of water lost by evapotranspiration would be 100g or 100ml per hour.

Measurements of water loss should be made between irrigation events and if this exercise is repeated throughout the day, the average values of weight loss for each crop can then be used to inform the duration and frequency of irrigation events. Note that if uncovered crops are being measured, even light rain or spray applications will affect the readings and result in an under-estimation of plant water use.

Estimating growing media water holding capacities

Knowing the water holding capacity for different growing media is important if irrigation is to be scheduled effectively, especially for peat-reduced and peat-free media. If the water holding capacity of the medium is less than the volume of irrigated water needed to return containers to capacity, irrigation should be pulsed or applied for short durations to ensure that run-through is minimised during re-wetting of the medium.

Water holding capacity can be measured by immersing several containers in water for five minutes, allowing the containers to stand until no more water drains from the bottom and then weighing each container. The plant and container weight at container capacity (the point at which the medium can hold no more water), will provide a target upper plant and container weight and this will help to schedule irrigation more effectively. Similarly, knowing the plant and container weight at which visible leaf wilting first occurs will provide useful information about the range over which plant quality will be optimised, as shown in Figure 4.

Using crop coefficients and estimates of potential evapotranspiration

To estimate how much water to apply to each crop at any given time, coefficients that relate gravimetric estimates of plant water loss to the accumulated evapotranspiration over 24 hours must be calculated.

For plants in one to ten litre containers, this can be achieved using a relatively inexpensive electronic balance and an estimate of daily evapotranspiration, computed from local weather station data or from a dedicated evaposensor and evapometer. With the former, the daily evapotranspiration is expressed in mm and can be used to programme the frequency and duration of irrigation events throughout the day to deliver the required depth of irrigation. When using an evaposensor, water loss per degree hour is determined and used in conjunction with the number of daily degree hours in the previous 24 hours to determine the average daily volume of water used by the plants. In both cases, the sum total volume of the daily irrigation events replaces the volume of water estimated to have been lost during the previous 24 hours. These calculations should be made weekly over the growing season to account for the increase in plant size and associated transpirational leaf area.

For example, if the average plant water loss over 24 hours is 440g, and the accumulated degree hours over the same period is 102, then the crop coefficient can be calculated as follows:

$$\text{Crop coefficient} = \frac{440}{102} = 4.31$$

Remembering that 1g of water is equivalent to 1ml or 0.001L, plant water demand over the next 24 hours under cloudy, cool conditions when the value of accumulated degree hours was 56, would calculated as follows:

$$56 \times 4.31 = 241\text{ml or } 0.24\text{L}$$

The crop coefficient of 4.31 in the above example could be used to estimate crop water needs in conjunction with accumulated degree hours until an increase in plant size necessitated a re-calibration of container and plant weight loss per accumulated degree hour.

It is important to measure accumulated degree hours over a 24 hour period, shorter times will result in an erroneously high crop coefficient which will lead to over-irrigation. If used carefully, this approach can be used to estimate the volume of water needed to replace that lost by evapotranspiration during the previous 24 hours or in the last few days, without applying excess. If rainfall is measured on the nursery using a rain gauge, the volume should be subtracted from the total, although rainfall of less than 3mm is generally assumed to be ineffective.

Using growing media moisture sensors

Several different brands of moisture sensors are available for use on commercial nurseries. Detailed instructions on their correct installation and use are provided in the respective user manuals; these can also be accessed via the suppliers' websites. If available, it is important to ensure that the correct calibration is used for the growing medium in question, failing that, sensors can be calibrated for specific media by the user; this involves measuring the moisture content at a range of known gravimetric values of media moisture content to construct a calibration curve such as that shown in Figure 9 for a Decagon 10HS sensor. Detailed instructions on how to do this are available online.

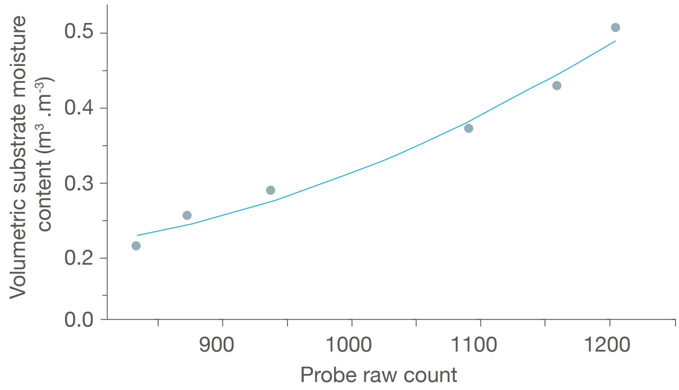

Figure 9. Example calibration curve for the Decagon 10HS sensor for an industry standard medium

Irrespective of the type of moisture sensor used, ensuring good contact between the probe and the medium is essential and it is vital that the probe is inserted fully into the medium, since an air gap will result in erroneously low readings that may lead to over-irrigation (Figure 10). To minimise disturbance to the root systems and to avoid breaking the capillary action of containers receiving sub-surface irrigation, routine measurements of moisture content should be carried out by inserting the probe vertically into the top of the growing medium surface, approximately 5cm in from the container rim wherever possible to avoid edge effects.

Ideally, two measurements should be taken on opposite sides of each container and the values averaged. In addition to volumetric moisture contents, data on the temperature and bulk or pore electrical conductivity of the medium can be collected at the same time. However, it is important to know where on the moisture probe the temperature sensors are located; if they are housed within the body of the probe, the entire sensor must be buried fully in the medium. Downloading data into spreadsheets allows the user to identify and interpret trends which can then be used to inform irrigation scheduling over the current and subsequent growing seasons.

Sensors can also be inserted into the root ball and left in representative containers to provide data on volumetric substrate moisture content, temperature and pore E.C. Although values from these in situ sensors can be read with hand-held meters, the greatest value is in connecting them to data loggers so that changes in the parameters can be monitored continuously, throughout different stages of crop development and variable weather conditions. These sensors can also be used to trigger irrigation automatically once pre-determined moisture contents are reached.

Adopting automated precision irrigation systems

An automatic irrigation system comprising of Delta-T SM200 moisture sensor connected to GP1 data loggers was developed in AHDB Horticulture-funded project HortLINK 97b and used with great success at Hillier Nurseries. Water savings of 80% were achieved over the season, compared with plants where irrigation frequency and duration were decided by staff members.

The automated irrigation system used in conjunction with the lower irrigation set points developed in AHDB Horticulture-funded project HNS 182 were particularly effective during the rainy 2012 growing season since any uncertainty about whether rainfall events were effective or not was removed and the system prevented over-irrigation of the HNS crops during the very wet summer of 2012.

However, it would be risky to schedule irrigation to blocks of high-value HNS crops using a system that relies on the output from a single moisture sensor. New technology is now available that can overcome this limitation.

Keeping records and using spreadsheets

It is relatively easy to take repeated ‘spot’ measurements to help schedule irrigation but once the data is averaged and used to inform irrigation decision-making, the raw data is often discarded. The value of this approach lies in downloading the data to a spreadsheet so that a database can be built up over the season for individual crops. This allows trends and irregularities to be examined and adjustments to be made to continually improve the effectiveness of irrigation scheduling.

Developing technologies to improve irrigation precision in UK horticulture

Precision irrigation systems utilising gantries and thermal imaging were developed in AHDB Horticulture-funded project HNS 97b (Figure 11) but these have not been commercialised for use by the HNS industry, and would perhaps only be economically viable on large nurseries (A prototype system with supporting software has been developed by The Vineland Research and Innovation Centre, Ontario, Canada and recently trialled with success on a commercial protected ornamentals nursery).

However, other more cost effective systems are now available. Although the Delta-T GP1 was used with great success on Hillier Nurseries, the risk associated with scheduling irrigation to blocks of high-value HNS crops using a system that relies on the output from a single moisture sensor is significant, and currently represents a barrier to the commercial uptake of the some of the outputs from the research on optimising irrigation to HNS.

Figure 10. Example of poor sensor positioning – the probes are proud of the medium and the sensor is too close to the container rim which will lead to erroneously low readings

The Delta-T GP2 Advanced Datalogger and Controller can average values from up to 12 different SM300 or SM150 moisture sensors, and this system is being used with great success in soft fruit experiments at NIAB EMR. A detailed cost-benefit analysis is needed to determine whether such a 'closed loop' precision system would be cost-effective for use on medium to large HNS businesses.

Sensors that measure volumetric substrate moisture content have been used in the majority of AHDB Horticulture-funded work on optimising irrigation scheduling in HNS, and other research groups are also using this approach to develop water-saving irrigation scheduling regimes for HNS crops. Although these measurements, when combined with a detailed knowledge of plant physiology, provide useful information on the optimum range of growing media moisture contents, they are influenced by differences in bulk density and so it is likely that the absolute values will change as the medium settles or slumps during the growing season.

While these numeric changes may be relatively minor and therefore impact very little on irrigation scheduling, it would be preferable to base irrigation scheduling on substrate matric potential, as this value is not influenced by changes in bulk density. Matric potential is a measure of water availability and this is likely to differ in media with different percentages of peat content. Hitherto, this has not been possible due to the lack of suitable matric potential sensors (mini-tensiometers have been available for many years, however, they can be time-consuming to maintain and are not suitable for use in drier growing media), however Delta-T Devices Ltd and NIAB EMR have recently completed a project in which a foam-based electronic matric potential sensor was developed and tested in a coir growing medium. The range over which this new electronic tensiometer operates coincides with the matric potentials that trigger the first adaptive responses to limited water availability in plants (equivalent to the a-c range of VSMC as shown in Figure 4).

There is great potential to use this new sensor in conjunction with the GP2 to achieve multi-zone irrigation control based on changes in substrate matric potential; this approach is currently being tested on commercial soft fruit and mushroom farms.

Figure 11. Chris Burgess demonstrates a gantry containing sensors utilised as part of project HNS 97b during an open day event at Hillier Nurseries

Supplier listing

Moisture sensors and data loggers

Agri-tech Services (UK) Ltd
Shefford Hardwicke Farm
Shefford
Bedfordshire
SG17 5NU
Tel: 01462 813303
Email: sales@agri-tech.co.uk

Agrovista UK Ltd
T/A Plantsystems
Rutherford House
Nottingham Science
and Technology Park
Nottingham
NG7 2PZ
Tel: 01945 870356
Email: admin@plantsystems.co.uk

Delta-T Devices Ltd
130 Low Road
Burwell
Cambridge
CB25 0EJ
Tel: 01638 742922
Email: sales@delta-t.co.uk

Decagon Devices Ltd
2365 NE Hopkins Court
Pullman
WA 99163
USA
Tel: 1 (509) 332 275
Website: www.decagon.com

Electronic and Technical Services Ltd
40 Acreville Road
Bebington
Wirral
CH63 2HY
Tel: 0151 645 8491
Email: john@ets-controls.co.uk

Skye Instruments Ltd
21 Ddole Enterprise Park
Llandrindod Wells
Powys
LD1 6DF
Tel: 01597 824811
Website: www.skyeinstruments.com

Irrigation controllers and equipment

Heron Electric
Unit G15
Rudford Industrial Estate
Ford, Arundel
West Sussex
BN18 0BD
Tel: 01903 724343
Email: sales@heron-electric.com

Netafim UK Ltd
2B Penketh Place
West Pimbo
Skelmersdale
Lancashire
WN8 9QX
Tel: 01695 556222
Website: www.netafimuk.com

Glossary

Available water capacity: The difference in the water content at container capacity and wilting point.

Container capacity: The volume or weight of water remaining in a container of growing medium after it has been fully saturated and allowed to drain freely.

Crop coefficient: A crop dependant factor used to adjust or convert a measured parameter. (In this context, the value of the crop coefficient can also take into account container size, efficiency of irrigation method, uniformity of precipitation, water absorption and retention by the growing medium as well as the type and size of the crop. Evapotranspiration units as measured by a pan evaporimeter (mm), or evapometer (°C h) are adjusted or converted into a crop irrigation figure (e.g. mm, litres applied per bed or minutes of sprinkler duration) by multiplying by a single value established via a calibration procedure involving the change in weight of a sample of containers containing well-watered, transpiring plants).

Degree hours: The number of degrees Celsius by which an average temperature is below or above a standard temperature. (The evapometer records the temperature difference between wet and dry probes on the evaposensor unit. The wet probe will be cooler than the dry probe due to the energy (latent heat of evaporation) taken by the water as it evaporates. The more conducive the environment to evaporation (warm, breezy, dry, bright), the greater the temperature difference between the probes. When sited in a similar environment to a plant, the recorded units in degrees Celsius hours (°C h) are approximately proportional to the transpiration from a well-watered plant. For example, the wet and dry probes might average 12.5°C and 16°C, respectively, over one hour. This difference would equate to 3.5°C hours. Over the next hour, 5°C hours might be accumulated and so on. During the summer, a 24 hour total of 180°C hours on hot sunny days may be recorded, whilst values less than 20°C hours may occur on cool, overcast days).

Dielectric potential: A measure of how easily a substance polarizes in response to an electric field.

Evaposensor and evapometer: Instruments that provide an electrical signal approximately proportional to potential transpiration from a model leaf. They integrate the effects of humidity, radiation, temperature, wind, and leaf wetting.

Gravimetric estimate: A procedure involving the change in weight over a defined period of time of a sample of containers containing well-watered, freely transpiring plants. During the measurement period, it is important to prevent any water uptake by the plant from overhead irrigation (or rain) and sub-surface irrigation. This is best achieved by taking measurements in dry conditions and by standing containers on upturned saucers.

Lysimeter: A measuring device which can be used to calculate the amount of evapotranspiration by plants. By recording the amount of precipitation that an area receives and the amount lost through the growing medium, the amount of water lost to evapotranspiration can be calculated.

Potential evapotranspiration: The rate at which a plant would lose water under prevailing environmental conditions if the water supply was non-limiting. It includes evaporation from the plant (transpiration) and from the medium in the container.

Substrate matric potential: A measure of the capillary forces holding water in the growing medium and therefore the force required to remove it. Since matric potential will differ within a container, for example it will be less negative at the base of the container where the growing medium is often wetter, tensiometers should be placed in the same position in each container.

Tensiometer: A device for measuring the water tension in the soil or growing medium. Tensiometers measure matric potential rather than volumetric water content, and it is measured in kiloPascals (kPa). Matric potentials become more negative as the medium dries (Figure 12).

Volumetric substrate moisture content: The water content of the medium expressed as a fraction or percentage of the total volume occupied by water. Its optimum value depends on the type of growing medium, but for those used in the production of HNS, it is generally between 30 and 50%.

Wilting point: The water content of the growing medium when a plant can no longer draw water from it. At this point, the capillary forces holding the water in the medium just exceed the capillary pull, 'suction' or water tension capable of being exerted by the plant.

Figure 12. A commercial tensiometer for measuring the water tension in growing media

Further information

AHDB Horticulture factsheets and publications

Factsheet 18/17: 'Methods and equipment for matching irrigation supply to demand in container-grown crops'.

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

Factsheet 15/06: 'Water quality for irrigation of container ornamentals'.

Factsheet 01/06: 'Capillary irrigation of container grown nursery stock'.

Factsheet 07/05: 'Securing your water supply for the future'.

Other publications

ADAS (2008) Environmental Best Practice for the Ornamentals sector: A Guide for UK Growers.

BOPP Best Practice Guide: Managing water and preventing pollution on ornamentals nurseries.

AHDB Horticulture grower summaries and reports

HNS 182: 'Developing optimum irrigation guidelines for peat-reduced, peat-free and industry standard media'.

HNS 159: 'Nursery stock propagation: Nursery evaluation and demonstration of the Evaposensor towards its commercial availability as a mist controller'.

HNS 141: 'Improving the quality of HNS and roses using irrigation and fertigation management techniques'.

HNS 122: 'Container nursery stock irrigation: Demonstration and promotion of best practice'.

HNS 117: 'Identifying the key factors controlling HNS uniformity'.

HNS 107a: 'Improving water management within growing media'.

HNS 107: 'Container HNS irrigation: Use of capillary matting under protection'.

HNS 97b/Horticulture LINK project HL0168: 'Enhancing the quality of hardy nursery stock and sustainability of the industry through novel water saving techniques'.

HNS 97/Horticulture LINK project 201: 'Improving the control and efficiency of water use in container-grown hardy ornamental nursery stock'.

PO 017: 'Enhancing crop quality and diminishing water use in bedding plants'.

SF 118: 'Irrigation scheduling of substrate-grown raspberry as a tool for improving cane management'.

CP 110: 'Developing a water strategy for UK horticulture'.

CP 64: 'Development of a water strategy for horticulture'.

Acknowledgements

The majority of the project work reported here has been undertaken within AHDB Horticulture-funded projects HNS 182 and HNS 141, with references to factsheets originally authored by Chris Burgess, Horticultural Agronomist.

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