The Role of the Evaposensor in the Propagation of Hardy Nursery Stock©

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Standard mist controllers (such as simple timers, electronic leaves, or those using solar radiation integral) often fail to match misting frequency to the needs of the cutting very well, leading to reductions in rooting percentage and quality. The need for mist (or fog) varies with light level, humidity, temperature and air movement, all of which fluctuate with the weather, season and time of day. The Evaposensor, with its wet and dry artificial "leaves," responds to all these factors making it possible to measure and control the evaporative demand on cuttings in a reliable and reproducible way. The Evaposensor was invented in the 1990s as a research tool for controlling mist and fog environments, but only recently has equipment suitable for growers become available. Starting in 2007, a Horticultural Development Company (HDC) project promoted the development of a dedicated controller for use with the Evaposensor and funded trials on six nurseries. Evaposensor control gave significant improvements in rooting across a wide range of subjects, combined with easier management of the propagation environment. The new mist controller is made by E&TS Ltd. It can be used independently, or integrated with existing controllers in a variety of ways, for example to allow multiple beds to be controlled from a single Evaposensor.

INTRODUCTION

Mist or fog propagation environments for leafy cuttings reduce the evaporative demand on the cutting, thus helping it to maintain its water balance, limit stress and thus promote vigorous wound healing and rapid rooting. The problem is that the optimum amount of mist required will vary (even hour to hour) according to the weather, season, type of propagation facility, degree of shading etc. A good mist or fog control system needs to vary the application of water according to the needs of the cutting, to avoid either over or under wetting the foliage and rooting medium, either of which can increase cutting stress, risk of tissue damage and development of disease. Mist controllers vary in sophistication from simple timers to glasshouse computer algorithms involving solar radiation integral, temperature and humidity. Many growers favour the simplicity of timers but find they are not able to keep up with the manual adjustments needed to account for changes in the weather. The widely used "wet leaf" or "electronic leaf" sensor, which is based on the conductivity between two electrodes to trigger mist bursts, is notoriously temperamental and unreliable. It is rapidly affected by hard water deposits, tends to over mist in dull weather or at night, and the sensitivity adjustment provided on some controllers is often unreliable. The "Solarmist" controller (Access Irrigation Ltd), or other solar integral controller, can give better results but takes account only of light.

Principles of Evaposensor Control. The Evaposensor (Fig. 1) is the ideal sensor for control of mist or fog because it measures all factors that contribute to evaporative demand on cuttings. Indeed, its invention at East Malling Research stemmed from a need to monitor the propagation research environments in a way that reflected the needs of cuttings (Harrison-Murray, 1991a & 1991b). It consists of two temperature sensing "leaves," the wet leaf, which is kept permanently wet via a wick, and the "dry" leaf, which is initially dry but gets wetted periodically by bursts of mist or fog. Unlike conventional wet/dry hygrometers in an aspirated screen for measuring relative humidity, the Evaposensor is placed just above cutting height. Here it is influenced by the mist, solar radiation, air temperature, humidity and air movement — i.e., *all* the factors affecting the rate of transpiration water loss from the cutting. Both the 'leaves' and the wick are black so that they absorb similar amounts of radiation. Typically, the wet leaf remains cooler than the dry leaf by evaporative cooling. The *temperature difference* between the leaves is called the Wet Leaf Depression (WLD). The WLD is proportional to potential transpiration from, and hence potential water stress on, the cutting.

Following misting, the "dry" leaf becomes wet and the WLD falls rapidly to near zero, reflecting the effect of mist on reducing transpiration from the cutting. As the dry leaf dries out, the WLD rises until the set point on the controller is reached, and another burst of mist is triggered. The WLD set point represents a *level of cutting support* that can be reproduced across different facilities, nurseries and seasons. Whatever the background environment, the system applies the amount of mist (or fog) needed to limit transpiration to the level set on the controller. The higher the set-point, the drier (or less supportive) the aerial environment is allowed to become. The Evaposensor is thus an excellent basis for controlling mist or fog in propagation, as it senses WLD in an analogous way to the transpiration stress experienced by cuttings or plants. Misting frequency is automatically adjusted along with the weather to accurately reflect changes in evaporative demand.

MATERIALS AND METHODS

Project Objectives. The HDC project's first objective was to develop and test an Evaposensor Control Interface (ECI) to read the Evaposensor and trigger mist, and to make this commercially available to the industry (Burgess and Harrison-Murray, 2009). This was to replace the now obsolete Nobel humidity controller used in the original research with the Evaposensor at EMR. A prototype developed by Electronic & Technical Services Ltd, Cheshire, UK (E&TS), was compared to the Nobel controller in the first year of the project, subsequently leading to a production version with more functionality (Fig. 1), which was tested and demonstrated on more nurseries in subsequent years. The second objective was to compare Evaposensor mist control with growers' existing systems in terms of rooting percentage across a range of HNS subjects. Data logging equipment from Delta-T Devices Ltd and Skye Instruments Ltd was also used to monitor the duration of misting, relative humidity, air temperature and light levels.

Propagation Facilities. The nursery trials were undertaken between summer 2007 and summer 2009 in open mist propagation facilities at New Place Nurseries,

Figure 1. The Evaposensor (left) and the Evaposensor Control Interface (right).

Pulborough, W. Sussex; Binsted Nursery, Arundel, W. Sussex and Lowaters Nursery, Warsash, Hampshire. Further Evapomist testing and demonstrations took place in summer and autumn 2009 at Boningale Nurseries, Wolverhampton, W. Midlands; Living Landscapes Nursery, Chester, Cheshire and Micropropagation Services, Loughborough, E. Midlands. Nurseries used mist nozzles on either low risers from the propagation beds or on overhead lines. Most inserted cuttings into cell trays stood on drained capillary sand bases to help pull any surplus water from the rooting medium, but one nursery laid trays on capillary matting over polythene on a concrete glasshouse floor and another on benches covered with capillary matting with a 100 mm overhang to improve drainage. Summer shading was used as necessary with whitewashed glass and / or shade screens.

Standard Treatment. For nurseries using manually adjusted timers as their standard treatment, mist burst frequencies were varied during the day and with the season, but typically ranged from 10 to 30 min intervals during daylight hours in late spring to early autumn, but less in winter. Some applied one or two mist bursts during the night. At Lowaters and Micropropagation Services nurseries, additional mist bursts were triggered under bright conditions using a solar radiation integral with a light sensor connected to a Heron timer. At Binsted Nursery, a complex algorithm involving light sum and vapour pressure deficit was used in conjunction with their environmental control computer. Boningale and Living Landscapes Nurseries used a 'wet leaf' sensor as their standard system.

Evaposensor Treatment. The Evaposensor treatments used WLD set points ranging from 1.3 °C to 5.0 °C during the summer. The higher set points of 4.0–5.0 °C were necessary on nurseries where less shading was used and either good capillary contact between cutting trays and sand beds was compromised by a layer of geo-textile, or where a poorly drained capillary matting base was used. In these situations, during very bright periods when mist burst frequency was highest, lower WLD set points could result in over wetting of the rooting medium because drainage was impeded. Additionally, at Binsted Nursery, where stress insensitive subjects were being propagated, and where rooting media could easily become over wet, the maximum mist burst frequency was capped at 15 minute intervals to partially override Evaposensor control, by using the 'Off Minutes' dial on the ECI.

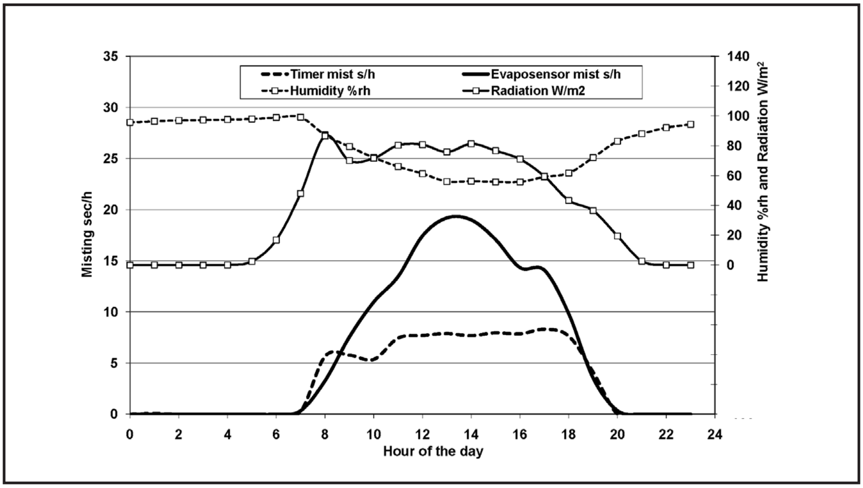

Figure 2. New Place Nursery. Mean diurnal pattern of mist and ambient environment for ETS Evaposensor vs. Heron Timer treatments averaged mid-May through mid-June 2008.

Mist burst durations for both 'grower standard' and Evaposensor control treatments were 2–4 seconds depending on the nursery and the time of year. Where available, three or four replicate module trays per environment treatment were compared, (20–104 cuttings per tray depending on species).

RESULTS & DISCUSSION

Control of Propagation Environment and Ease of Management. The Evaposensor and amount of mist applied responded sensitively to changes in the environment, such as solar radiation level and humidity, whereas control based on timer alone (New Place) or with an additional light sum sensor (Lowaters) was relatively unresponsive (Figs. 2 & 3). Figure 2 illustrates that with Evaposensor control, average mist frequency peaked when light levels were highest and ambient humidity lowest in the middle of the day (i.e., under conditions of highest transpiration stress for the cuttings). Evaposensor misting was invariably restricted to daylight hours, and on very dull, cool or humid days little or no mist was applied (Fig. 3). On other nurseries, the "wet leaf" control was not easily adjusted and this treatment typically applied too much mist in dull conditions and even at night. The amount of mist applied in autumn, winter and early spring under Evaposensor control was considerably less than in the summer and it automatically adjusted for the occasional bright days that often cause difficulties with other control methods.

Growers reported that a major advantage of Evaposensor control was the ease of management. Unlike timer programs, frequent manual adjustment of misting frequency to suit the weather or day length was not required and dials on the E&TS controller were simple to understand and use. The WLD set point also defines the propagation environment as a readily understood and measurable unit, that relates directly to transpiration and cutting stress, and that is reproducible across different propagation facilities and seasons.

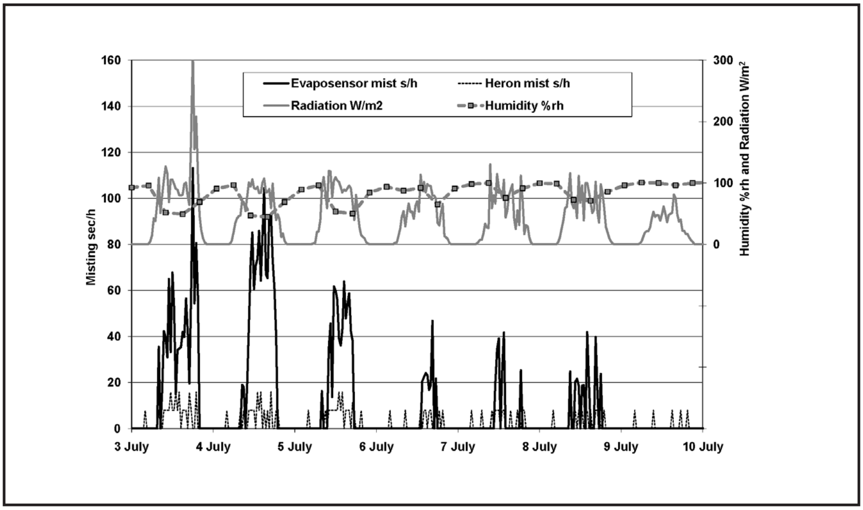

Figure 3. Lowaters Nursery. Half-hourly plots of misting and ambient environment July 2008, showing the sensitive response of Evaposensor control.

Rooting Performance. In the original research at East Malling, Evaposensor control had contributed to successful propagation of difficult to root species such as *Cotinus coggygria*, *Garrya elliptica*, *Acer cappadocicum and A. palmatum* cvs., *Rhododendron* and *Pieris* cvs., and *Corylus maxima*. These species were not available for this project, but Table 1 summarises results for the two nurseries where the greatest numbers of cutting batches and species were trialled. At New Place Nurseries (shrubs), the Evaposensor gave a mean overall rooting improvement of 4.4 percentage points. However 82% of the 55 batches compared gave similar or better rooting and some, such as *Berberis darwinii, Hydrangea petiolaris, Pittosporum* cvs., *Spiraea* Arguta, *Teucrium fruticans* 'Compactum' and *Viburnum sargentii*, gave significant improvements up to 20–30 percentage points. At Lowaters Nursery (shrubs and perennials), a larger mean rooting benefit of 11.7 percentage points was achieved, with 80% of the 69 batches compared giving similar or better rooting. Species showing the greatest benefits included *Choisya ternata, Cistus* cvs., *Coleonema* cvs., *Coprosma* cvs., *Escallonia* cvs., *Fuchsia genii*, *Halimium* spp., *Myrtus romana* 'Compacta', *Olearia* cvs., *Phygelius* ×*rectus* cvs., *Polygala myrtifolia*, *Ulmus procera* and *Vinca minor* cvs. with improvements from 20–70 percentage points.

The increase in rooting with the Evaposensor probably comes from the way it concentrates misting into periods when the potential for cuttings to be stressed is highest. In this project, a wide range of subjects was propagated at the same time under each propagation environment, and the control set-point was adjusted to meet the needs of the majority. The ability to adjust evaporative demand to suit particular cutting subjects is likely to further increase average rooting percentage on nurseries that adopt this approach. For example, species sensitive to leaf wetting (some hairy leaved subjects) would benefit from a drier regime in an independently controlled zone.

Table 1. Summary of rooting results 2007–2009 at New Place and Lowaters Nurseries.

New Place Nursery			
Batches compared	Rooting (%) evaposensor	Rooting (%) standard	Mean difference in rooting (%)
55	78.1%	73.7%	+ 4.4
Number of batches where rooting under evaposensor control was:*			
Better	Similar	Worse	
23	22	10	
Lowaters Nursery			
Batches compared	Rooting (%) evaposensor	Rooting (%) standard	Mean difference in rooting (%)
69	72.7%	61%	+ 11.7
Number of batches where rooting under evaposensor control was:*			
Better	Similar	Worse	
37	18	14	

*Better = evaposensor rooting percentage at least 5 percentage points more than standard; worse = at least 5 pp less than standard.

Mist control hardware. The Evaposensor and ECI are now commercially available to growers through E&TS Ltd at a price of about £320 including the sensor. Skye Instruments Ltd also supplies a range of Evaposensor models to suit data loggers as well as the E&TS ECI. The ECI features very stable electronics and a large digital display of WLD, with LEDs to indicate current status. It has built-in timers for control of burst length and minimum interval between bursts. It can thus be used as a stand-alone mist controller (e.g., for connection direct to a solenoid valve), or as an interface for existing equipment such as sequential controllers for operating multiple mist beds and valves.

An analogue output of WLD further expands the options for integration with other equipment including irrigation sequencers, computers and loggers. This has already led to success in the automatic scheduling of irrigation for protected and outdoor crops in other projects involving the authors (Harrison-Murray et al., 2002; Davies, 2010).

CONCLUSION

Evaposensor control of propagation environments has given much improved control of the mist environment, compared with alternative control systems tested, in five out of six propagation nurseries. Rooting results have been as good or significantly better for most cutting species tested. Growers find the equipment easy to use, affordable, and it can be flexibly integrated with many existing nursery mist systems.

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