Project Title	Container nursery stock irrigation: demonstration and promotion of best practice
Project number:	HNS 122
Project leader:	Dr Olga M Grant, East Malling Research
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Location of project:	East Malling Research, East Malling, Kent Darby, Thetford, Norfolk W Godfrey & Sons, Surrey Hillier, Brentry, Hampshire Johnsons of Whixley, Yorkshire
Project Co-ordinator:	The steering committee: John Adlam (Dove Associates) Chris Lane (Sevenoaks) John Richards (John Richards Nurseries) David Hooker (Hillier) Chris Burgess (private consultant)
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Date completion due:	30 September 2007
Keywords:	Best practice, HNS, irrigation, sprinklers, water use efficiency

Disclaimer:

The results and conclusions in this report are based on a series of experiments conducted over a one-year period. The conditions under which the experiments were carried out and the results have been reported in detail and with accuracy. However, because of the biological nature of the work, it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.

AUTHENTICATION

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

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Grower Summary

Headline

- The combination of an “improved” overhead irrigation system with scheduling irrigation according to plant demand for water, resulted in substantial water savings compared to a “typical” industry standard system with no scheduling.

Background and expected deliverables

This project aims to demonstrate and promote efficient and sustainable irrigation management practices for container nursery stock nurseries. There are two aspects to this work. One is the demonstration and assessment of different beds, different irrigation systems, and different methods of irrigation scheduling on the East Malling Water Centre (EMWC). At the EMWC, the performance of existing and developing irrigation technology is being assessed in a more realistic setting than that to which the manufacturers of irrigation technology may have access. Such a site also overcomes the constraints that apply to demonstration trials on commercial nurseries where the need to supplement irrigation with hand-watering to guarantee optimum quality can disrupt obvious differences between systems. The information can then be disseminated to both hardy nursery stock growers and irrigation technology companies. In the longer term, assessment of plant performance under different systems will allow protocols to be developed for best irrigation practice on nurseries. The other aspect of this project is the monitoring of water use on various nurseries around the country.

Expected deliverables from this work include:

- Set up the EMWC, incorporating demonstrations of different irrigation systems and scheduling methods.

- Establish a water use monitoring scheme (WUMS) with grower participation.

- The means to aid nurserymen in making sound investments when upgrading or expanding water management systems in their production areas.

- Deliver technology transfer activities including technical factsheets and grower demonstration visits to the EMWC.

Summary of the project and main conclusions

The original plan for the EMWC was constructed and developed to the point that it is now a facility for the demonstration of hardy nursery stock irrigation systems. The centre incorporates different kinds of beds, with facilities for different methods of applying irrigation and different methods of scheduling irrigation. A gantry overhead irrigation system was added in the summer of 2006. In addition to being a demonstration site, a substantial amount of experimental data has been collected in 2006 to allow the assessment of water use under different systems. Information gathered at the EMWC will be useful in assisting growers to make decisions on optimum methods of irrigation and to increase awareness of wasteful irrigation. Information gathered at the EMWC will also be useful in assisting the manufacturers of scheduling technology, as the practical limitations of different systems can now be identified. Such information will lead to improved irrigation practice which will be extremely beneficial to growers as changing climate and legislation influence water availability.

Water use has now been monitored on nurseries in different locations for two years (2005 & 2006). The objectives in the second year were firstly to add to the dataset for irrigation water use collected in Year 1, and secondly for the nurseries to build on the experience gained in the first year in monitoring application uniformity, scheduling and overall water use.

Conclusions:

- On gravel beds, the “typical” industry standard unscheduled system used at least twice as much water as the improved scheduled systems.

- On gravel beds, daily water use varied considerably between two scheduling methods. The first used an evaposensor to determine how much water is required to replace water lost by plants due to evaporative demand. The second used a soil moisture sensor to maintain soil moisture at a determined percentage. However over three months, the difference in water use between these scheduling methods was fairly small, with a little less water used with the soil sensor.

- When a gravel bed and a Mypex bed were compared using the same overhead irrigation system and same method of scheduling (using an EvapoSensor), it was found that less water was used on the Mypex bed. The Mypex drained more slowly and plants could take up more water during and after irrigation than on the gravel bed.

- Non-uniformity of overhead irrigation was seen to be a problem even with the "improved" system. This leads to non-uniformity of soil moisture across beds and non-uniformity of plant growth and quality. Additionally, non-uniformity of water distribution makes the use of scheduling methods more complicated. Production of plants with different demands for water on the same beds is an additional complication.

- An Efford sandbed used substantially less water than the scheduled overhead-irrigated beds. Soil moisture on this bed appeared to be generally more uniform than on the other beds.

- Monitoring of water use on a range of commercial nurseries indicated that there can be very large differences in water consumption between nurseries or beds growing broadly similar crop subjects. It was also noted that water was used much more efficiently and economically where some methodical scheduling practice was employed.

Financial benefits

Improving overhead irrigation systems and scheduling irrigation, or using subirrigation, can reduce water use and may help increase uniformity of plant production. However, given the amount of work conducted to date, it is too early to identify definite financial benefits associated with any system.

Action points for growers

- Interested growers will be able to attend an open day at the EMWC in 2007, in addition to following progress in this project via HDC bulletins.

- Monitoring water distribution on different beds will identify wastage and determine where changes would be most beneficial.
- Where possible, minimizing the number of subjects under one irrigation system can help reduce overwatering of some subjects and thus reduce wastage of water.

- Scheduling of irrigation can be beneficial in reducing water usage and improving uniformity, as can the use of Efford sandbeds.

Science Section

Introduction

This project aims to demonstrate and promote efficient and sustainable irrigation management practices for container nursery stock nurseries. There are two aspects to this work. One is the demonstration and assessment of different beds, different irrigation systems, and different methods of irrigation scheduling on the East Malling Water Centre (EMWC). On the EMWC we can assess the performance of existing and developing irrigation technology in a more realistic setting than that to which the manufacturers of irrigation technology may have access, and without the constraints that may apply on commercial nurseries. We can then feed back this information to both producers of irrigation technology and HNS growers. In the longer term, assessment of plant performance and quality under different systems will allow us to develop protocols for best irrigation practice on nurseries. The other aspect of this project is monitoring of water use on various nurseries around the country.

There is currently increasing interest amongst HNS growers in management of water use. This interest relates partly to increased concern over dwindling water supplies and legislation as to how the water supplies should be distributed. Awareness that water supplies may be more limited in future has been heightened by recent water shortages during the summer, particularly in the south-east of England. In addition, there is increasing awareness amongst HNS growers of the advantages of good management of irrigation, including reduced labour costs as a result of improved uniformity of distribution of irrigation (limiting the need for hand-watering) and of improved uniformity of plant quality (reducing the labour requirement associated with grading of plants for marketing).

HNS 97 (Water LINK I) showed large variation between nurseries in water use. Building up a picture of water use on different nurseries will assist in determining how and where water use on nurseries in general can be reduced. HNS 97 also indicated that a substantial reduction in water use can be obtained by regulating irrigation to match evapotranspiration (ET_p). We are building on this work in HNS 122, regulating irrigation on some beds to match ET_p, and on another to maintain constant soil moisture. In this project we are doing this on small but realistic nursery beds, with overhead irrigation. Thus we are moving regulation of irrigation from an artificial experimental set-up forward to a realistic demonstration of a system that is possible to implement on a nursery with existing irrigation. Finally, in HNS 97 and now HNS 97b (Water LINK II), the potential advantages of applying a deficit irrigation regime are being studied, but information as to how well regulation of irrigation performs under existing nursery systems is required to determine how realistically such a deficit regime would work in commercial situations. It is expected that such information can be gathered in HNS 122.

Materials and Methods

Objective 1

East Malling Water Centre

Demonstration treatments

The steering committee of this project, which consists of a small group of HNS growers, irrigation technology manufacturers, consultants and scientists, discussed the development of the beds on the EMWC in January 2006. At a later stage, members of the HDC HNS Panel asked for some changes. The resulting combination of beds, irrigation systems, and scheduling technology now on use on the EMWC is as follows:

<u>Beds</u>:

10 m × 5 m beds drain into a culvert, and a larger bed has been divided into three sections for the purpose of the current project (Figure 1). The larger bed (D-F) and one of the smaller beds (A) are gravel beds; of the remaining smaller beds one consists of Mypex over polythene (B), and one is a sandbed in the Efford style (C).

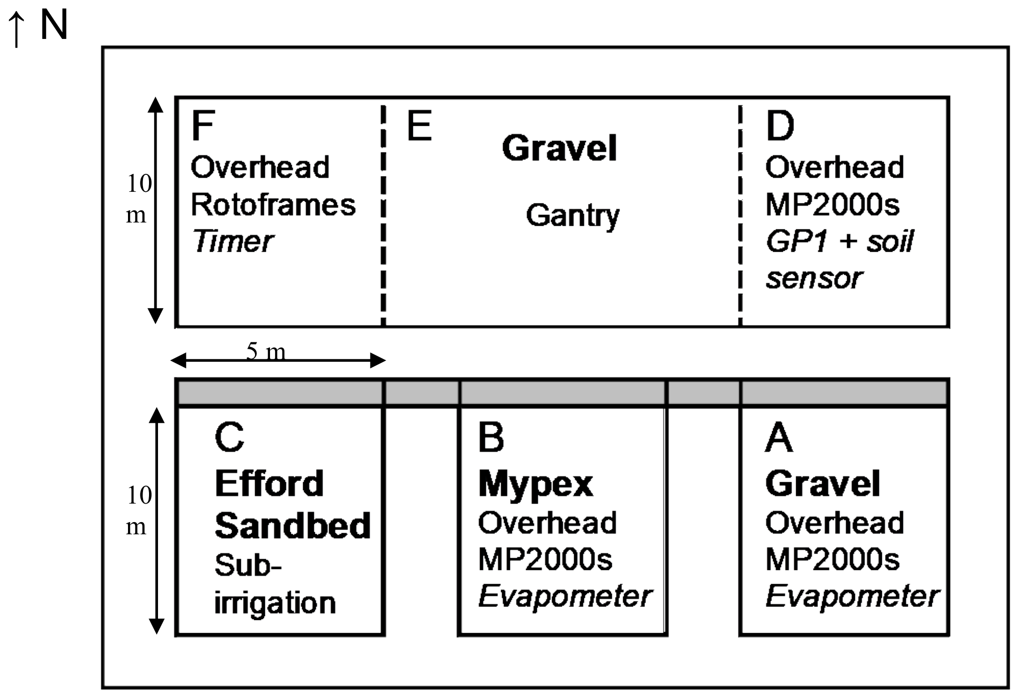


Figure 1. Layout of beds A-F on the EMWC, showing the different types of bed (in bold type), the different types of irrigation system (plain text) and the different technology used for scheduling, where applicable (italics)

<u>Irrigation systems</u>:

In the Efford sandbed system, irrigation is provided *via* a tank at the end of the bed – the sand wets up and the media in the pots takes up water from the sand below by capillary action. There are three overhead sprinkler irrigation systems. One of these is a traditional Rotoframe system (on Bed F), which is commonly used on nurseries. Three other beds (A, B, D) have MP2000 nozzles on risers along the edges of the bed, spaced so as to maximise the uniformity of irrigation on the bed. These nozzles are adjustable – the arc and radius of the projection of irrigation can be altered to suit the bed – and are considered to be an improvement in overhead irrigation compared to earlier less precise sprinklers. The Rotoframes were provided by Evenproducts and the MP2000 systems by Revaho. These companies advised us as to suitable spacing of these systems on our 5 m x 10 m beds. The Rotoframe system is intended to be a "typical" system, and water distribution was expected to be uneven. This allowed comparison of water distribution and the effects of that distribution on plant growth, quality, and uniformity under a "typical" system and under "improved" overhead irrigation. A gantry overhead irrigation system has been installed on part of the large gravel bed (Figure 2). This was specifically requested by the steering committee in January 2006 and approved by the HNS Panel later in the year, as project HNS 122a. It is expected that this system will provide more uniform irrigation than traditional overhead. The gantry is manufactured by the German company Rathmakers. It is a robust machine, as required for outdoor use. It can operate in either of two gears and at several speeds, which determine the rate of irrigation. In addition to having irrigation sprinklers, there is a separate set of sprinklers which can be used with a Dosatron for fertigation or spraying. The gantry has two arms and it is possible to turn off an arm or half an arm while irrigating from the remaining sections.

Figure 2. Overhead irrigation gantry on the EMWC

To determine the application rate and uniformity of distribution under the different sprinklers, catch pots have been used on each of the beds at 1 m intervals to collect water (Figure 3) during 5 mins of irrigation. The captured water in each pot was measured and the HDC Irrigation Calculator to determine the mean application rate and coefficients of uniformity and scheduling (see HDC Factsheet 16/05):

1. Mean application rate (MAR) in mm of water received on the bed per hour of irrigation.

2. Christiansen's Coefficient of Uniformity (CU): this is the average difference between the catch in each saucer and the average catch (absolute value) over the average catch, and is expressed as a percentage.

3. Scheduling Coefficient = MAR/lowest catch rate

This was repeated on a number of different dates, including still and windy days to determine the impact of wind speed on uniformity.

Scheduling:

In the case of the Rotoframes, irrigation is not adjusted to daily fluctuations in the demand of the plants for water. On three of the beds, however, irrigation is adjusted to allow for such fluctuations. On two of these beds (A and B) this is application of water is matched to evaporative demand. To achieve this, an “Evapometer” (Skye) is used, which has two temperature sensors, one dry and one kept wet with a wick in a small reservoir of water. This meter records the difference in temperature between the two sensors and records “degree hours”, where 1 degree hour is a difference of 1 degree Celsius between the wet and the dry sensors over a period of one hour. We monitor the accumulated number of degree hours over a day. If we weigh the plants after they have been well irrigated and a day later, we can work out how much water the plants use per degree hour. After this calibration, we only need to read the Evapometer every day and know how long we need to irrigate to replace the water they have lost through evaporation. The calibration, however, needs to be repeated at intervals as the plants grow, since they use more water per degree hour when they are larger. We carried out this calibration after the plants were placed on the beds and at intervals thereafter. We used two plants per block i.e. 8 plants per species (see below) on either bed in the calibrations. Since we used an Evapometer to schedule irrigation on a gravel bed and on a Mypex bed, and since the irrigation system was the same (MP2000s), we can directly compare differences in water use and plant growth, quality and uniformity resulting from the two different types of bed surface. To determine how much water the plants receive in a given length of irrigation, we used values obtained from collecting water in saucers over the bed during an irrigation run of 5 minutes. However, it became clear during the season that plants on the Mypex were taking up additional water from the surrounding Mypex. We therefore weighed plants before and after irrigation to see how much water they were taking up, and adjusted the calibration for the Mypex bed accordingly. This means that for the latter part of the season, plants on the Mypex bed were given less irrigation per degree hour than plants on the gravel bed.

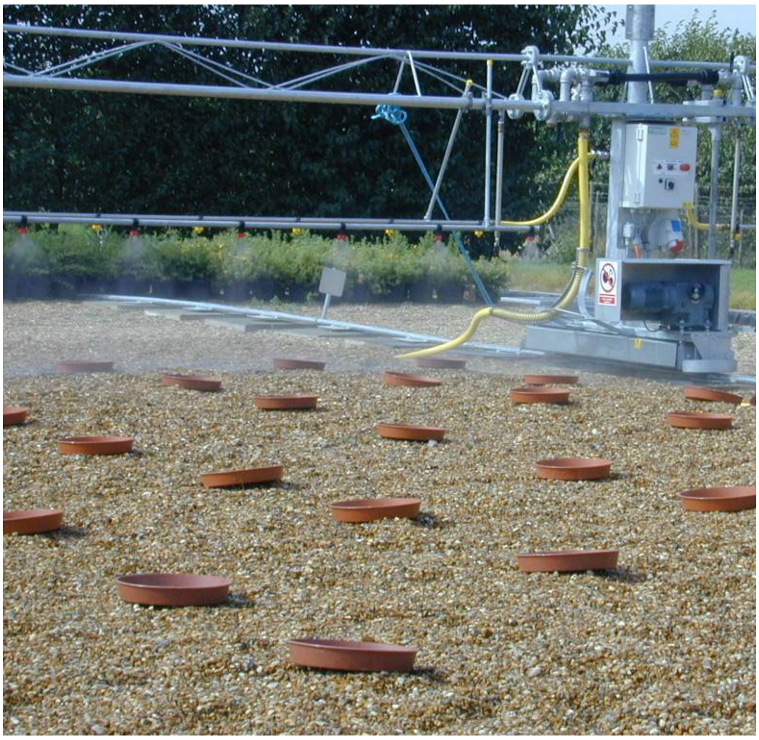


Figure 3. Capturing irrigation water in saucers to determine application rate and uniformity of water distribution

On another bed (D) a soil moisture sensor (SM200, Delta T) in the media in one of the pots measures the volumetric moisture content. This sensor is connected to a small logger (GP1) which both monitors the soil moisture over time and controls whether or not the irrigation is turned on. If the soil is sufficiently wet, the irrigation stays off. If the soil moisture falls below a determined value, however, then the irrigation turns on. This system was installed with the help and advice of Chris Nicholl from Delta-T. We initially had to determine a suitable value at which irrigation would turn on. After experimenting with some different values we decided that 35% moisture (by volume) in the compost was suitable to maintain the compost in a well-watered but not overwatered state. We are using the GP1 with a battery-operated timer (Galcon). With such a timer, it is necessary to set the irrigation to go on at certain times of day (in our case 8, 12, 16 and 20 h) for a certain length of time (15 mins in this case). If the compost moisture is below 35% the irrigation turns on and stays on for 15 mins. The next time the irrigation is set to turn on, if the soil moisture has not reached an upper set value (50% in our case) then the irrigation will turn on. This will continue until the soil moisture reaches the upper set value. Once the soil moisture is above the upper value, then the GP1 will override the signal from the solenoid timer and the irrigation will stay off. The irrigation will not go on again until the compost moisture falls below 35% (Figure 4). It should be noted that with an electrically-operated timer the GP1 works slightly differently. In that case the irrigation would be turned off *during* an irrigation run if the soil moisture reaches the upper set value.

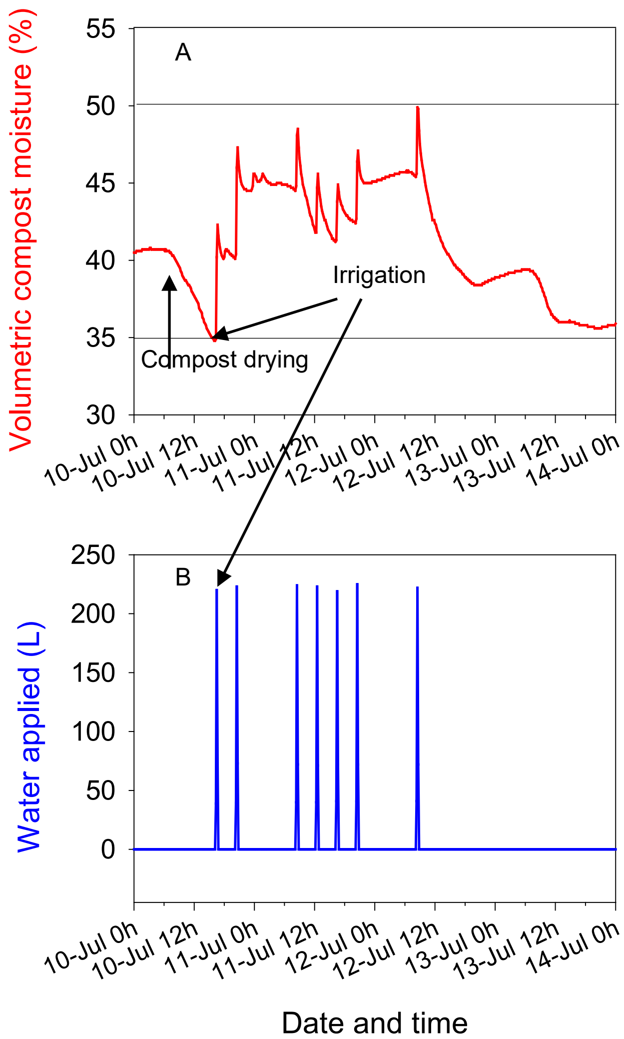


Figure 4. A typical sequence showing the interaction of compost moisture and irrigation. When volumetric compost moisture falls below 35% (A), irrigation goes on (B), but once soil moisture reaches 50%, irrigation does not go on again until the soil moisture falls below 35% again. This is the mode in which a GP1 operates when connected with a battery-operated timer

Since it is known that overhead irrigation is not entirely uniform, any scheduling system cannot necessarily schedule irrigation optimally for *all* plants on a bed. In addition, where different species are grown on the same bed, they will not necessarily use water at the same rate, so it is impossible to irrigate them all to exactly replace the amount of water they use, without over-irrigating some, using an overhead system. We therefore had to decide whether to irrigate to suit the area of the bed that receives the least water and the species that uses the most, or to irrigate to suit the area of the bed that receives the most water and the species that uses the least, or to irrigate to suit the average plant on the bed. We chose the latter, so how much water the average species was using was determined and irrigation runs were set according to what the average pot on the bed receives on a still day. This was chosen so that the effects of non-uniform irrigation and of growing different species together could be clearly demonstrated.

Monitoring:

To compare water use on different beds, we used the same numbers of plants and same species on each bed. The species this year are: *Cistus creticus, Potentilla fruticosa* "Tangerine", and *Spiraea nipponica* "Snowmound". These were purchased as liners from New Place Nurseries in June 2006 and potted up into 3 L pots in a 100% peat media in Hillier nursery before being delivered to East Malling Research where they were immediately placed on the beds at the EMWC. Four blocks of each subject were laid out on each bed. Each block consisted of 45 plants, arranged in 5 columns of 9 plants, with columns staggered and 3 cm between pots. Blocks were arranged in three columns of four; the location of each subject was randomly selected. Within each block, 10 plants were randomly selected for monitoring purposes. Their growth is being monitored (heights and widths in perpendicular directions were measured when the plants were placed on the beds and again in September) over the season and quality will be assessed at the end of the season.

We measure the quantity of water use applied to each bed with a water meter. These meters were connected to data-loggers (Delta-T) for continuous recording of water use.

Run-off (water applied to the beds that drains through and is collected in tanks at the end of the beds) is captured for Beds A and B in containers in the culvert into which these beds drain separately. Measurement of run-off indicates how much of the water applied is wasted either through missing the pots or draining through the pots. Run-off is measured every day.

The accumulated degree hours from 8 am one day to 8 am the next is recorded 7 days a week. This is necessary to set the irrigation daily on Beds A and B. Additionally, we have logged degree hours using Evaposensors connected to data-loggers at different locations on the EMWC in order to determine whether Evaposensor measurements are affected by such factors as proximity to overhead irrigation.

The GP1 logger records moisture in the compost of the “control” pot i.e. the pot with the moisture sensor that is used to determine whether or not irrigation is required. It additionally records moisture in a second pot. Other soil sensors (Thetaprobes) monitor moisture in a wider selection of pots – one of each species on Bed D and one pot on each bed A, B, C and F. To determine variability within beds, moisture was measured in the pots of each of the selected plants (i.e. 120 plants per bed) monthly from July to September.

The incidence of a leaf fungus on *Spiraea* was recorded on each of the selected plants. It is intended to record the incidence of mosses and liverworts in each of the selected pots later in the season.

Meteorological data is continuously recorded on the EMWC – this includes rainfall, air temperature, relative humidity, and solar radiation amongst other measurements.

Objective 2

Water Use Monitoring Scheme (WUMS)

In this second year of the project, nurseries were given the option of extending their monitoring to include a simple “two treatment” comparison e.g. to compare irrigation systems such as areas with different sprinkler types or layouts, or to compare scheduling methods such as a standard manual / timeclock control vs. automatic scheduling using an in-pot moisture probe (Table 1).

Four of the five nurseries involved in the WUMS in 2005, participated in the scheme in 2006. All were using overhead irrigation on outdoor crops in pot sizes 2 – 3 L. Apart from W Godfrey & Sons, the nurseries were not routinely using any methodical scheduling to decide when and how much to irrigate, but rather relying on judgment by the irrigation manager to set appropriate timeclock settings on the irrigation controller. W. Godfrey was, however, using a simple 'bucket evaporimeter' as described in the report for HNS 38 (1993-1995) as a basis for irrigating beds of herbaceous subjects.

At Hillier Nurseries' Brentry container unit, a similar additional bed to last year was monitored, with one bed 'manually' scheduled conventionally, and the other using Delta-T's in-pot SM200 moisture probe and GP1 logger and irrigation controller (Figure 5). Two SM 200 probes were used, both initially being inserted into separate containers of the green *Spiraea* 'Little Princess'. Probe 'Moisture 1' was programmed by the GP1 to control the irrigation by switching the irrigation solenoid on and off according to upper and lower growing medium moisture level set points. Probe 'Moisture 2' was inserted in a second pot to replicate moisture level monitoring but with no control function. The probes were inserted near to the centre of the container and partly buried so that the sensor pins were in the centre zone of the rooting medium. The GP1 unit was installed on 16th May. The master irrigation control panel was set to provide power to the solenoid irrigation valve wired in series with the GP1 control relay for 1 hour at 16:30 and 21:30 each day. Irrigation events were moderated by the GP1 with initial moisture set points of 30% on /40% off with a check frequency of 20 mins × 25% duty cycle to provide pulsed irrigation, i.e. once the moisture level in the controller pot fell below 30%, the relay switched between 5 min on (irrigation) and 15 min off (soak-in) cycles, until irrigation had rewetted pots to above the 40% level. While the GP1 might call for water at any time, irrigation would only occur within the twice daily one hour opportunities set by the pump-house control panel, thus moisture levels might fall below 30% before irrigation started on hot days. Based on crop observations and recorded data, the set points were changed to 35% on/45% off on 2 June. On 12 June the duty cycle was increased to 50% (i.e. 10 mins on/10 mins off) to give more time to apply water within the available irrigation opportunities. On 16 July, the controller probe was moved to one of the *Physocarpus* pots as this crop on part of the bed was demanding more water than the *Spiraea* and was requiring some occasional hand watering top-ups. The second monitoring probe was retained in the *Spiraea*. Finally, on 5 September the set points were changed to 40% on / 45% off and a 5 min check frequency × 100% duty cycle to see whether a tighter moisture fluctuation regime could be achieved.

As in 2005, all nurseries recorded water meter, rainfall, and Skye Evapometer readings daily where possible. Some interpolation of missing values (such as over weekends) was possible and this had little effect on the accuracy of weekly summarised data.

Table 1. Details of beds, sprinkler layouts and crops monitored in 2006

Nursery	Bed size	Sprinkler layout	Crop / standing base
Johnson's of Whixley, Yorkshire			
Mamkad sprinklers	18 m x 85 m = 1530 m^2	3 lines Super Mamkads 7 m apart x 8 m in-line. Centre line Ivory nozzles 335 Lh^{-1}; outside lines Red 670 Lh^{-1}, until 7 June. Then 7 of 11 centre line nozzles replaced with Naan 437-AG 4.0 mm impact sprinklers 850 Lh^{-1} 180° arc.	Lavenders 3 L and Grasses 3 L. Mypex on polythene sloped to central collecting channel.
MP Rotator sprinklers	18 m x 85 m = 1530 m^2	3 lines MP Rotator sprinklers 9 m apart x 5 m in-line. Windward edge and centre lines on full circle operation (283 Lh^{-1} @ 2 Bar); leeward edge line at 210° arc (165 Lh^{-1} @ 2 Bar).	Mainly *Viburnum tinus* 3 L plus some Lavenders 3 L. Mypex on polythene sloped to central collecting channel.
Darby Nursery Stock, Norfolk			
Wide-spaced sprinklers	43 m x 40 m = 1720 m^2	Naan 423-AG brass impact sprinklers 850 Lh^{-1} @ 2 Bar. 18.5 m x 9.25 m in staggered rows.	Mainly *Sambucus* 3 L. Gravel hard standing base.
Close-spaced sprinklers	24 m x 72 m = 1728 m^2	Naan 423-AG brass impact sprinklers 4.0 mm 850 Lh^{-1} @ 2 Bar. 6 m x 6 m.	Mainly *Sambucus* 3 L. Gravel hard standing base.
Hillier Nurseries, Hampshire			
Manual scheduling	15 m x 39.3 m = 590 m^2	Naan 427-AG impact sprinklers 4.0 mm 850 Lh^{-1} @ 2 Bar. Approx 7.0 m apart down bed edges set at 180° arc.	Mainly *Spiraea* cultivars in 3 L. Some *Cotinus*. Mypex on polythene sloped to central drain.
GP1 & SM200 probe scheduling	15 m x 39.3 m = 590 m^2	Naan 427-AG impact sprinklers 4.0 mm 850 Lh^{-1} @ 2 Bar. Approx 7.0 m apart down bed edges set at 180° arc.	Mainly *Spiraea* cultivars in 3 L. Some *Physocarpus*. Mypex on polythene sloped to central drain.
W Godfrey & Sons, Surrey			
Single treatment as in 2005	23.5 m x 10 m = 235 m^2	2 rows Rotoframe sprinklers (950 Lh^{-1} @ 2 Bar) 5.0 m x 5.0 m. 5.75 m between lines of adjacent beds.	Mainly *Penstemon* 2 L. Gravel standing base.

Figure 5. GP1 controlled bed (mainly *Spiraea* cvs in 3 L pots), 4 July 2006 at Hillier Nurseries

Results and Discussion

Objective 1

East Malling Water Centre

Assessment of overhead irrigation

The distribution of irrigation over a bed varied greatly according to how still or windy the weather (example for MP2000s in Figure 6). The distribution also differed between systems. As expected, under relatively still conditions a more uniform distribution was found on beds with MP2000 sprinklers than on the bed with Rotoframes (Bed F) (see Figure 7 for a typical distribution on the Rotoframes bed, and Table 2 for a comparison of coefficients for the different systems). Uniformity on the MP2000s beds (Beds A, B and D) , while better than on the Rotoframes bed was nonetheless not as good as specified by the distributors. Additionally, the scheduling coefficient was higher than advertised, indicating that more water would have to be used to ensure the plants receiving the least water received enough. However, while MP2000s are advertised as having a Christiansen's Coefficient of Uniformity of 98% and a scheduling coefficient of 1.1, these values are for application to a larger bed with 3 m between nozzles. In the case of our 5 m x 10 m beds it was necessary to have 5 m distance between nozzles across the bed and 2.5 m along the laterals.

Table 2. The best recorded irrigation performance of MP2000 and Rotoframe sprinklers on the EMWC, where MAR is mean application rate, CU is Christiansen's Coefficient of Uniformity, SC is the scheduling coefficient, and $SC_{5\%}$ is the scheduling coefficient when the MAR is divided by the fifth percentile value rather than the lowest catch

Performance	Sprinkler	
	MP2000s	Rotoframes
MAR (mm/h)	19.9	14.7
CU (%)	83	60
SC (%)	1.6	4.6
$SC_{5\%}$ (%)	1.5	2.5

a b

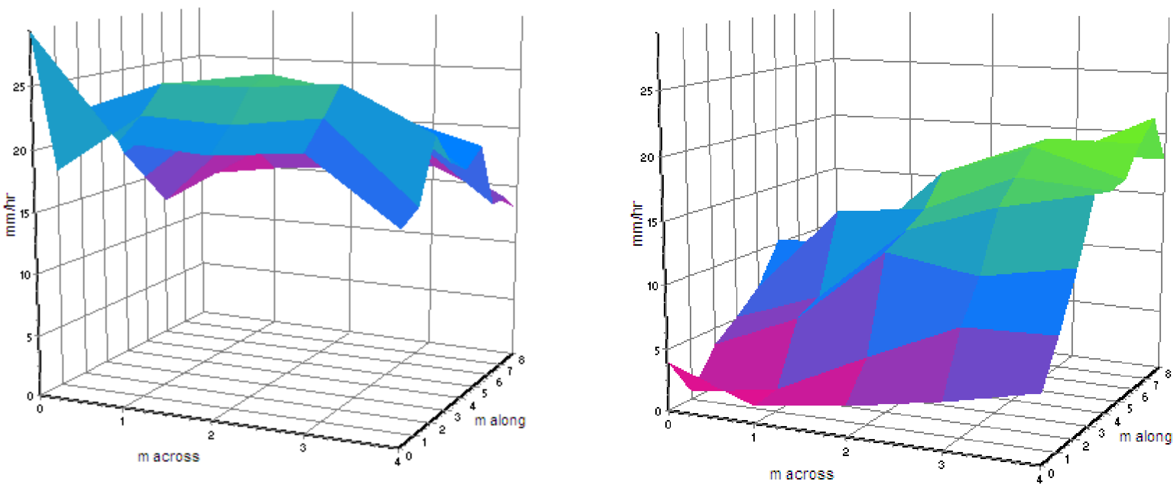


Figure 6. Distribution of irrigation water captured in saucers on a bed irrigated with MP2000 sprinklers (Treatments A, B and D) spaced at 2.5 m between sprinklers along the laterals of the bed and 5 m between the laterals, on (a) a still day and (b) a windy day

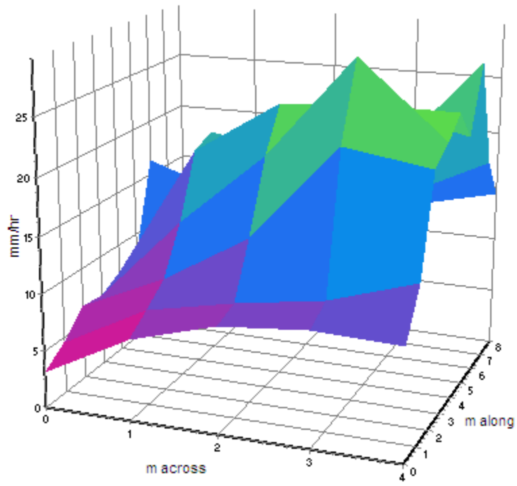


Figure 7. Distribution of irrigation water captured in saucers on Bed F, irrigated with Rotoframe sprinklers spaced at 5 m between sprinklers and sprinklers placed 2.5 m in from the edges of the 5 m x 10 m bed.

Meteorological data and accumulated degree hours

Air temperature and relative humidity varied over the season and, as a result, daily accumulated total degree hours varied considerably between dates (Figure 8). High values of daily accumulated degree hours were apparent on dates when the temperature was high and the relative humidity was relatively low. The length of irrigation run on a given date was determined from the accumulated degree hours from 8 am the previous morning to 8 am that day. The length of the irrigation run relative to the accumulated degree hours changes over the season because as the plants grow they need more water per degree hour i.e. the calibration factor increases.

Separate calibrations were performed for plants on Beds A and B from 7 July onwards, meaning that the length of the irrigation runs on the two beds sometimes differed. When it became apparent that plants on Bed B were taking up so much water from the surrounding Mypex that they required substantially less irrigation than plants on Bed A, the calibration factor for Bed B was reduced compared to Bed A according to the difference in uptake on the different beds (plants on Bed B increased their weight by 22% more than plants on Bed A after irrigation). As a result less irrigation was applied to Bed B later in the season (Figure 9).

Water use and run-off

42,391 L of water were applied to Bed A from 21 June to 18 September 2006. Comparing water use on Bed A and Bed B over the period 28 June to 18 September, almost 6,000 L more water was used on Bed A. This is due to less water being applied to Bed B later in the season when the calibration factor for Bed B had been reduced (Figure 10A). Run-off on Bed B was often less than on Bed A (Figure 10B), indicating that less water was wasted, due to retention of water on or in the Mypex.

From 21 June to 18 September, 37,703 L of water were applied to Bed D. Although on several days the irrigation did not turn on on Bed D (Figure 11), it is on for longer when on compared to irrigation on Bed A. Therefore the overall water use whether using an Evaposensor or a soil moisture sensor to schedule irrigation on a gravel bed did not differ as much as might be expected (it was less with the soil moisture sensor, but the difference over 3 months was under 5,000 L). Since the same irrigation system was used on these two beds and they were both gravel beds, the only difference between them was the method of scheduling. The main advantage of the soil moisture sensor in terms of reducing water use is that irrigation will not go on if rainfall has wet up the compost, whereas with the Evaposensor a decision needs to be made as to whether there has been sufficient rainfall to turn the irrigation off (and this needs to be done manually). 79,890 L of water were applied to the Rotoframes bed (Bed F) from 28 June to 18 September – this is twice the amount of water applied to Bed A scheduled with an Evaposensor and 2.3 times the amount of water applied to Bed D scheduled with the soil sensor. Daily application of water to the three gravel beds (A, D, F) can be compared in Figure 11.

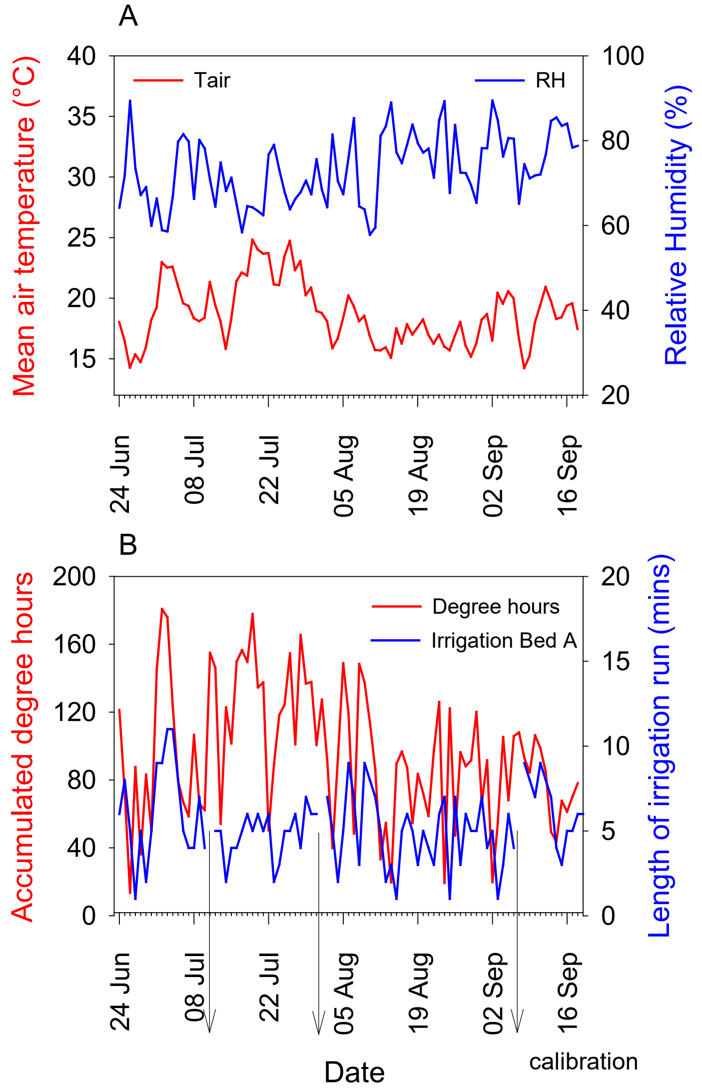


Figure 8. Mean daily air temperature and relative humidity (A) and daily accumulated degree hours between 8 am on the date shown and 8 am the following day, along with the length of irrigation runs used on Bed A on different dates (B). Irrigation was applied four times a day. The arrows indicate dates on which irrigation was not applied because the calibration was being undertaken. On a few dates irrigation was turned off due to rainfall (not shown)

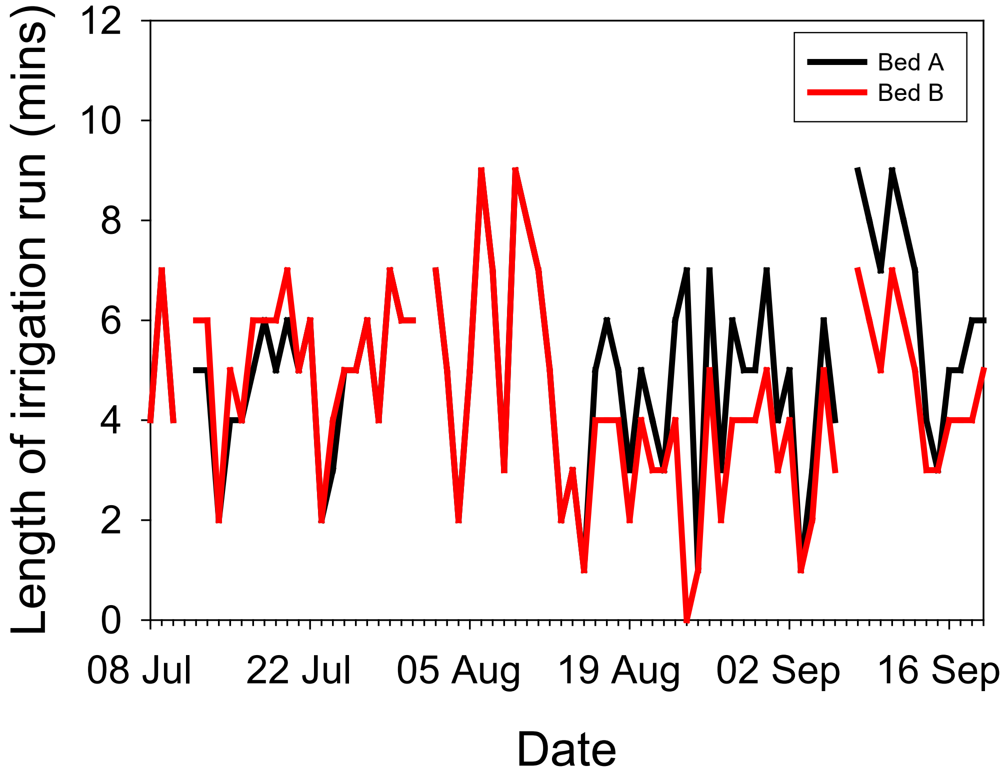


Figure 9. The length of irrigation runs used on Bed A (gravel) and Bed B (Mypex) on different dates. Irrigation was applied four times a day

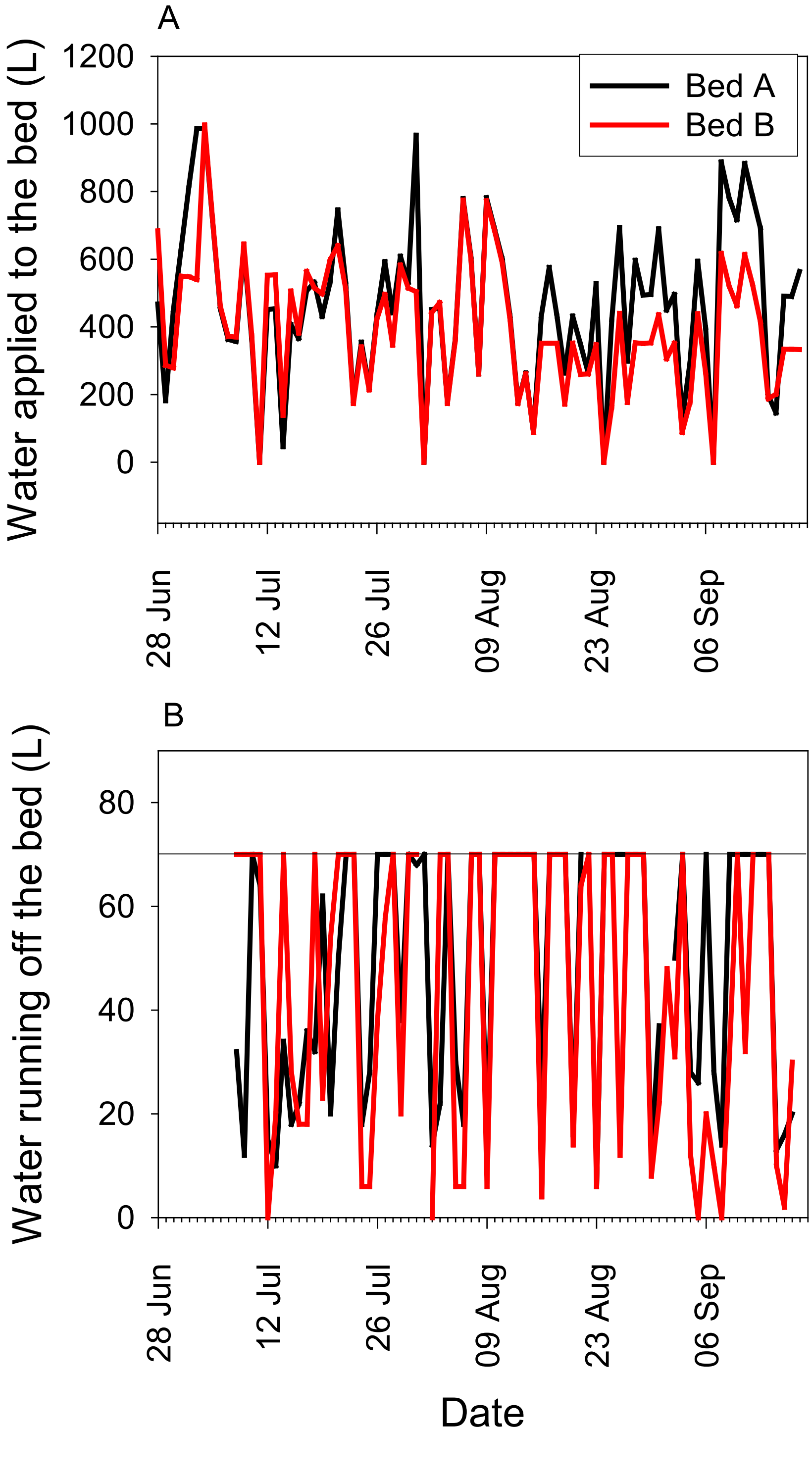


Figure 10. The quantity of irrigation water applied to Beds A (gravel) and B (Mypex) on different dates (A) and the quantity of run-off water collected from either bed (B). Run-off was measured every morning; quantities of over 70L in a day were not collected

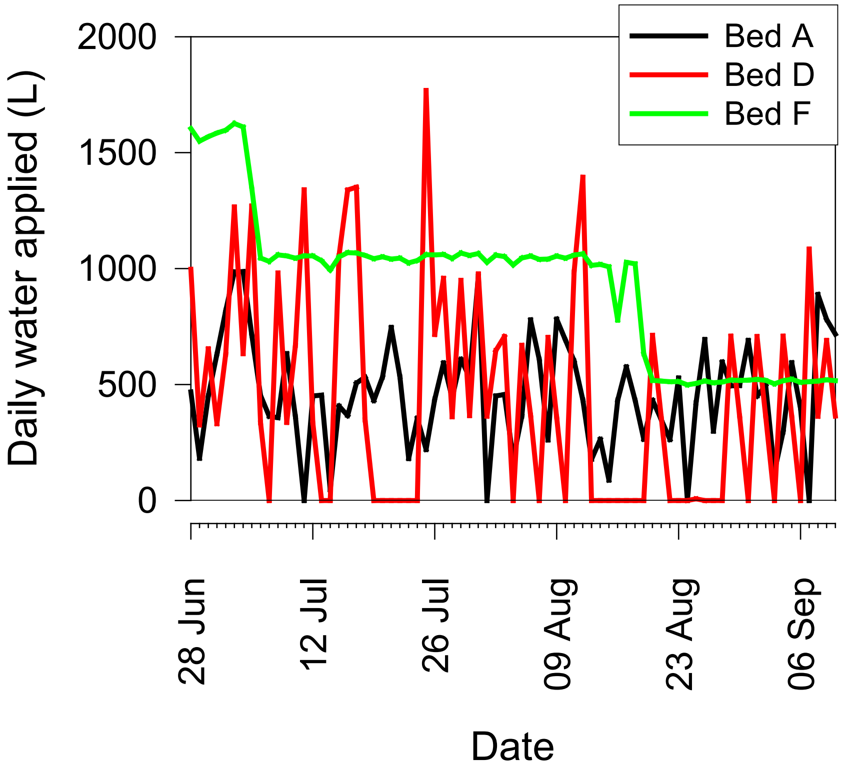


Figure 11. Daily application of water to three gravel beds – Bed A and D are irrigated with MP2000 rotators, while Bed F is irrigated with Rotoframes. Bed A is scheduled with an Evaposensor, Bed D is scheduled with a soil moisture sensor, and on Bed F there is no scheduling – irrigation was timed to go on for 5 mins (late August to early September), 10 mins (most of the season), or 15 minutes (in June while the plants were becoming established) four times a day

Comparing water application data from 22 August to 18 September on the different beds, Bed C used half of that used on Bed A and 0.7 times that used on Beds B or D. Therefore, the Efford Sand bed used approximately half as much water as the gravel bed scheduled with an evaposensor, which used half as much water as the unscheduled Rotoframe bed (Figure 12). Hourly data indicated that the Efford bed used water in small quantities but almost continuously.

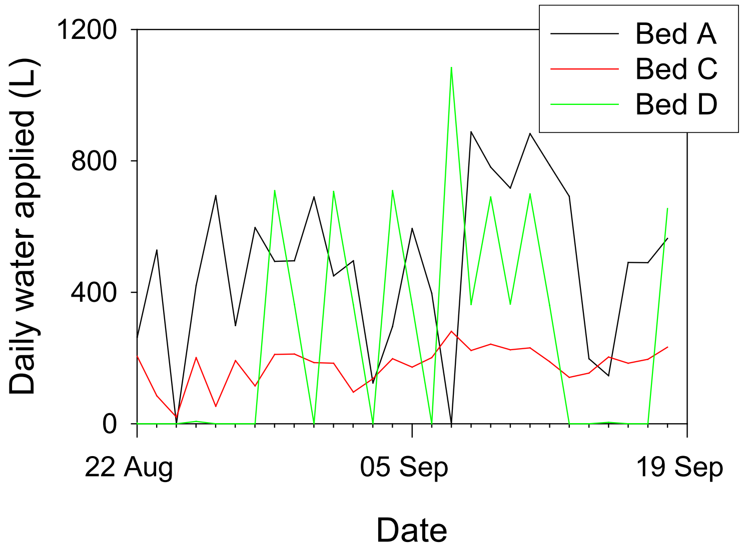


Figure 12. Daily application of water to Bed A and D (both overhead irrigated) in comparison to the Efford sandbed Bed C which is subirrigated

<u>Compost moisture</u>

Volumetric moisture of the compost varied within and between beds and over time (example in Figure 13). In July, compost moisture on Bed A was on average quite low. This may relate to substantial growth between calibration of degree hours against water use and the compost moisture measurements; when the calibration was repeated the distribution of compost moisture on Bed A centered around 35-40%. By September, however, a very wide spread of compost moistures was found on Bed A (from 10% to 90%), probably relating to the accumulated effect of a non-uniform distribution on an overhead-irrigated bed. Compost moisture on Bed B was higher than on Bed A in July and August, as a result of water being retained on the Mypex and distributed to the plants. The calibration factor was then reduced on this bed compared to Bed A, but nonetheless compost moisture was still generally very high on this bed in September. This may relate partly to rainfall, which would be expected to have more of an effect on the Mypex bed than on gravel beds. Pots on Bed C showed a fairly uniform distribution of compost moisture in July, with most pots having compost moistures between 20 and 40%. Compost moistures on Bed C were less uniform in August, but by September most pots had compost moistures of between 35 and 55%, with just a few pots with lower compost moisture – these are pots in which either a good contact with the sand or a substantial root system was not established early on in the season. Soil moisture on Bed D was very similar to that on Bed C in July and August, but was generally very low in September. This shows the danger of scheduling a bed based on the compost moisture in one pot: the sensor was in the middle of the bed in one of the relatively few pots with compost moisture above 35%, meaning that irrigation did not turn on even though most of the pots on the bed had much lower compost moisture.

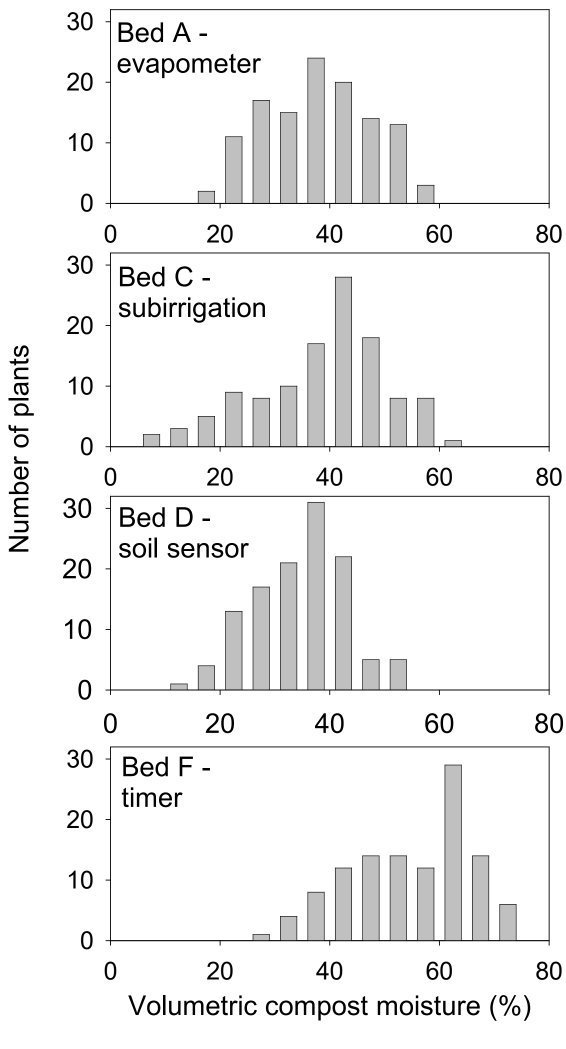


Figure 13. Numbers of pots on each bed with volumetric compost moisture falling between 5% categories from 5% to 90% compost moisture, measured on 16th August. Approximately 120 pots were measured per bed (40 plants per subject)

Plant growth

Plants grew substantially over the season on all beds (examples in Figure 14). By September 2006, the *Cistus* were tallest on Beds B and C, and shortest on Bed A (Figure 15). They also showed relatively little outward growth on Bed A. *Potentilla* were also shortest on Bed A but were relatively wide on this bed. *Spiraea* grew tallest on Bed C and widest on Bed B. In general therefore it is difficult to conclude that plants were smallest or largest on any one bed, but *Cistus* grew least on Bed A and most on Bed C, *Spiraea* grew tallest on Bed B but widest on Bed A, and grew least on Bed C, and *Potentilla* grew most overall on Bed B.

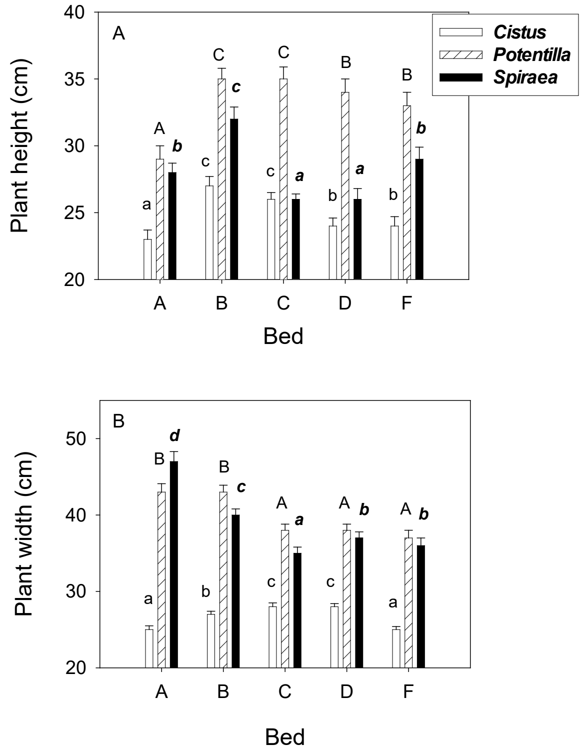


Figure 15. Plant heights (A) and widths (B) measured on 11 September 2006 on the EMWC. Different letters indicate significant differences between Beds for that subject (LSD tests after ANOVA; P ≤ 0.05). Widths are the average of two perpendicular measurements

Objective 2

Water Use Monitoring Scheme (WUMS)

The data collected from each nursery over the period w/c 5 June to w/c 11 September when all nurseries were collecting data are summarised in Table 3. Weekly values over a period including May where data was available are summarized in Figures 16 and 17.

Johnson's of Whixley

There was a large variation in the amounts of irrigation applied, and consequently the mean Water Use Index (WUI) both between different nurseries, and between different bed treatments within a nursery. For example at Johnsons, the Mamkad sprinkler bed averaged 6.02 mm/day (WUI 8.9 mm/100°C h) compared to 2.15 mm/day for the MP Rotator sprinkler bed (WUI 4.3 mm/100°C h). In this case the large differences were partly accounted for by the different crops placed on the beds as well as the different sprinklers used. The *Viburnum* were much slower growing and required less water than the vigorous grasses on the Mamkad bed, where higher output impact sprinklers were installed on part of one line to apply more water to the grass crop portion of the bed. Comparative uniformity data was not available from this site in 2006, so it is not clear how differences between the two beds here might account for some of the consumption differences. The site is exposed to a prevailing wind, and despite full circle MP Rotators being used along the windward edge of the bed, the nursery did report that the spray from these sprinklers was more susceptible to wind drift compared to the Mamkads, and some occasional hand edge watering was required.

Darby Nursery Stock

At Darby Nursery Stock, a similar crop (*Sambucus*) was grown on both areas, and using the same type of impact sprinklers, but at two different densities. Following a rather poor distribution pattern measured in a different area used for the 2005 trial, the nursery decided to try the sprinklers in a closer spaced arrangement this year. Water use was relatively high from both arrangements in 2006. This averaged 5.2 mm/day (WUI 6.68) for the wider spaced sprinklers and 5.3 mm/day (WUI 8.92) with the closer spacing. The nursery reported that hot, dry and breezy conditions, particularly in late June and July, resulted in pots drying out and many blowing over, and requiring particularly heavy irrigations to re-wet them. However, the data showed that substantial irrigations were being applied on most days over this period. Figure 18 shows the results from a distribution test on their close-spaced sprinkler arrangement using the HDC Irrigation Calculator. Irrigation uniformity was still poor (CU 73%; $SC_{5\%}$ 1.8), and this would also have contributed to higher water consumption. Unfortunately problems with the evapometer on this site resulted in some missing data during 4 weeks.

Table 3. Summary of Evapometer degree hour, rainfall, irrigation and Water Use Index for w/c 5 Jun – w/c 11 Sept (Weeks 23 – 37). "Useful precipitation" refers to the total of "useful rain" plus irrigation applied (see Figure 16 legend for explanation)

Nursery		**Evapometer (°C h)**	**Total rain (mm)**	**'Useful rain' (mm)**	**Irrigation (mm)**	**'Useful precipitation'**	***Water Use Index* (mm/100°Ch^{-1})**	**'Useful Rain' as % of 'Useful Precipitation'**
Johnson's of Whixley								
Mamkad sprinklers	Total	8597	192	125	632	756		
	Mean/day	81.9	1.82	1.19	6.02	7.20	8.87	17%
MP Rotator sprinklers	Total	8597	192	125	226	350		
	Mean/day	81.9	1.82	1.19	2.15	3.33	4.31	36%
Darby Nursery Stock								
Wide spaced sprinklers	Total	5809*	236	97	543	640		
	Mean/day	75.4*	2.25	0.92	5.17	6.09	6.68*	15%
Close spaced sprinklers	Total	5809*	236	97	559	656		
	Mean/day	75.4*	2.25	0.92	5.33	6.25	8.92*	15%
Hillier Nursery								
Manual scheduling	Total	12570	158	85	863	948		
	Mean/day	119.7	1.51	0.81	8.22	9.03	7.72	9%
GP1 scheduling	Total	12570	158	85	346	431		
	Mean/day	119.7	1.51	0.81	3.29	4.10	3.68	20%
W Godfrey & Sons								
	Total	10859	269	80	154	234		
	Mean/day	103.4	2.56	0.76	1.47	2.23	2.19	34%

* These data exclude Weeks 29, 31, 32 & 33 when Evapometer data were not available

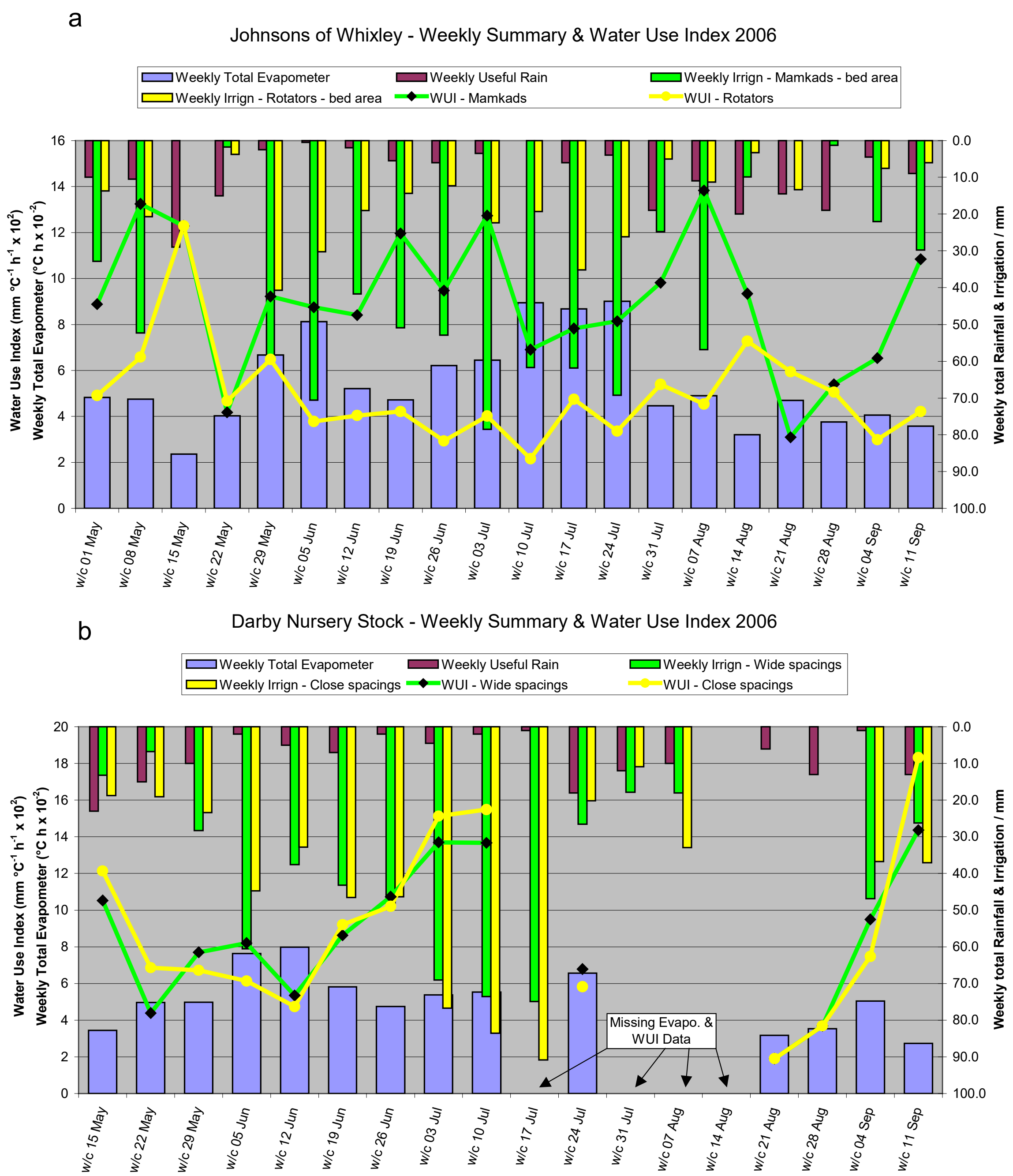
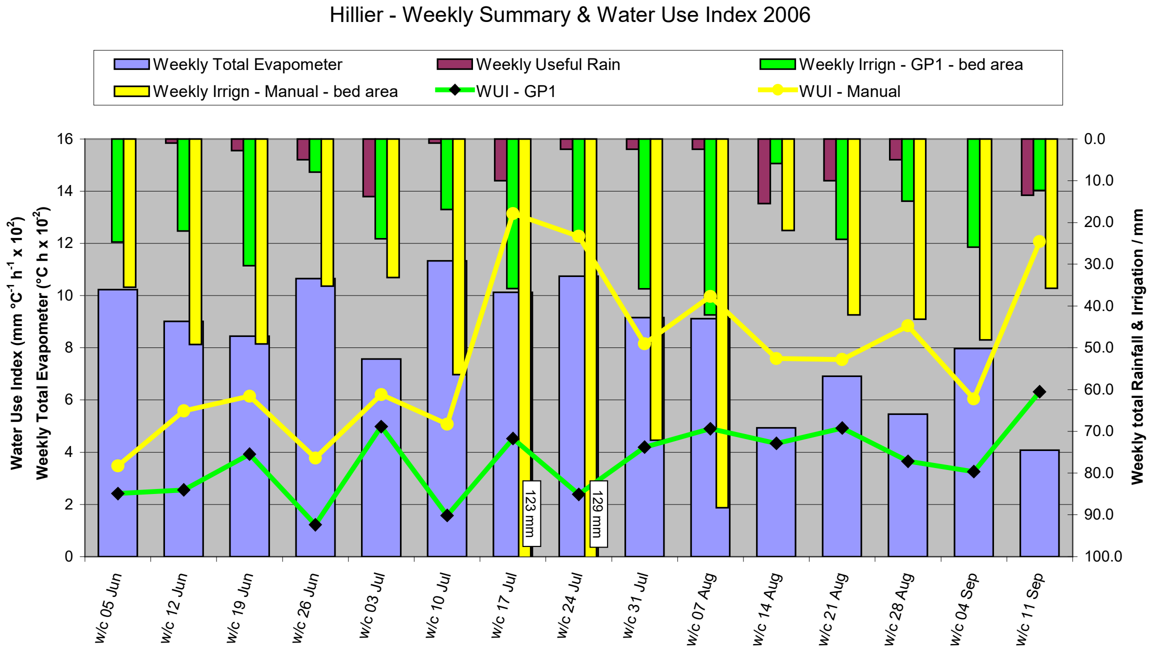


Figure 16. Summaries for 2006 of weekly Evapometer readings (°C h), useful rain (mm), irrigation (mm), and a Water Use Index (mm $°C^{-1}$ h^{-1} x 10^2) for Johnson's of Whixley, Yorkshire (a) and Darby's Nursery Stock, Norfolk (b)

Useful rainfall refers to rainfall in a day of up to 5 mm. Rainfall exceeding this was regarded as surplus to that required to wet-up containers. The water use index is mm irrigation + useful rainfall per 100 degree hours. Irrigation quantities in mm were calculated on a 'bed area' basis – i.e. litres applied per m^2 of bed area. This is more meaningful for comparing irrigation "efficiencies" between sites, though will slightly overestimate the actual mean precipitation reaching the crop where there is significant overspill beyond the bed area. In most cases here the differences were less than 20% between the irrigation calculated on a "bed area" compared to "irrigated area" basis.

a



b

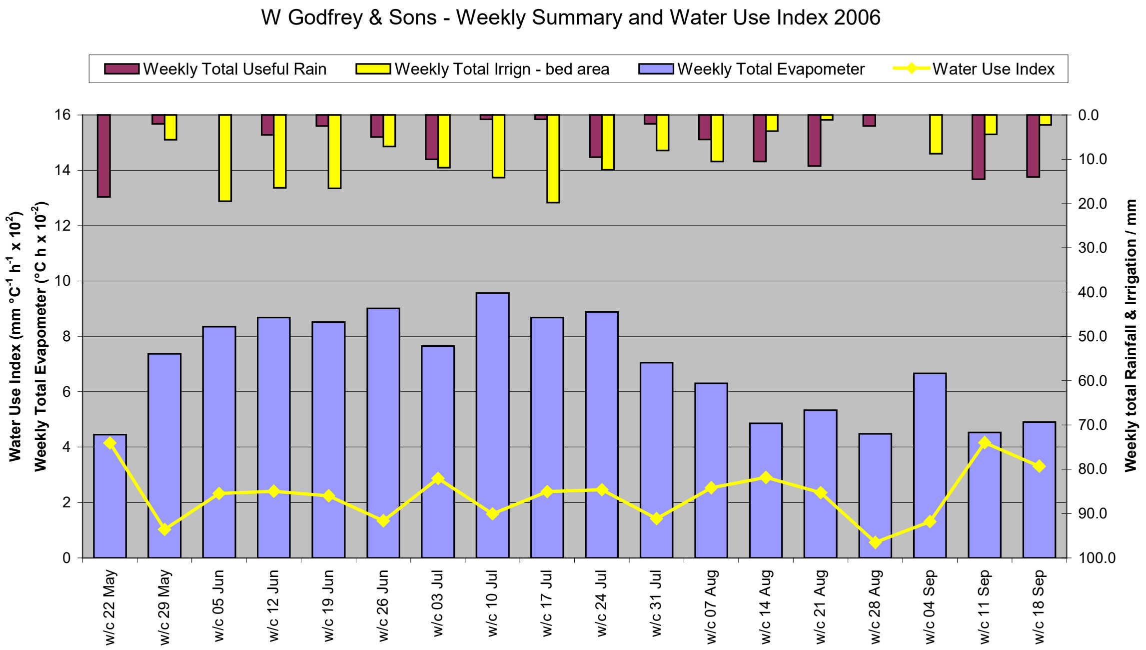


Figure 17. Summaries for 2006 of weekly Evapometer readings (°C h), useful rain (mm), irrigation (mm), and a Water Use Index (mm $°C^{-1}$ h^{-1} x 10^2) for Hillier Nurseries, Hampshire (a) and W Godfrey & Sons, Surrey (b). See notes for Figure 16

W Godfrey & Sons

Godfrey & Sons' herbaceous nursery, as in 2005, returned the lowest mean rate of irrigation with 1.5 mm/day (WUI 2.19). In 2005, is was assumed that the type of crop (fairly small herbaceous subjects in 9 cm pots) was largely responsible for the low water use, although irrigation distribution tests did show good uniformity from the sprinkler system employed. In 2006, however, the *Penstemon* in 2 L containers were quite tall and leafy, and arguably were as 'thirsty' as some of the subjects grown by other nurseries. However water consumption was still relatively low. It is likely that the use of an irrigation scheduling method (in this case a crude but effective 'bucket evaporimeter' as described in HNS 38) has provided a good guide to irrigation need, and has avoided over application. Excessive irrigation from overhead systems can be difficult to detect (particularly if the growing medium and standing base are fairly free draining), unless a method of observing 'run-through' as described in HDC Factsheet 19/05 is used.

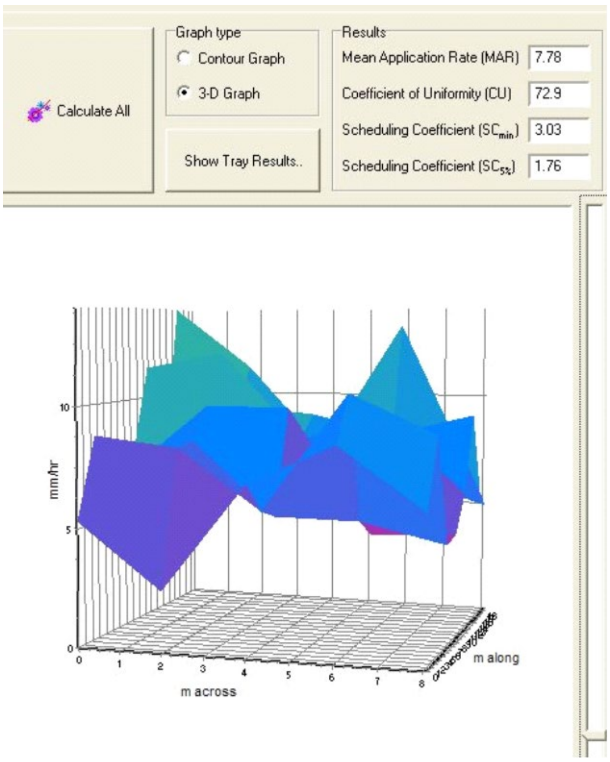


Figure 18. Results from an irrigation distribution test from Darby Nursery Stock close-spaced sprinkler treatment

Hillier Nurseries

Water use was much greater on the manually scheduled bed (mean irrigation 8.2 mm/day; WUI 7.72) compared to the GP1 scheduled bed (mean 3.3 mm/day; WUI 3.68). It is interesting that in 2005 a similar crop of *Spiraea* was grown on one of these beds with the same sprinkler system, but for the same period (Week 23 – 37) the manually scheduled mean irrigation was 3.5 mm/day and WUI 4.39 mm per 100 °C h. The GP1 automatic scheduling clearly showed a very significant water saving in this case. Occasionally, early in the season, a little extra spot hand watering was required on the *Physocarpus* on the GP1 bed to cope with its extra demand compared with the *Spiraea* (Figure 19). Overall, good control was achieved using the GP1. Moisture levels within the controller pot stayed broadly within the 35% - 45% set point band (Figure 20). Significant deviations outside this were either due to rainfall, additional manual watering, or occasional low points where rapid drying out occurred during very hot days before the evening watering opportunity provided by the master control panel. After 16 July, when the probe was moved to the *Physocarpus*, which has a higher water requirement, the replicate probe indicated that the *Spiraea* pot ran slightly wetter. However, the *Spiraea* generally on this bed were not obviously too wet. Despite large differences in water use between the GP1 and manually controlled beds, there was no obvious evidence of water stress or differences in plant growth between the same species in either location.

Influence of rainfall

Despite it being a generally hot and dry summer in many areas in 2006, many nurseries experienced some days with very heavy rain. As in 2005, an assumption was made that any rainfall in excess of 5 mm per day was regarded as “wasted”, as typically more than 5 mm of uniform rainfall would be more than enough to fully wet the containers. The quantities of both actual rainfall and “useful rainfall” that would contribute to irrigation need, and expresses the useful rain as a percentage of total useful precipitation received by the crop are presented in Table 3. Rainfall thus contributed to between 9% and 36% of the useful precipitation received. Where irrigation was most efficiently used (e.g. Godfrey, Hillier GP1 bed and Johnson’s MP Rotator bed), rainfall contributed to between 20% and 36% of the crop’s total water requirement.

Figure 19. *Physocarpus* growing in drier compost compared to *Spiraea* on GP1 controlled bed, 4 July 2006 at Hillier Nurseries

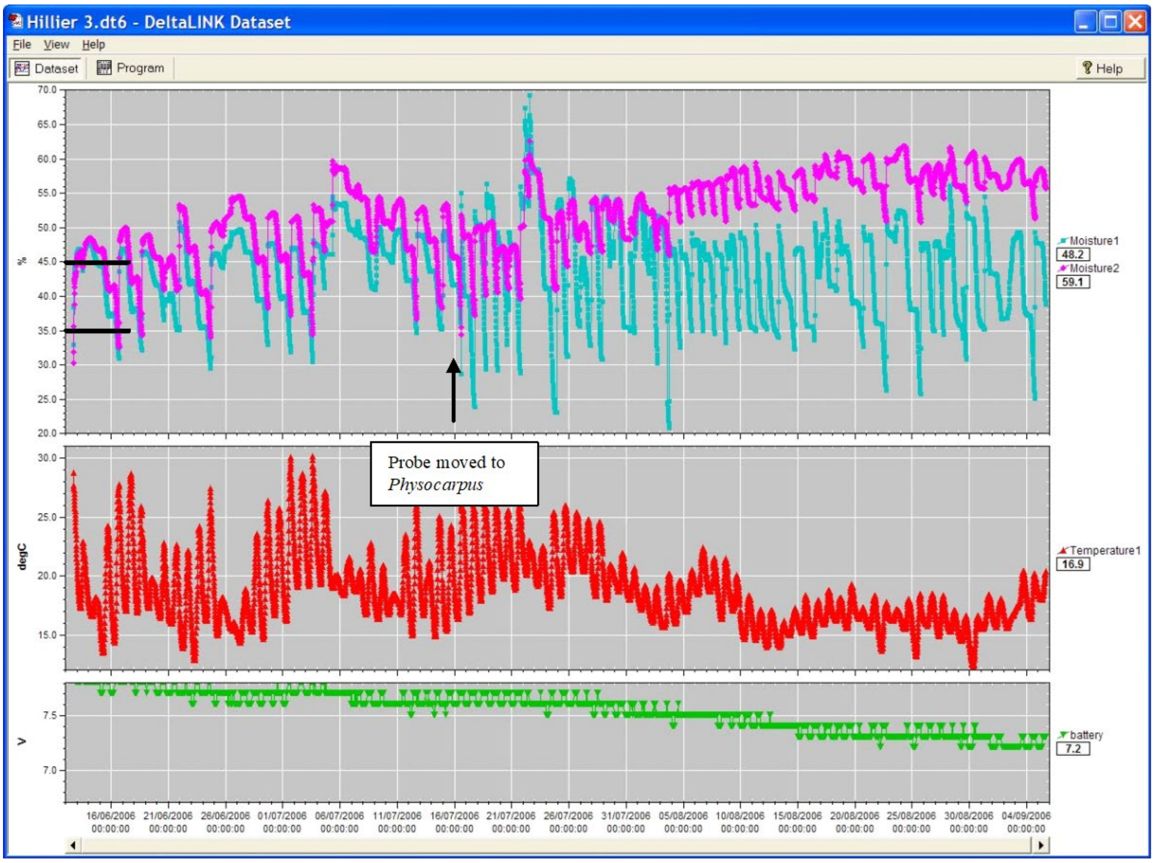


Figure 20. Moisture levels pots on GP1 controlled bed mid June to early September. Control pot (blue), replicate monitor pot (pink), growing medium temperature (red). 35% On and 45% off set points are marked

Conclusions

On the EMWC, substantial water savings were achieved through the combination of an "improved" overhead irrigation system and scheduling in response to plant demand for water, as compared to a "typical" overhead irrigation system and not scheduling irrigation. Even with "improved" overhead irrigation there is considerable non-uniformity of water distribution over a bed, particularly on windy days, and the effects of this were seen in very non-uniform soil moisture across some of the beds by September. Plant growth varied between beds, but the trends in plant growth were not consistent across different subjects.

The results from the WUMS this year have indicated that there can be very large differences in water consumption between nurseries or beds growing broadly similar crop subjects. Water has also been used much more efficiently and economically where some methodical scheduling practice has been used.

Technology transfer

The EMWC was demonstrated to growers and other interested visitors during Fruit Focus 2006. The West Sussex Fruit Growers and Kent Ambassadors also visited the EMWC during the summer.

A summary of the treatments and some results was prepared for HDC for inclusion in Four Oaks 2006.

Articles on the EMWC and gantry irrigation appeared in HDC News:
Indexing your way to water saving. HDC News April 2006, issue 122, p. 19-22.
Irrigation management in nursery stock. HDC News September 2006, issue 126, p. 8.

Factsheet 16/05 Measuring and improving performance of overhead irrigation for container-grown crops.

Poster presented at DEFRA Water Day at HRI Warwick, July 2006.

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The contributing nurseries – Darby, W Godfrey & Sons, Johnson's of Whixley, Hillier
The steering group – John Adlam, Chris Lane, John Richards, Chris Burgess, David Hooker, Peter Robinson, Julian Gruzelier, Lindrea Latham, Jenny Lang
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The EMR facilities team, particularly Nigel Osborne, Mick Buss and Roger Payne
The EMR Crop Physiology team, particularly Mike Davies and Helen Longbottom

Glossary

Evaporative demand – the power of an environment to evaporate water. It differs from humidity in that it takes into account other factors that influence evaporation e.g. radiation.
Evaposensor – an instrument invented at HRI East Malling and now available from Skye Instruments that provides an electrical signal approximately proportional to potential transpiration from a model leaf. It integrates the effects of humidity, radiation, temperature, wind, and leaf wetting.
ET_p – potential evapotranspiration – the rate at which a crop would lose water under prevailing environmental conditions if water supply was non-limiting. It includes evaporation from the plants i.e. transpiration and from the soil – or in the case of this work from the growing medium in the container.
Scheduling coefficient – a measure of the effect of non-uniformity of irrigation on the degree of over-irrigation required if the driest areas are to receive the intended (i.e. mean) volume of irrigation. It is defined as the mean catch rate divided by the minimum catch rate.
Volumetric soil moisture content – water content of the soil or growing medium expressed as a fraction or percentage of the total volume occupied by water. Its maximum value, when the soil is saturated, depends on the percentage of pore space in the soil, which in peat based media is generally about 90%.
(adapted from HNS 97 final report 2003).

References

ADAS Independent Water Audit for Container Grown Nursery Stock Producers – Summer 2000

HDC HNS 97/Horticulture LINK project 201 Improving the control and efficiency of water use in container-grown hardy ornamental nursery stock. Final Report 2003.

