The Application of Advanced Irrigation Technology in Hardy Ornamental Nursery Bed Systems©

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Precise control over plant water status can provide growers with a means of using controlled water deficits to beneficially modify growth, development, and quality. Infra-red (IR) thermographic technology allows remote monitoring of leaf temperature, which can be a good indicator of plant water status because leaf tissues heat up as transpiration is reduced by closure of stomata (a common response to shoot or substrate water deficit). Precise methods of delivering irrigation and nutrients, based on IR imaging and gantry booms that tailor dose to the needs of individual plants, are being developed as part of a new Water-LINK project (Department for Environment, Farming and Rural Affairs). Expected benefits compared with existing nursery systems include minimal water run off, increased crop uniformity, a lower reliance on growth regulators, and less need for nurserymen to monitor the water status of beds. The technology is compatible with a number of emerging technologies in irrigation and plant monitoring.

INTRODUCTION

Most hardy ornamental nursery stock (HONS) growers in the U.K. rely on overhead sprinkler irrigation systems. These are relatively easy to install and require little maintenance. However, they have numerous disadvantages:

- Far more water is applied to the plant than is required to satisfy the demand from evapo-transpiration. This problem has become more important as the cost of water is increasing and extraction licenses are becoming restricted. It also leads to a reduction in crop quality, since the plants grow tall and unbranched and crop uniformity suffers.
- Sprinklers often have an uneven delivery when compared to other systems such as drippers. This leads to a proportion of the crop needing extra irrigation, achieved either by over-watering of other sections of the bed or by the use of hand-held hoses.
- Plants on the edge of a bed have a greater irrigation demand than those within the crop. This is not easy to compensate for with an overhead fixed sprinkler system.
- Constraints on space require growers to have numerous species on a bed, each with a different irrigation requirement resulting in over- or under-watering of most species.
- The foliage gets wet every time the irrigation is applied, and this can lead to greater risk of fungal disease, sun-scorch, and greater water loss through evaporation.
- Any area of bed without a crop on it also receives irrigation, and large quantities of water can be lost as a result.

In addition to these disadvantages, overhead irrigation is generally associated with manual assessment of plant/soil water status, which adds additional labour costs to the overall cost of production.

More efficient and uniform irrigation systems are available, and as the cost of water and labour continues to increase they are becoming more desirable alternatives to overhead systems. Dripper systems deliver irrigation directly to the growing medium and thus have greater control over the volume of irrigation delivered per plant. Gantry systems are starting to receive greater attention and are already being used by HONS growers in Germany and Holland.

GANTRY IRRIGATION FOR HONS

A gantry system consists of a mobile boom to which irrigation spray nozzles are attached. The boom travels over the crop while the nozzles release the water. With appropriate controls, water can thus be delivered to specific areas of the crop or even to individual plants.

This delivery system can be much more precise than overhead irrigation and has the potential to be modified and calibrated to suit the needs of the nursery. The gantry nozzles and locomotion can be controlled by a computer linked to sensors so that it can be programmed to account for edge effects, to differentiate between different species and their irrigation demand, to recognise bare ground, to apply water-deficits, and to add fertiliser treatments in the irrigation stream (fertigation).

Water Status Sensors. There are number of commercially available sensors that could easily be installed to control the irrigation delivered by a gantry system. Sensors that measure the soil dielectric can be used to determine the soil moisture content and these can be successfully linked into irrigation systems. Also, sensors that measure the evaporative demand received by a crop (e.g., evapo-sensors, SKYE Instruments) can also be incorporated into control systems. Leaf temperature (as an indicator of stomatal conductance) can be measured using thermocouples attached to a leaf of a sample plant to compare air temperature to leaf temperature. However, thermocouple sensors can be difficult for nurserymen to install and are too delicate to be used in unprotected environments. These and other sensors can only feasibly measure several points within the bed at most.

Thermal Imaging. Thermal imaging of crops to assess leaf temperature has the potential to measure plant water status and stress levels individually and adjust the water delivered to those plants accordingly. As soils dry, the leaf stomata close and the resulting lack of evaporation leads to a rise in leaf temperature. Although the difference in leaf temperature between well-watered and drought-stressed plants can be as little as one or two degrees, this can be clearly picked up if the sensors are calibrated correctly. A stress-induced rise in leaf temperature can happen rapidly after the stomata close and is therefore one of the first drought stress indicators, with the advantage that it can be assessed at a distance. An additional advantage of using leaf temperature to measure water stress is that species that have adapted to arid environments will close their stomata at much lower soil moisture contents than species that require very moist media to continue to grow. Therefore, the degree of stress in each species should be roughly equal once leaf temperatures have risen.

With prices of thermal imaging cameras dropping in the past few years it means that the technology is coming into the range where it will become economically feasible to use on HONS nurseries. One challenge is to develop a method of scanning beds that relies solely on the temperature of the foliage. The camera will also pick up the growing medium, container, and ground surface temperatures, and the data analysis must be capable of ignoring these areas of the image when making a calculation for the irrigation to deliver.

Image analysis software (Jones and Leinonen, 2004) can identify pixels in the electronic image that correspond only to the foliage. Reference surfaces can be used to differentiate between shaded and sun-lit foliage, which strongly influences leaf temperature (Jones 1999).

By logging the delivery of water supplied over a set period it can be determined if a plant has been over- or under-watered. If the thermal image temperature readings are more or less than expected for the amount of water supplied this will indicate if there is a problem with that particular plant (for example, a rise in temperature caused by disease stress). A warning message could then be generated for the grower to advise checking the plant located at a specific grid point on the bed.

If the thermal-imaging system is to be used outdoors, it would need to be able to cope with the effects on the plant temperature of increased wind speed and wetting effects from rain, fog, and dew. Problems can occur when trying to detect stress-induced high leaf temperatures in humid environments or with high airflow. Under these conditions leaf cooling due to transpiration is severely reduced. These hurdles will be overcome during development of a working demonstration rig for the LINK project.

Species Considerations. There are a number of species that will have to be given special considerations, as their leaf temperature doesn't relate to water status in the same way as that of most plants. Some species do not regulate their internal water status by closing stomata as soon as drought stress occurs. These species, termed anisohydric species, first lower internal water potentials before stomatal conductances are significantly affected. In these species, the thermal cameras may not be able to detect mild stresses as is the case in normal (isohydric) species. We are currently finding out which of the most commonly grown ornamental species fit into which of the two categories. When a large number of species from several plant families have been sampled, it is hoped that we will be able to develop a means of determining which groups of plants have the ability to act isohydrically and see if there is an evolutionary link from the response.

Another set of plants that needs special consideration are the species belonging to the arum lily family (Araceae), which have inflorescences that are thermogenic — the temperature of the inflorescence increases dramatically as the flowers ripen (Skubatz et al., 1990). Therefore, any thermal scanning system would confuse this with stress-induced heating and provide far too much irrigation. Other potential problems with the use of thermal imaging may arise if the plants are experiencing other types of stresses, such as viral attack, waterlogging, and frost damage, which are known to reduce stomatal conductance. These stresses will result in increased leaf temperature, but should not be treated with increased irrigation (Chaerle and Van Der Straeten, 2001; Wan et al., 1998).

CONCLUSION

Thermal imaging technology has the potential to provide great advances in the HONS sector by reducing water waste, but most importantly increasing quality and uniformity of plants. Signs of drought stress can be picked up early, and irrigation can be individually tailored to thousand of plants on the beds with gantry boom sprayers. There are still significant challenges faced in the development of such systems, but the technology is now at the stage where demonstration rigs are being developed and commercialisation is foreseen in the near future.

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