Grower summary

HNS 122

Container nursery stock Irrigation: demonstration and promotion of best practice

Annual report 2005

Project title:	Container nursery stock irrigation: demonstration and promotion of best practice
Project number:	HNS 122
Project leaders:	Dr Christopher J Atkinson Principal Research Scientist East Malling Research New Road East Malling, Kent ME19 6BJ
Report:	Year 1, October 2005
Previous reports:	None
Location:	East Malling Research, East Malling Darby's, Thetford, Norfolk W Godfrey and Sons, Surrey Hillier's, Brentry, Hampshire Johnson's of Whixley, Yorkshire Wyevale, Hereford
Project co-ordinators:	'Steering Committee': John Adlam (Dove Associates) Chris Lane (Coblands) John Richards (John Richards Nursery) David Hooker (Hilliers) Chris Burgess (Private Consultant)
Date commenced:	1 October 2004
Date completion due:	30 September 2007
Key words:	Best practice, HNS, irrigation, sprinklers, water

‘The results and conclusions in this report are based on an investigation conducted over one year. The conditions under which the experiment was carried out and the results obtained have been reported with detail and 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’

HNS 122

Container nursery stock irrigation: demonstration and promotion of best practice

Headline

- A new water centre facility has been designed and developed for the hardy nursery stock industry at East Malling Research, Kent.
- The new East Malling Water Centre has a range of irrigation systems which includes: capillary matting, micro sprinklers, large overhead sprinklers and an Efford bed, along with a covered gravel bed.
- A national water use monitoring scheme, specifically for the hardy nursery stock industry, has been established with data on water use provided by the industry.

Background and expected deliverables

This project aims to demonstrate and promote efficient and sustainable irrigation management practices for container nursery stock nurseries. This will be achieved through the development of the East Malling Water Centre, where a range of irrigation systems and recent advances from R&D to improve water use efficiency, scheduling etc. will be demonstrated. Collaborating nurseries will also provide water use and efficiency data from their nurseries which will be published regularly. Information to help nurseries make the most appropriate irrigation investment options will also be developed. Other key technology transfer activities will include workshops and seminars, where nurserymen can see and discuss work first hand. This will be backed up by technical leaflets.

The project will help nurserymen comply with ongoing environmental and water related legislation; it will also improve profitability through direct cost savings for water and labour, better plant uniformity, quality and overall productivity.

The expected deliverables from this work include:

- Set up the East Malling Water Centre (EMWC) incorporating demonstrations of different irrigation systems and scheduling methods on both outdoor and protected crops.
- Establish a water use monitoring scheme (WUMS) with grower participation.
- The means to aid nurserymen in making sound water management investments when upgrading or expanding production areas.
- Deliver technology transfer activities including technical fact sheets, seminars and grower visits to the EMWC.

Summary of the project and main conclusions

In the first year of this project two objectives have been addressed, these are:

- Set up the East Malling Water Centre (EMWC) incorporating demonstrations of different irrigation systems and scheduling methods on both outdoor and protected crops
- Monitor water use and irrigation efficiency on commercial crops on at least four nurseries at different locations around the UK.

Additionally, a fact sheet has been produced, and growers have visited the EMWC.

Results

- A new facility (East Malling Water Centre) has been designed and constructed at EMR (see construction photographs in the science report).
- A dedicated weather station has been purchased by EMR and installed at the EMWC site.
- Currently, experiments with various HNS species are being initiated to look at methods to schedule irrigation using environmental data.
- Irrigation rigs have been built to measure, comparatively, differences in irrigation efficiency. This work also includes rigs to evaluate overhead sprinkler efficiency and uniformity of distribution.
- Five collaborating nurseries in different regional UK locations (Hampshire, Hereford, Norfolk, Surrey and Yorkshire) have been supplied by EMR with irrigation monitoring equipment and Evaposensors to monitor irrigation supply and plant water use.
- Data regarding Evaposensor readings, rainfall and irrigation have now been recorded and routinely collected from all these sites. First season results (early June – end October 2005) show differences in mean overhead irrigation use of 0.7 mm day^{-1} for an herbaceous crop in 9 cm pots, up to 3.1 mm day $^{-1}$ for shrubs in 3 litre containers.
- A Water Use Index (WUI) has been formulated to help evaluate irrigation over different sites. This takes into account geographical differences in evapotranspirative demand and rainfall, WUI thus being a function of crop demand and efficiency of application.

Financial benefits

Important financial benefits have already been identified in previous work upon which this project is based from improving irrigation practices and water use efficiency (e.g. see reports from HNS 97, HNS 107 and Factsheet 16/05). However, it is too early to provide further financial information specific to this project.

Action points for growers

- To ensure EMR delivers answers to your questions, please contact and visit us at the EMWC.

- Nurseries that are interested and able to supply more regional data on water use would be welcome to contact us at the EMWC.

Acknowledgements

We are especially grateful to those listed below who have contributed time and effort into the establishment of this project.

The contributing nurseries:
Darby's, Norfolk; W Godfrey and Sons, Surrey; Johnson's of Whixley, Yorkshire; Hillier, Brentry; Wyevale, Hereford.

The steering group:
John Adlam (Dove Associates), Chris Lane (Coblands), John Richards (JR Nurseries); Chris Burgess (Private Consultant - co-ordinator for nursery WUMS) and David Hooker (Hilliers).

*Equipment supplier*s:
Palmsted Nurseries (plants), Haygrove Tunnels (Spanish Tunnel), Evenproducts and Delta-T Devices (irrigation equipment).

The EMR facilities team – Nigel Osborne, Mick Buss and Roger Payne – for assistance in designing and construction for the EMWC.

Science Section

Introduction

This project aims to demonstrate and promote efficient and sustainable irrigation management practices for container nursery stock nurseries. This will be achieved through the development of the East Malling Water Centre, where a range of irrigation systems and recent advances from R&D to improve water use efficiency, scheduling etc. will be demonstrated. Collaborating nurseries will also provide water use and efficiency data from their nurseries, which will be published regularly. Information to help nurseries make the most appropriate irrigation investment options will also be developed. Other key technology transfer activities will include workshops and seminars, where nurserymen can see and discuss work first hand. This will be backed up by technical leaflets.

The project will help nurserymen comply with ongoing environmental and water related legislation. It will also help improve profitability through direct cost savings for water and labour, better plant uniformity, quality and overall productivity.

Recent HNS research has made significant progress in developing irrigation scheduling techniques, and highlighted improvements that can be made with irrigation systems (particularly overhead irrigation), to improve uniformity of distribution, and to use water much more economically and in a sustainable way. In addition to straightforward savings in water consumption and water costs, there are significant economic benefits to be gained from savings in labour (reducing hand watering and plant quality grading), reduced plant wastage, and an overall improvement in crop quality and uniformity. On top of this, a raft of UK and EU legislation designed to protect and fairly distribute an increasingly scarce water resource, and protect the environment, is forcing the horticulture industry to adopt and demonstrate measures to manage water more efficiently.

Part of the recent water LINK project (HNS 97) involved measuring water use on several nurseries and large variations in water use (up to 3X) were found between sites. This project aims to build on that work but using more precisely controlled cropping regime and monitoring procedure. The water LINK project also showed that regulating irrigation to match ETp (with an in-pot sensor), could save 30-40% of water applied compared to the grower’s current sprinkler system. There is scope for water savings up to 75% where regulated deficit irrigation is exploited with uniform distribution systems.

The ADAS Water Audit of container nursery stock nurseries, in 2000, highlighted some important facts and needs. A large proportion (90%) of smaller nurseries was reliant on (relatively expensive) mains water. The majority of nurseries use overhead irrigation, but relatively few have adopted any recycling of water. In general, the report states that growers rely heavily on inefficient irrigation systems, but there was a willingness to adopt improvements provided the advantages could be clearly demonstrated, and there was help and training available to use new systems effectively. This project aims to address these requirements.

Materials and Methods

Objective 1

East Malling Water Centre

Demonstration treatments
A small working group consisting of consultants, equipment suppliers, growers and scientists has been formed to discuss the design and construction of the irrigation and control/scheduling systems to be used at the EMWC, including discussion of 'best practice' treatments appropriate to the site.

The following comparative 'treatments' are included:

A Efford Drained Sand Bed. This is the benchmark against which other systems will be judged for water use efficiency, and uniformity of plant growth and quality.

B Overhead Sprinklers System 1. A best practice option that incorporates a well designed, uniform output sprinkler design for the area to be irrigated, and using a scheduling method to balance applications with evapotranspiration (e.g. Skye Evapometer & Sensor).

C Overhead Sprinklers System 2. An identical sprinkler design to B, but using an in-pot sensor (e.g. Delta-T Thetaprobe & controller) to automatically schedule and control irrigation, will be demonstrated in 2006.

D Overhead Sprinklers System 3. A 'typical' sprinkler layout often seen on nurseries that gives poorer distribution than B/C and uses time clock control. This treatment is to observe and demonstrate the effects of uneven water distribution on both water use (expected to be higher) and plant uniformity and quality (expected to be poorer).

E Capillary Matting Flowbed. This extends the work started under HNS 107, and will illustrate a less capital intensive system for capillary irrigation than a sand bed. It will be the first time we will have tested this capillary flowbed outdoors. Irrigation may be automatically controlled by a 'WaterBug' device, which is proving successful under protection.

Measurements at EMWC include:

- Estimated evapotranspiration losses (Evaposensor data, including some sample plant weighing for calibration). This is the basis for scheduling treatment B.
- Water consumption - from separately metered supply to each system. Additional water use for any spot watering by hand also recorded.
- Rainfall record (outdoor crop). This will be used to modify evapotranspiration estimates and schedules for outdoor crops.

- Temperatures (outdoors and under polythene), and solar radiation / sunshine hours.
- Water distribution uniformity.
- Stage of crop growth related to ETp demand.

Objective 2

Water Usage Monitoring Scheme (WUMS)

The first year's objective was to collect reliable data for some outdoor crops using grower's normal irrigation practice and obtain an initial benchmark for water use.

In the first growing season (2005), five contributing nurseries are each monitoring water use on an overhead irrigated outdoor crop. Monitored beds have been fitted with a separate water meter. Complete standardisation of crop, pot size, potting date etc. has not possible between sites, but most are growing a broadly similar 'spring potted liner crop' in 2 or 3 litre containers, and specific crop details that are likely to influence water requirements have been noted for each site. Nurseries were also visited initially to record sprinkler type and layouts, standing base material, cropped areas etc. and to measure irrigation system application rates and uniformity.

All growers are routinely recording the following:

- Irrigation dates (scheduled according to grower's usual practice)
- Water consumption after each irrigation (meter readings)
- Daily rainfall (rain gauge)
- Evapotranspiration estimates (Skye Evapometer & Sensor)
- Observation on crop stage of growth and other comments

Data are sent (during the growing season) for collation and analysis. Each nursery's Evapometer and rainfall data provide common environmental measures against which water consumption can be referred. Water use for the different nurseries can then be examined in relation to the other two key factors affecting consumption: the crop (type and size) and efficiency of water application.

Results and Discussion

Objective 1

Objective 1 was to set up the East Malling Water Centre (EMWC) incorporating demonstrations of different irrigation systems and scheduling methods on both outdoor and protected crops.

The aims are to measure water requirements, consumption and irrigation efficiency for small commercial scale comparative beds at EMWC, and formulate benchmark data. An additional aim is to demonstrate different irrigation scheduling and control techniques.

With the aid of a steering committee, a hardy nursery stock water centre (the East Malling Water Centre, EMWC) has been established at East Malling Research. The funds to design and build this facility were provided by East Malling Research (see Annex I). The facility has been designed and developed to enable a range of irrigation practices to be evaluated and demonstrated. The accompanying set of photographs show how the initial green site has been developed to its current status (Figures 1 to 12). The design brief was to construct a centre which would be flexible and could be further developed and modified over time to provide a ‘state of the art’ demonstration facility. These facilities are now being used to evaluate new irrigation technology, to create baseline data sets on crop water use and guide the industry on best economic practice. East Malling Research has also purchased a dedicated high-tech meteorological station which has now been located at the site (Figure 13). This is intended to provide detailed environmental records of factors which are know to influence plant water use and irrigation efficiency.

During the development of this facility visits and advice were obtained from the project steering group (John Adlam, Dove Associates; Chris Lane, Coblands Nurseries; David Hooker, Hillier Nurseries; John Richards, John Richards Nurseries and Chris Burgess, Consultant). Both John Adlam and Chris Lane visited the site during construction to inspect and provide further on-site advice. John Adlam has provided technical advice, on many aspects, throughout the construction of the centre. The facility has also been examined by visits from the HDC Council and more recently the HNS Panel. The centre was also a major exhibit at East Malling Research’s trade Open Day on the 22 September 2005, where staff were available at the centre to discuss is current applied research ideas along with future plans.

Experimental work has been initiated with experiments involving crop irrigation, as well as, evaluation trials (Figures 11, 14 and 15). Currently this involves an experiment to monitor water consumption in HNS plants of different types, and at different spacings and prunings, and under two environmental regimes – one under a polytunnel (Figure 12) and one outside (Figure 11). Plant material for this experiment has been supplied by Palmsted Nurseries, Kent.

Water consumption is being related to potential evapotranspiration as measured using Evapometers. In particularly, we are looking at ways to improve Evaposensor performance by better understanding of the factors needed to calculate plant transpiration, which is partly determined by plant size and management. This will enable plants of different sizes and at different spacings to be uniformly treated and more effectively irrigated.

Additionally we are monitoring rainfall, temperature, humidity and radiation both on an open bed and under cover. We are also monitoring soil moisture, to look at variation in soil moisture between pots. To do this we are using Delta-T ThetaProbes, which measure volumetric soil moisture content – the ratio between the volume of water present and the total volume of the sample.

Work involving demonstration and evaluation of irrigation equipment has also begun with the installation of various irrigation systems to conduct comparative tests on watering efficiency. Much of this equipment has been loaned from Evenproducts Ltd.

One of the experimental protocols which will frequently be used to evaluate the efficiency of overhead sprinklers is shown in principle in Figures 14 and 15. This involves the use of 'catch pots', which are weighed before and after irrigation events to determine the volume of water captured over time (application rate) and the uniformity with which it is delivered (variation between pots), on an area basis (uniformity of distribution). The technical details of how these measurements are made have recently been described in HDC Factsheet 16/05. This factsheet makes use of data collected from this project. The factsheet also described the use of the HDC irrigation calculator to make measurements of mean application rates (MAR), Christiansen's coefficient of uniformity (CU) and scheduling coefficient (SC). These measurements form an integral part of the HNS 122 on-going sprinkler evaluation protocol.

Figure 1: The early stages of ground preparation at site of the East Malling Water Centre, excavating the main drainage culvert

Figure 2: **Construction of the main supply and drainage culvert at the East Malling Water Centre**

Figure 3: **Construction of the pathway bases intended for the main forklift access track into the East Malling Water Centre**

Figure 4: Laying the main drain within the culvert at East Malling Water Centre. On the left are 3 (5 x 10m) beds and on the right the forklift access track

Figure 5: Construction of the Efford bed at the East Malling Water Centre. The u-shaped channel is for the bed water supply/drainage pipe (not in place)

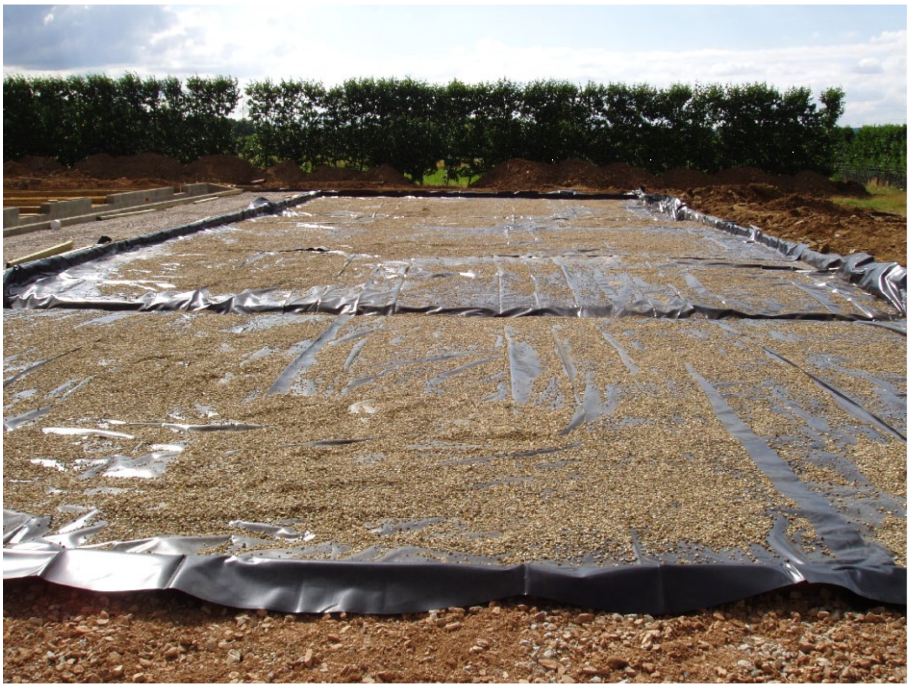


Figure 6: Construction of the large (10 x 30m) overhead sprinkler gravel bed at the East Malling Water Centre. The bed is sloped from left to right and contains two main drains

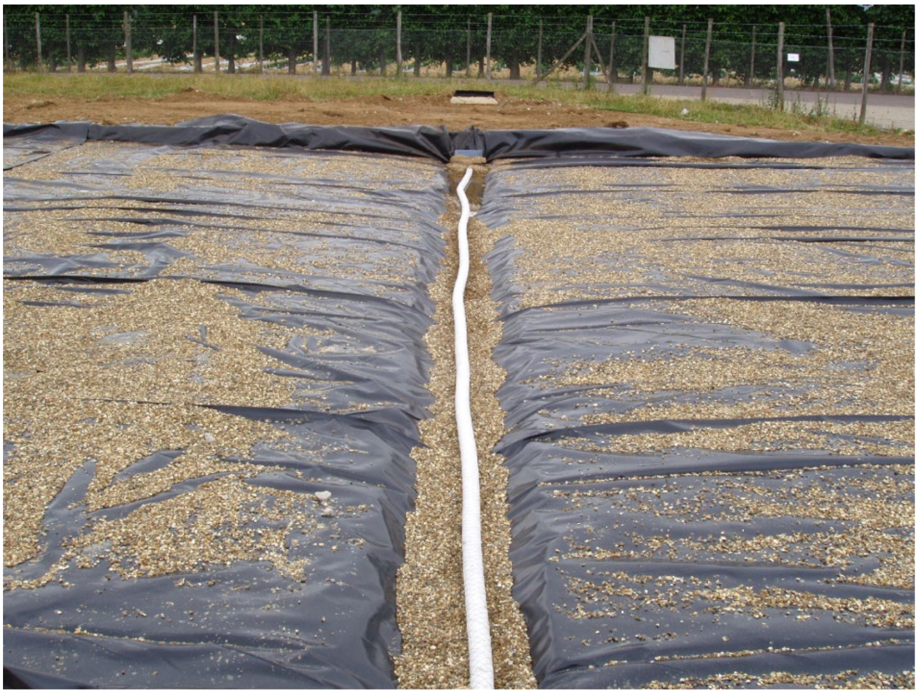


Figure 7: Main drain of the large overhead sprinkler (10 x 30m) gravel bed at the East Malling Water Centre. The central rapped drain pipe is shown along the bed length

Figure 8: **Laying the water collecting polythene under the capillary bed and waste water collection areas, left and right of the main bed, at the East Malling Water Centre. Waste water missing the bed, when sprinklers are in operation, is collected in the waste overflow drain as seen on the left**

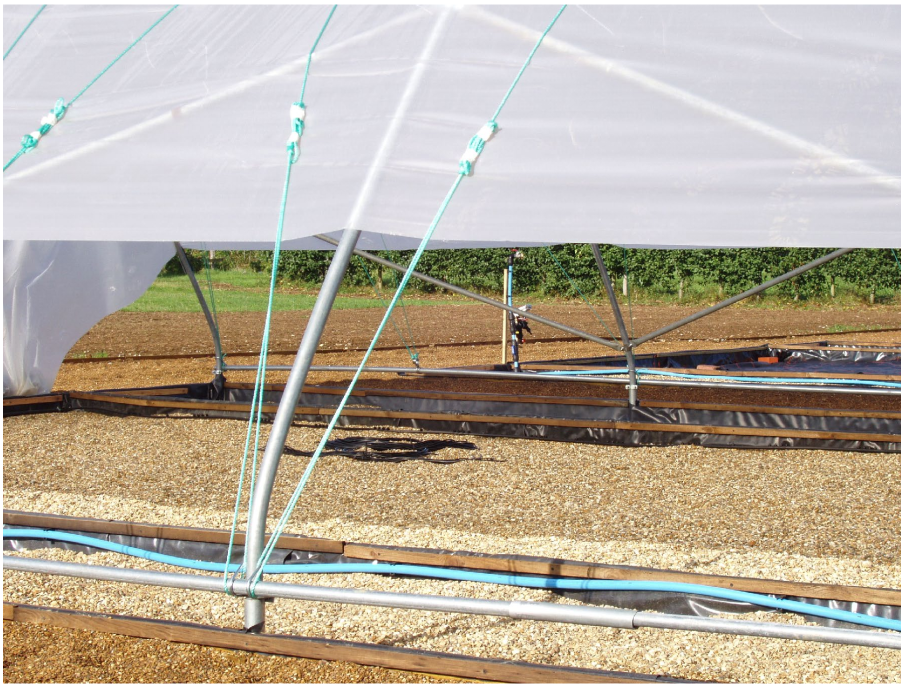


Figure 9: **A small (5 x 10m) gravel bed which has been used to provide crop cover with a Spanish tunnel supplied by Haygrove Tunnels Ltd**

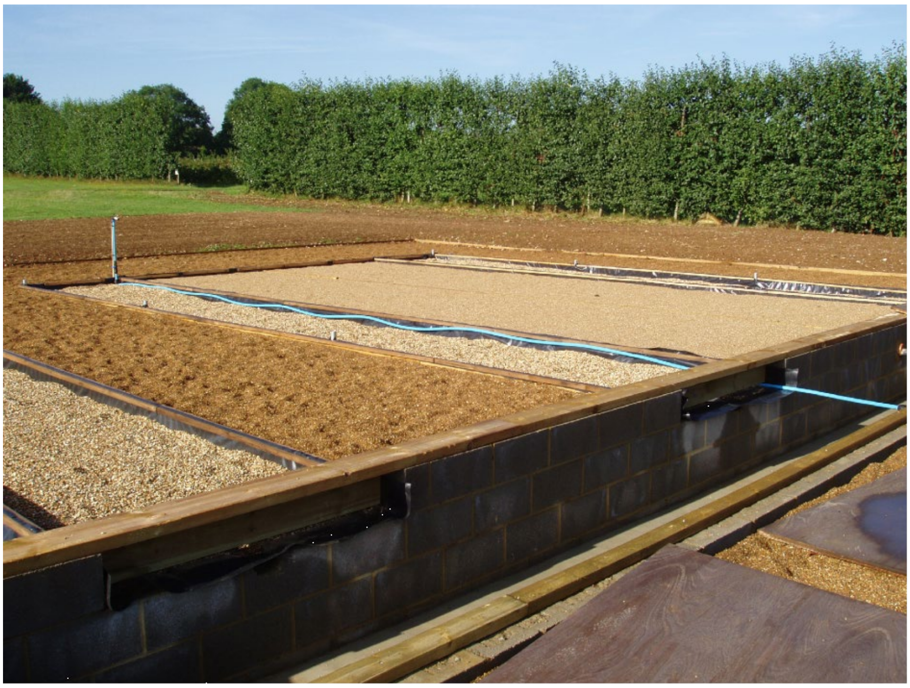


Figure 10: The final stages of bed construction with the installation of water supply at the East Malling Water Centre

Figure 11: An initial experiment with a range of HNS species being used to evaluate the influence of canopy variation, spacing and management on crop water use at the East Malling Water Centre. The crop is without protection and is irrigated using the Evaposensor and drippers

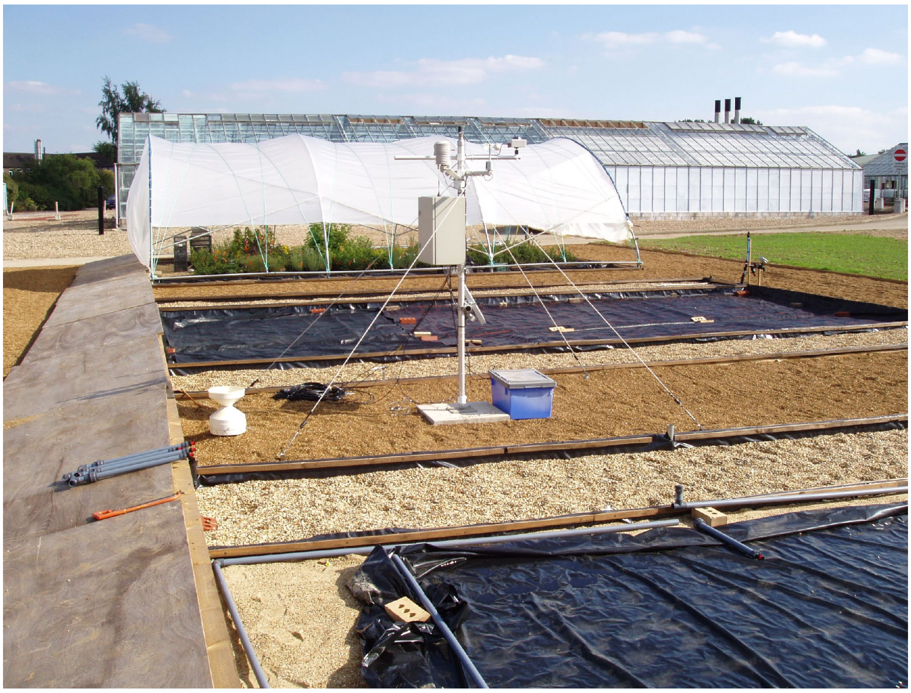


Figure 12: An initial experiment with a range of HNS species being used to evaluate canopy variation, spacing and management on crop water use at the East Malling Water Centre. The same crop as in Figure 11 is under protection

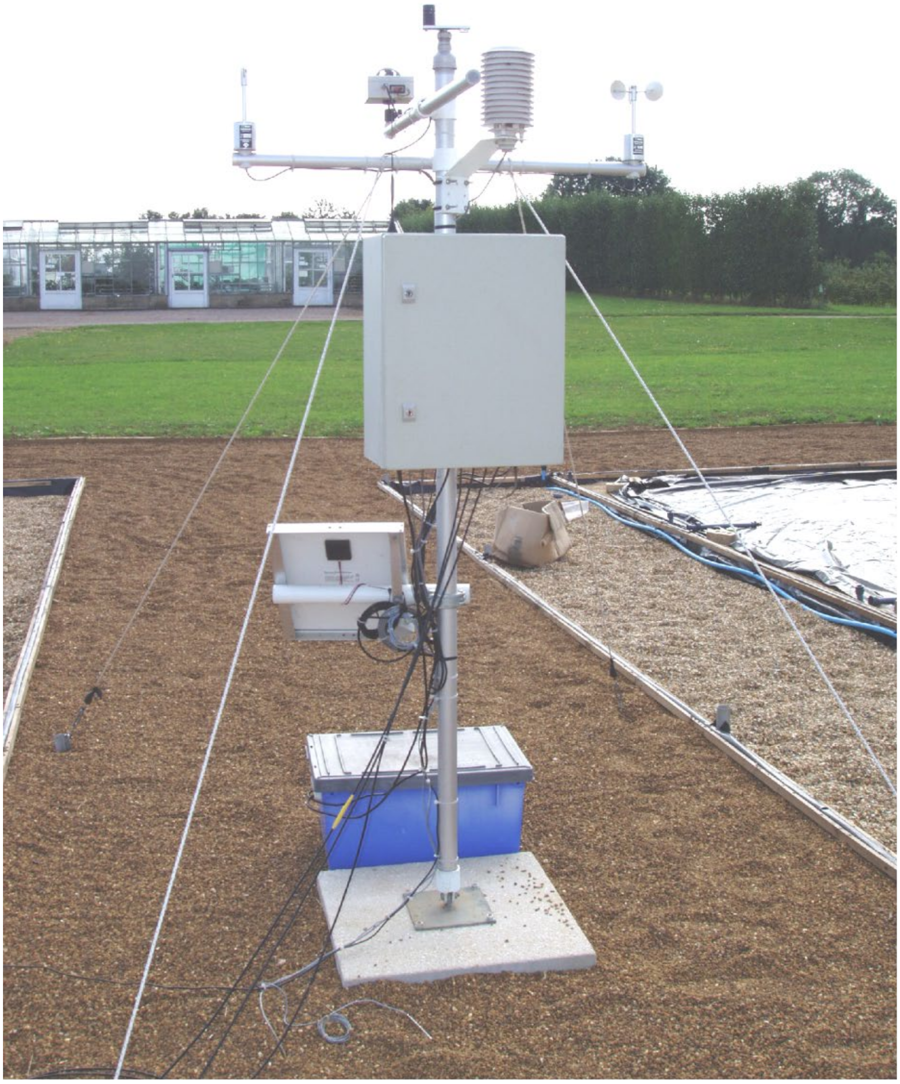


Figure 13: The meteorological station at the East Malling Water Centre. Environmental data quantifying radiation, temperature, relative humidity, soil moisture and rainfall are being used to determine climatic impacts on plant water use and irrigation application efficiency

Figure 14: The use of the large gravel bed (10 x 30m) to evaluate irrigation equipments at the East Malling Water Centre, here with overhead sprinklers

Figure 15: The procedure used to evaluate irrigation sprinkler distribution using the large gravel bed (10 x 30m) at the East Malling Water Centre, 'Catch pots' quantitatively determine the amount of irrigation received and their distribution is used to calculate efficiency and uniformity of application

Objective 2

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

The aims of this objective are to monitor water use and irrigation efficiency on commercial crops on at least 4 nurseries at different locations around the UK, and relate to EMWC data. Data from nurseries and EMWC will be reported at regular (e.g. monthly) intervals during the growing season. Plans are being developed to make these accessible through a website, and in HDC News (journal and e-weekly), and Grower or Horticulture Week.

Daily climate data have been collected, as described in Annex II and III, since mid summer 2005, by the five contributing nurseries and are now undergoing detailed analyses. Plans of the beds under examination are shown for four sites in Annex IV. A set of preliminary data is present for each location in Figures 16 to 20. Each data set summaries on a weekly basis total accumulated temperature differences (°C h) obtained from the Evaposensor. Also recorded are weekly total rainfall (mm) and the irrigation applied by the nursery (expressed as mm based on the bed area). The initial evaluation of these data has already shown clear regionally different patterns, particularly with respect to Evaposensor readings. Evaposensor temperature measurements reflect geographical differences in climate and are therefore a key driver in determining water evaporation rates, plant transpiration and plant water use. Table 1 summarises totals and averages for the recorded season early June to end of October.

The average Evapometer reading varied from about 65 °C h / day for Johnson's near York to 86 °C h / day for Hilliers near Winchester, with the remaining three nurseries experiencing similar values overall. Three of the sites, Thetford, Whixley and Wyevale can all be seen to exceed an arbitrary threshold accumulative weekly temperature value of 625°C h for around 30% of the summer (June to mid-August). However, for the more southerly, Hampshire and Surrey locations, this value is exceeded by 65% and 45% respectively, over the same time period. This simply shows, as might be expected, these two sites are warmer and therefore nursery water use may be greater. As might be predicted, the site in Hampshire irrigates more frequently and at a greater intensity than the one in Surrey and in particular more than the one at Thetford. Average total rainfall was broadly similar across nurseries (2.0 – 2.4 mm / day), but 'useful rain' of up to 5 mm/day averaged 0.95 – 1.23 mm / day.

The quantity of irrigation applied varied a lot between nurseries. Godfrey's used by far the least, averaging 0.7 mm / day, followed by Darby's at 1.34 mm / day. Johnson's averaged 2.25 mm / day, and Hillier's 2.72 mm / day. The two beds at Wyevale used different quantities – Bed 401 using Rainbird impact sprinklers used more, at 3.06 mm / day, than Bed 402 using a new low output Nelson Rotator design sprinkler, at 2.52 mm / day.

An aim of this project is to promote efficient irrigation management. Unfortunately, the concept of "water use efficiency" is ill-defined in relation to container ornamentals, where the notion of increased yield per unit water applied, as used in other agricultural sectors, may not be relevant. A particular problem is that the nurseries studied grow different plant subjects, in different container sizes, at different densities, and with different physiologies. Thus it is not possible here to easily define efficiency of irrigation at the different nurseries. Nevertheless, we have here provided a water use index to allow comparison across nurseries. This is expressed as mm of useful precipitation (Figures 16-20 and Table 1; see Figure 16 legend for definitions of terms) per 100°C hours. This index takes into account environmental differences between sites in potential evapotranspirative demand and rainfall. Variation between sites in this index therefore reflects a combination of variation between crop types – large leafy plants would be expected to have a higher index than small compact plants – and the "efficiency" of the irrigation scheme and schedule – an excessively irrigated crop would have a higher index than a similar crop that is only irrigated to its requirements.

The values for Water Use Index (WUI) broadly follow the same rank as for mean irrigation between nurseries, with Godfrey's having the lowest WUI (2.07 mm $°C^{-1}$ h^{-1} x 10^2) and Bed 401 at Wyevale the highest (5.95 mm $°C^{-1}$ h^{-1} x 10^2). However Hillier's is slightly lower than Bed 402 at Wyevale for WUI but higher for mean irrigation. The WUI data also has a lower relative range between nurseries than the mean irrigation data, which reflects the environmental effect accounted for by the WUI. At Wyevale nurseries, the gentler output from the Nelson Rotator sprinklers may have contributed to a lower mean WUI for Bed 402 than Bed 401 by wetting up the pots more efficiently. Although the two beds had different crops, they were both using mainly 3 litre pots. The low WUI value for Godfrey's is probably largely a reflection of the herbaceous crop in mainly 9 cm pots on this nursery, compared to the other nurseries where 3 litre (and some 2 litre) crops were being grown.

Although this index may be expected to change as plants grow, and is less useful in weeks where even "useful" rainfall exceeds the demands of the plants, one way in which to use this index to monitor efficiency may be to note its pattern over time. In the case of both Darby's and Johnson's Nurseries, for example, the index drops between the week starting 8 August and that starting 15 August, recovering the following week. The limited irrigation applied the week of 15 August, despite little rainfall that week and a quite high evaporative demand, may indicate that nursery irrigation scheduling is not always consistent with the real environmental demand. At Hilliers no irrigation was applied the week commencing 1 August, resulting in a fairly drastic decline in the Water Use Index. Conversely at different sites during some weeks with rainfall and a fairly low evaporative demand, large quantities of irrigation applied result in a high Water Use Index (e.g. Wyevales, w/c 26 September). It would be expected that a smoother pattern over time for the index than seen in some of the nurseries would be desirable. Thus the strength of such an index could be to allow growers to monitor the consistency of their response to plant irrigation requirements.

Data collected in Year 2 will consolidate on these initial results. In addition, it is planned that comparisons can be made on some nurseries between standard and improved irrigation scheduling techniques or between alternative water application methods. A similar crop will be grown on 5 beds using separate irrigation systems and schedules at the East Malling Water Centre in 2006, which will allow direct comparison between different systems without the confounding factor of different crops.

Figure 16: Summaries for 2005 of weekly Evapometer readings (°C h), useful rainfall (mm), irrigation (mm), and a water use index for various nurseries (a-e)

Useful rainfall refers to rainfall in a day of up to 5 mm – rainfall exceeding this quantity is regarded as surplus to that required to wet-up containers. The water use index = (irrigation + useful rainfall)/degree hours.

Figure 16 (a) Darby's, Thetford, Norfolk

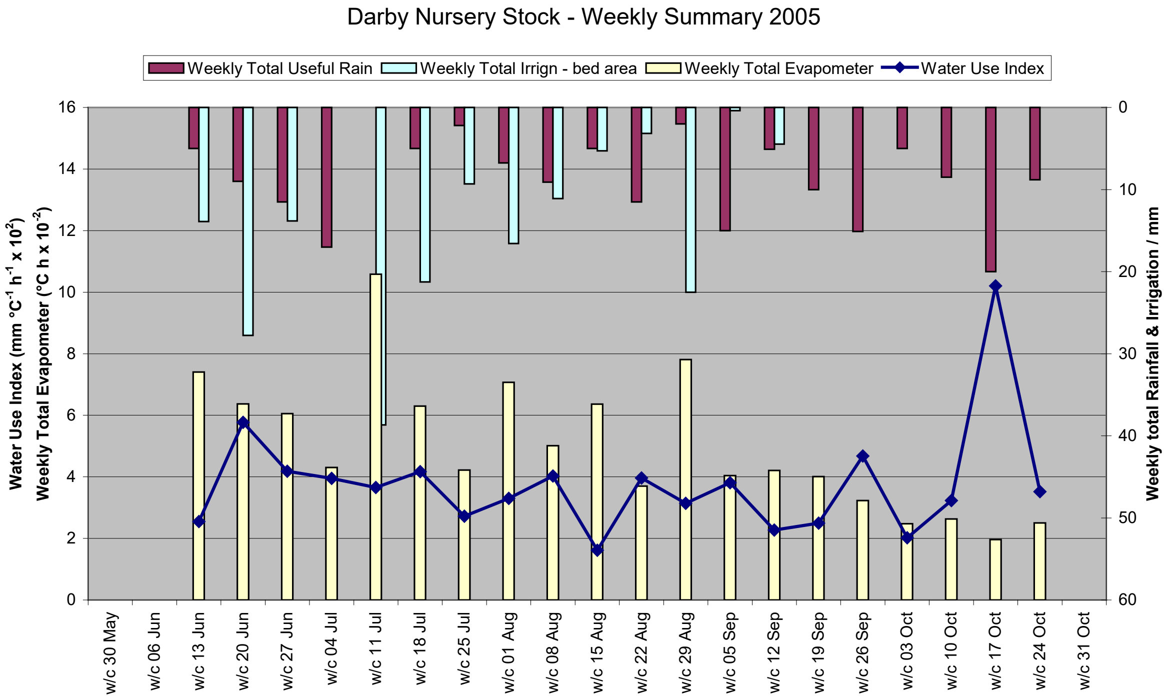


Figure 16 (b): Johnson's of Whixley, Yorkshire

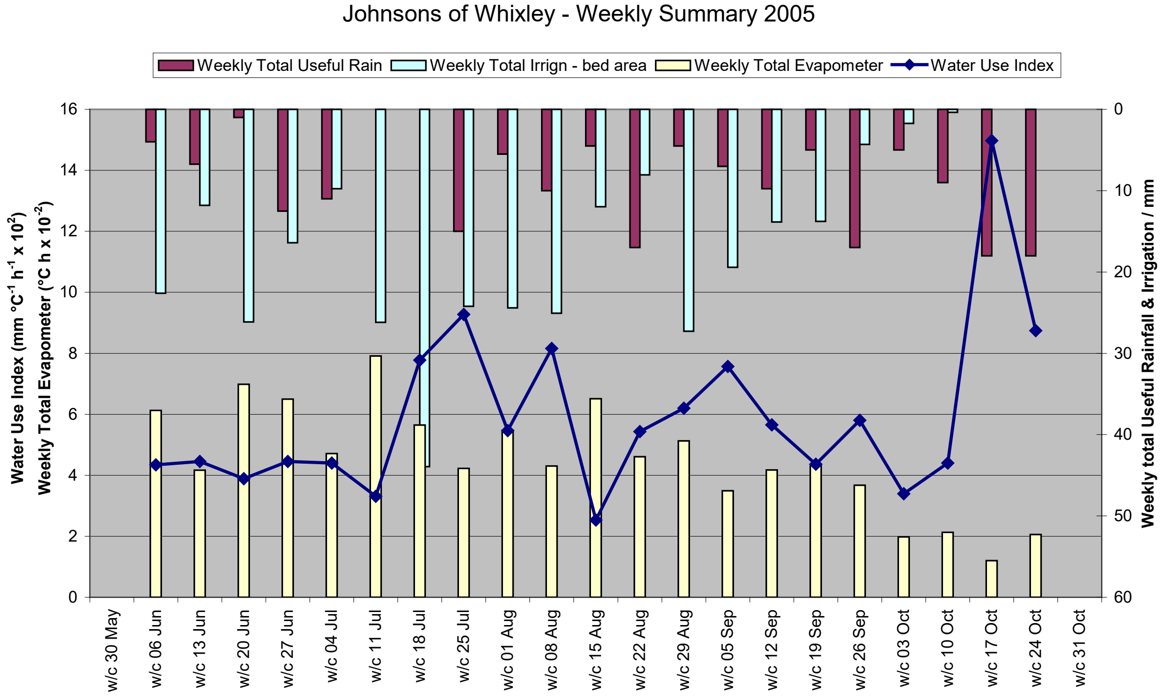


Figure 16 (c): Hillier's, Brentry, Hampshire

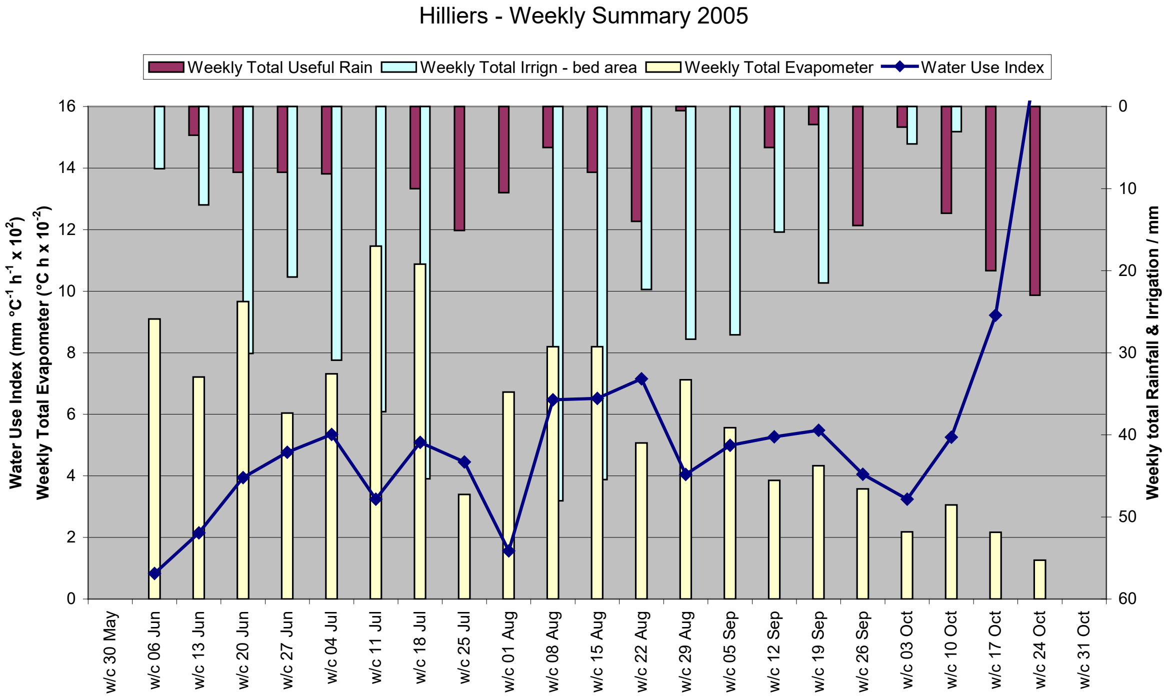


Figure 16 (d): Godfrey and Sons, Surrey

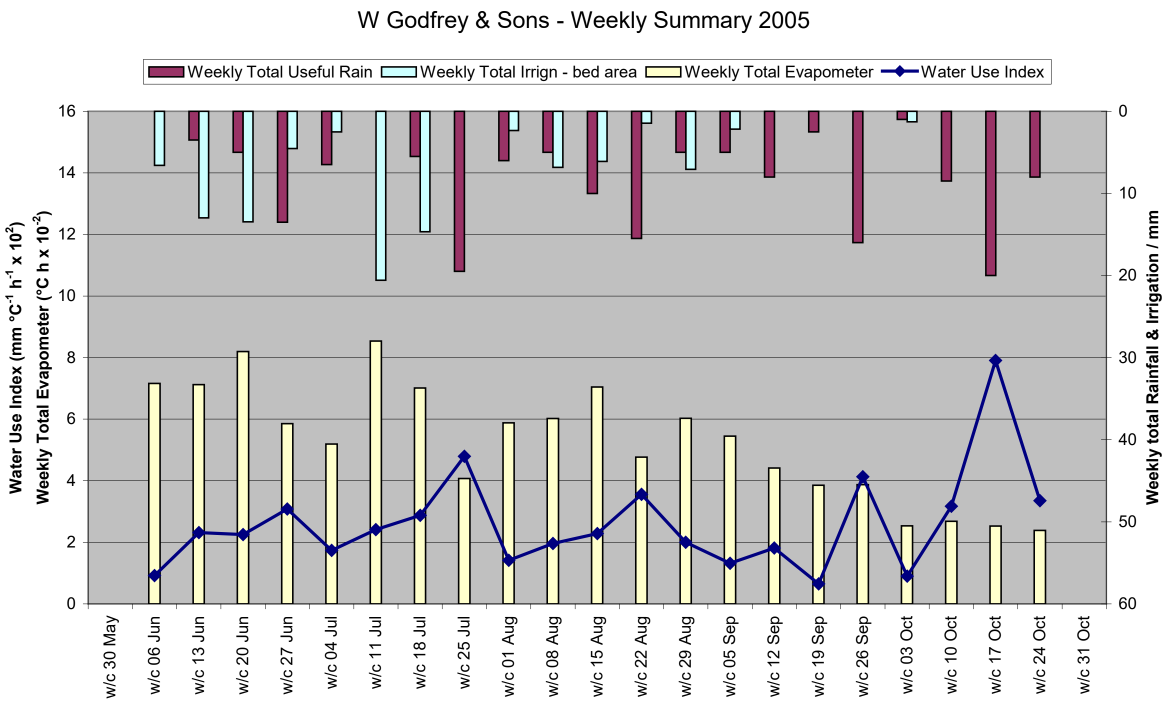


Figure 16 (e): Two beds at Wyevale Nurseries, Hereford

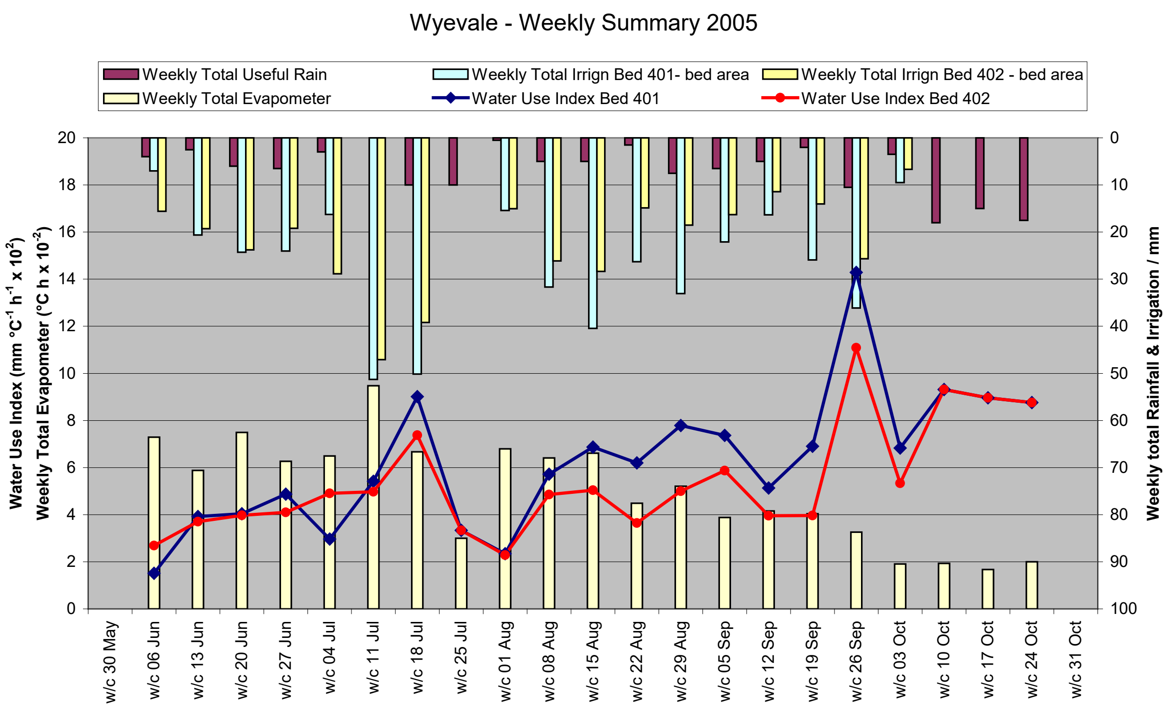


Table 1. Summary of Evapometer, Rainfall, Irrigation and Water Use Index data for w/c 6 Jun – w/c 24 Oct (Weeks 23 – 43)*
"Useful precipitation" refers to the total of "useful rain" (see Figure 16 legend for explanation) plus irrigation applied.

Nursery		**Evapometer (°C h)**	**Total rain (mm)**	**'Useful rain' (mm)**	**Irrigation (mm)**	**'Useful precipitation' - rain + irrigation (mm)**	**Water Use Index (mm °C^{-1} h^{-1} x 10^{2}) Average**	**Water Use Index (mm °C^{-1} h^{-1} x 10^{2}) Irrigation weeks only****
Johnson's of Whixley	Total	9532	298	181	331	512		
	Mean/day	64.8	2.02	1.23	2.25	3.48	5.37	5.31
Wyevale - Bed 401	Total	10493	292	140	450	590		
	Mean/day	71.4	1.99	0.95	3.06	4.01	5.62	5.95
Wyevale - Bed 402	Total	10493	292	140	370	509		
	Mean/day	71.4	1.99	0.95	2.52	3.47	4.86	4.87
Darby's	Total	10026	332	172	188	360		
	Mean/day	71.6	2.37	1.23	1.34	2.57	3.59	3.48
Hillier's	Total	12636	290	171	400	571		
	Mean/day	86.0	1.97	1.16	2.72	3.89	4.52	4.61
W Godfrey & Sons	Total	11060	354	164	103	267		
	Mean/day	75.2	2.41	1.12	0.70	1.81	2.41	2.07

* Except Darby's – w/c 13 Jun – w/c 24 Oct (Weeks 24 – 43)
** Irrigation weeks – i.e. weeks in which irrigation was applied

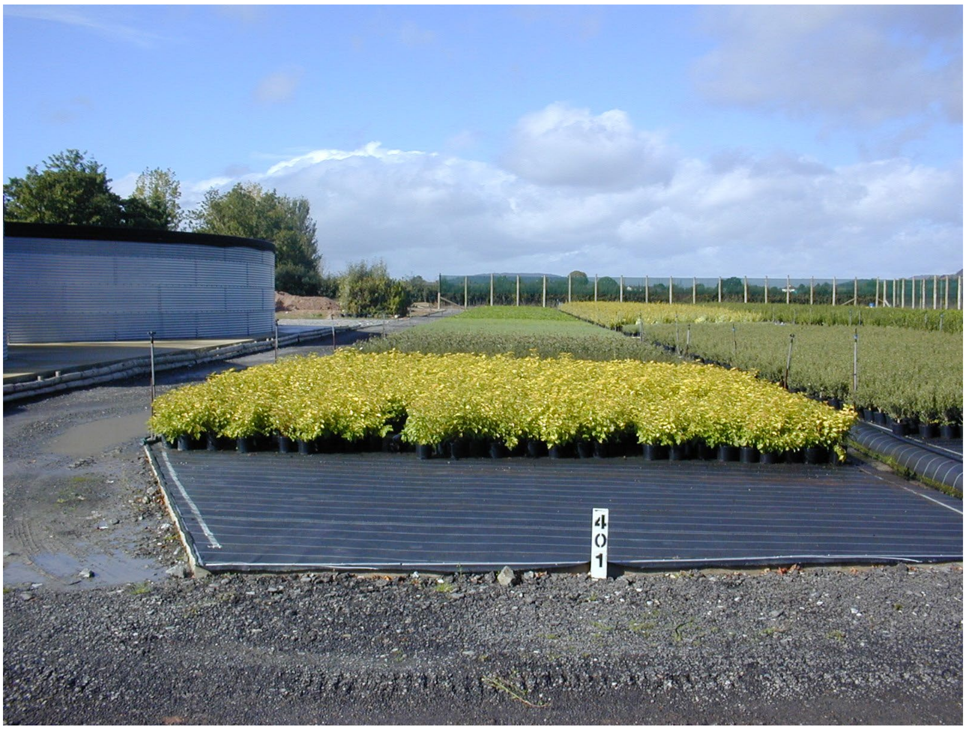


Figure 17: Wyvale Nurseries, crops on Beds 401 and 402 on 27/09/05

Figure 18: Rotoframe sprinklers on herbaceous crop bed at Godfrey's nursery

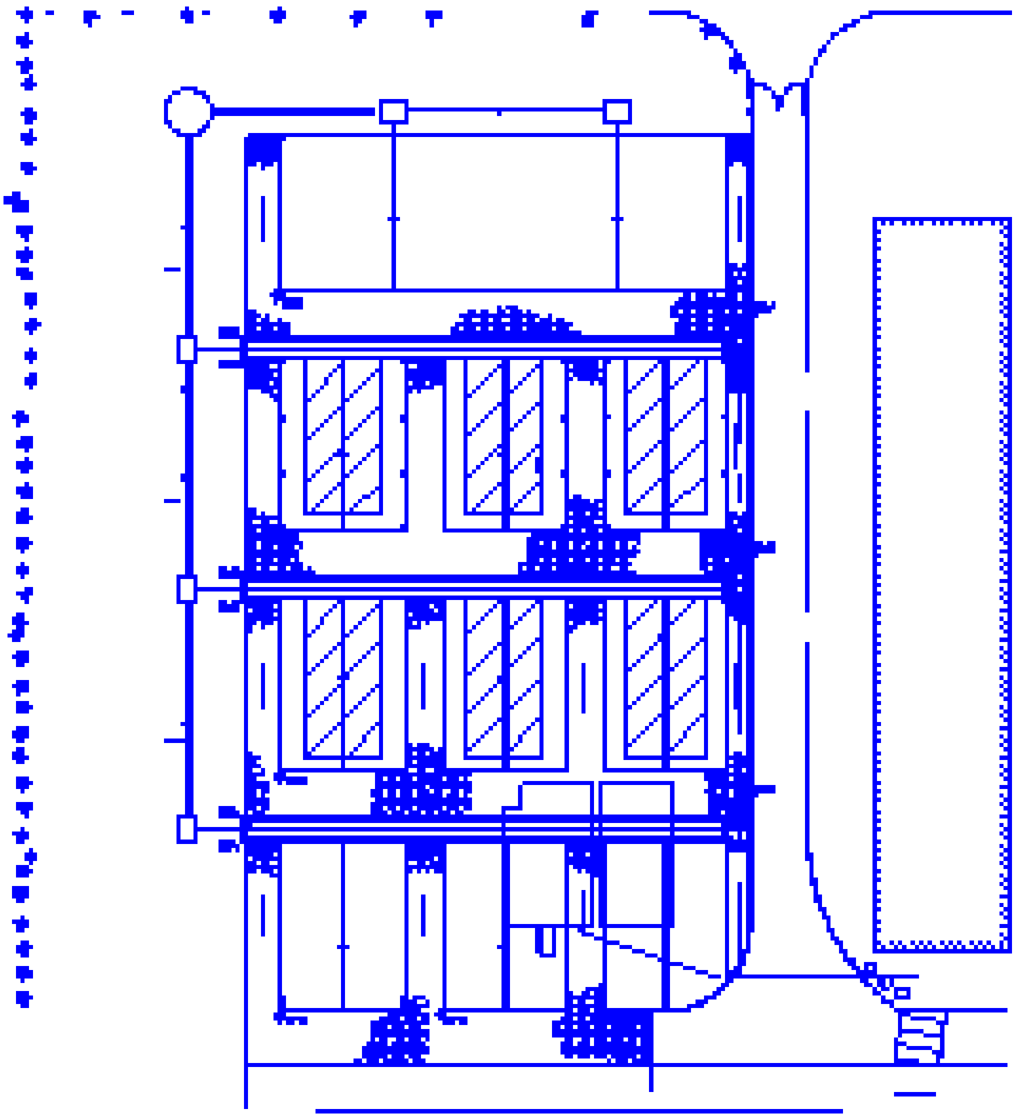
Figure 19: Golden Spiraea on monitored bed at Hillier Container Nursery on 08/09/05 irrigated with Naan 427 AG impact sprinklers

Annex I

Schematic of the EMWC beds

Site plan of the East Malling Water Centre as originally designed by the 'steering group'. The plan below was revised due to cost and the area constructed to include the large gravel bed (10 x 30 m) at the north end and the three smaller beds (5 x 10 m) immediately below. The current construction will be extended, within the site, if research funds are available.

North



South

Annex II

Guidelines for the collaborating nurseries

Evapometer and Evaposensor

- Site the sensor where it will receive full exposure to light and air typical of the crop area being monitored. This can be away from the crop (e.g. near the raingauge) if more convenient, as long as the environment is similar. Avoid shading or wind shelter. If you do place it in or near the crop, mount the sensor above the crop canopy. It makes little difference if the sensor gets wet during irrigation. The meter is waterproof, but keeping it under a cover is a wise precaution against tampering.
- Batteries – 9v PP3 alkaline. Should last 6 – 7 weeks. Scroll display to end to get health (OK / Low / Expiring). Can replace battery without losing stored readings.
- Periodically check reservoir and condition of wick. Top-up with distilled or boiled rainwater to help prevent wick getting caked up with lime and algae.
- Set the 24 hr start time at a time shortly before you are most likely to read the meter each day. Preferably in the morning e.g. at 8.00 am if you aim to read the meter between 8.00 and 9.00 am. The 'Previous 24 hr' value thus relates to the 24 hrs up to that point.

Rain gauge

- Site this in the open well away from buildings, hedges or tall vegetation. Also away from any overhead irrigation (!). The base may need to be partly buried or supported for stability. Ensure the top is level.
- Aim to read this by 9.00 am daily so, like the Evapometer, it refers to the previous day's rain.

Water meter

- It may be more convenient to plumb in the meter to just one sprinkler line, even though the recorded area may be being irrigated by two or more lines. Provided I know what proportion of the total sprinklers it represents, and that the other lines operate identically, I can adjust the record appropriately. The meters provided by John Adlam also work on a minimum flow rate of 300 litres/hour and max of 5 m^3/hr or 5000 litres/hr, so it needs to be plumbed into a section within this flow range.
- The 'mileometer' digits on the meter go down to m^3 (1000 litre) units. The next 4 red dials (all rotate clockwise) read in units of 0.1 to 0.0001 m^3 (or 100 to 0.1 litres). Just record the mileometer digits plus the NEXT THREE red dials remembering to round down the pointer reading where it falls between digits (like reading an old style gas meter). This gives a reading down to litre units.
- Try checking the meter and readings make sense before installation by running a hose supply through it into a large bucket or container of known volume.

Completing and returning Record Sheets

If at all possible, readings of Evapometer, Rainfall and Water Meter should be done routinely at a similar time every day. However, the accumulated data over more than one day is still important and valuable if a day or so is missed out occasionally.

- **Evapometer** – record the <u>'Previous 24 hr value'</u> and the <u>'Accumulated Total'</u> daily. The Accumulated Total is a good cross-check, and is particularly helpful if a day's

reading is omitted. Provided readings are recorded close to the '24 hr start time', I can get the missing reading by subtraction.
e.g. Sat record gives Fri 24 hr period and Acc. Tot. = 253.5
Sunday missed. Mon record give Sun 24 hr period = 75.0 and Acc. Tot. = 392.1
Therefore Sat 24 hr period is 392.1 - 253.5 – 75.0 = 63.6
If more than one day is missed, I will have to average out the Acc. Total difference for each day.

Please reset the Accumulated Total periodically, and tick column on record sheet. E.g. once a week or before it reaches the 'Alarm setting' value (default alarm setting at 3000 °C hrs).

- **Rainfall**. Again should be recorded daily near the start time. However if a record represents more than one day's rainfall, mark the missing record(s) with a "-" and a note in the Comment column that the rainfall is for more than one day. Use "0" rather than "-" for dry days.

- **Water meter.** A single daily reading is sufficient, even if more than one irrigation per day is applied. However it may be helpful to note the irrigation schedule (e.g. 2 x 10 mins per day) in the comments column esp. as it changes during the season, or when unusual amounts are needed. Also if there have been breakdowns or bursts causing odd readings.

  It is also helpful to comment on additional spot watering by hand that may be required, particularly as this will probably not be recorded by the meter. Finally, your occasional notes on plant size here (approx height / spread / species / pot size) will really help with the data interpretation on water use.

Please submit records to me weekly if possible. This will help keep analyses and summaries up to date. I hope these will be available for access either via the electronic HDC Weekly News or on a website.

I've given you blank record sheets in both Word and Excel format (choose either), from which you can print hard copies for your clipboard record. Fill in your own dates or edit the Excel version.

Either:

1. Best option for me: Copy your data from the hard copy into Excel using my template file. Note there are separate sheets for the Evapo / Rainfall and Water meter records.
2. Next best: Fax me your record sheets weekly to 0871 6729695. You may like to mark your sheets when the record has been faxed. This is a 'fax to email' number (costs you 10p/min) as I haven't a fax machine, but you should get a couple of A4's through pretty quickly. Alternatively scan the record sheets as .pdf or other image files and email me those.
3. Final option: Post me a clear photocopy.

Please keep your record safe until we're sure it's OK this end.

Finally, do get in touch if there are any problems.

With thanks for your participation and help.

Annex III

Nursery data information sheets

EVAPOMETER AND RAINFALL RECORD

Nursery name: ____________________ Bed identification: ____________________

Evapometer 24 hr start time:

Day / Date	Time	Evapometer Readings °C hrs Previous 24 hr value	Accumulated total	Tick if Acc. Tot. reset.	Rainfall mm since yesterday	Comments
Tue 10-May						
Wed 11-May						
Thu 12-May						
Fri 13-May						
Sat 14-May						
Sun 15-May						
Mon 16-May						
Tue 17-May						
Wed 18-May						
Thu 19-May						
Fri 20-May						
Sat 21-May						
Sun 22-May						
Mon 23-May						
Tue 24-May						
Wed 25-May						
Thu 26-May						
Fri 27-May						
Sat 28-May						
Sun 29-May						
Mon 30-May						
Tue 31-May						
Wed 1-Jun						
Thu 2-Jun						
Fri 3-Jun						
Sat 4-Jun						
Sun 5-Jun						
Mon 6-Jun						
Tue 7-Jun						
Wed 8-Jun						
Thu 9-Jun						
Fri 10-Jun						
Sat 11-Jun						
Sun 12-Jun						
Mon 13-Jun						
Tue 14-Jun						
Wed 15-Jun						
Thu 16-Jun						
Fri 17-Jun						
Sat 18-Jun						
Sun 19-Jun						
Mon 20-Jun						
Tue 21-Jun						
Wed 22-Jun						

WATER METER / IRRIGATION RECORD

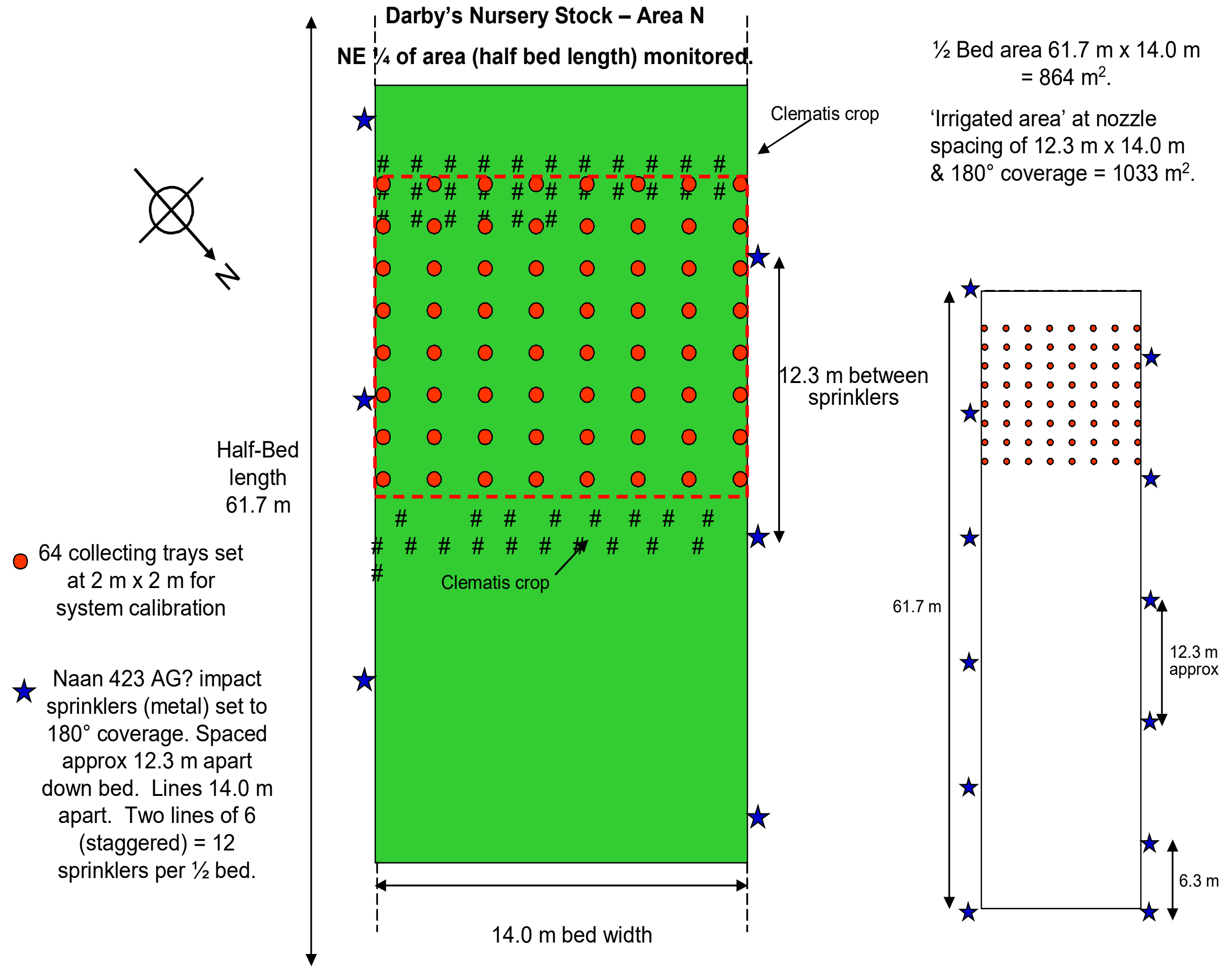
Nursery name: Bed identification:

Day / Date	Time	Water meter - litres	Comments e.g. irrgn notes, hand watering, crop size etc.
Tue 10-May			
Wed 11-May			
Thu 12-May			
Fri 13-May			
Sat 14-May			
Sun 15-May			
Mon 16-May			
Tue 17-May			
Wed 18-May			
Thu 19-May			
Fri 20-May			
Sat 21-May			
Sun 22-May			
Mon 23-May			
Tue 24-May			
Wed 25-May			
Thu 26-May			
Fri 27-May			
Sat 28-May			
Sun 29-May			
Mon 30-May			
Tue 31-May			
Wed 1-Jun			
Thu 2-Jun			
Fri 3-Jun			
Sat 4-Jun			
Sun 5-Jun			
Mon 6-Jun			
Tue 7-Jun			
Wed 8-Jun			
Thu 9-Jun			
Fri 10-Jun			
Sat 11-Jun			
Sun 12-Jun			
Mon 13-Jun			
Tue 14-Jun			
Wed 15-Jun			
Thu 16-Jun			
Fri 17-Jun			
Sat 18-Jun			
Sun 19-Jun			
Mon 20-Jun			
Tue 21-Jun			
Wed 22-Jun			
Thu 23-Jun			
Fri 24-Jun			
Sat 25-Jun			

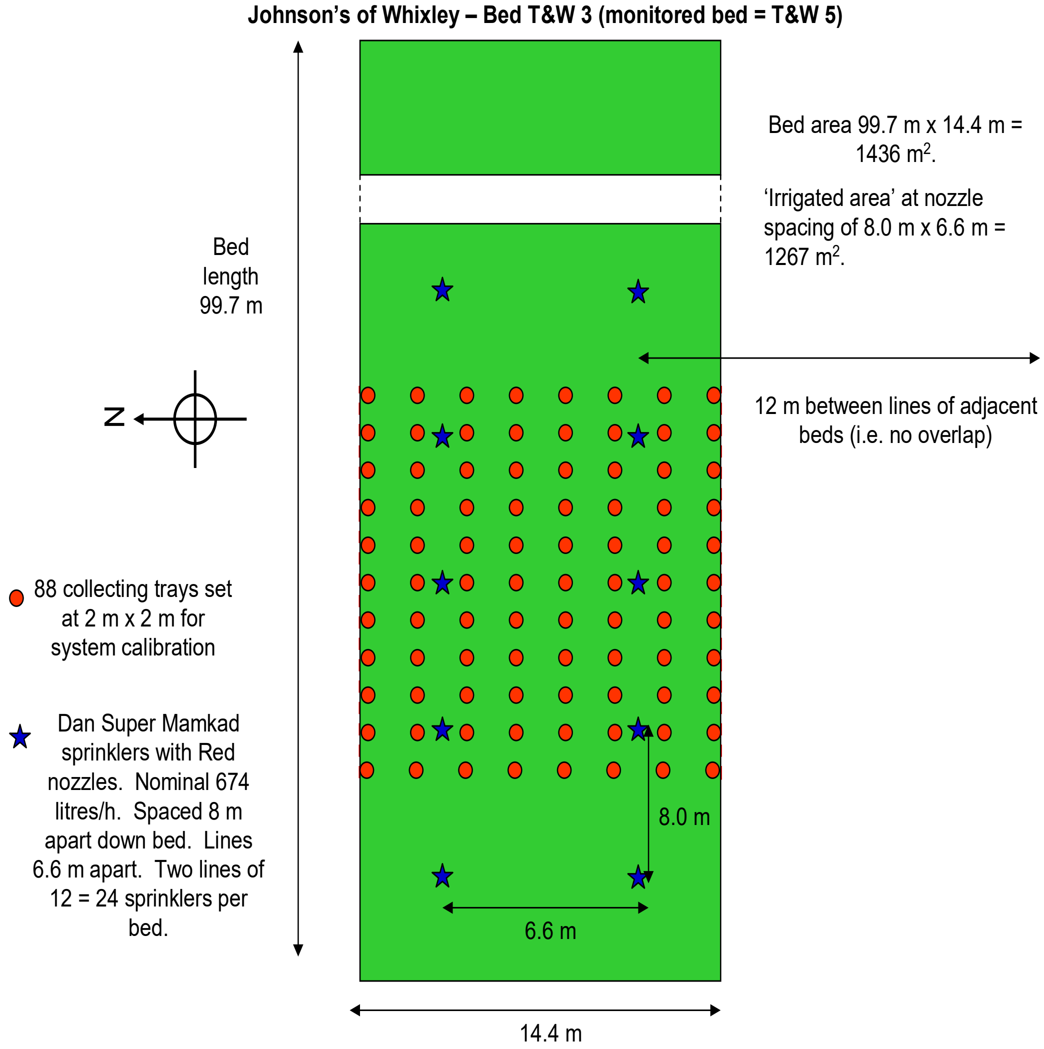
ANNEX IV

Collaborating nurseries site plans

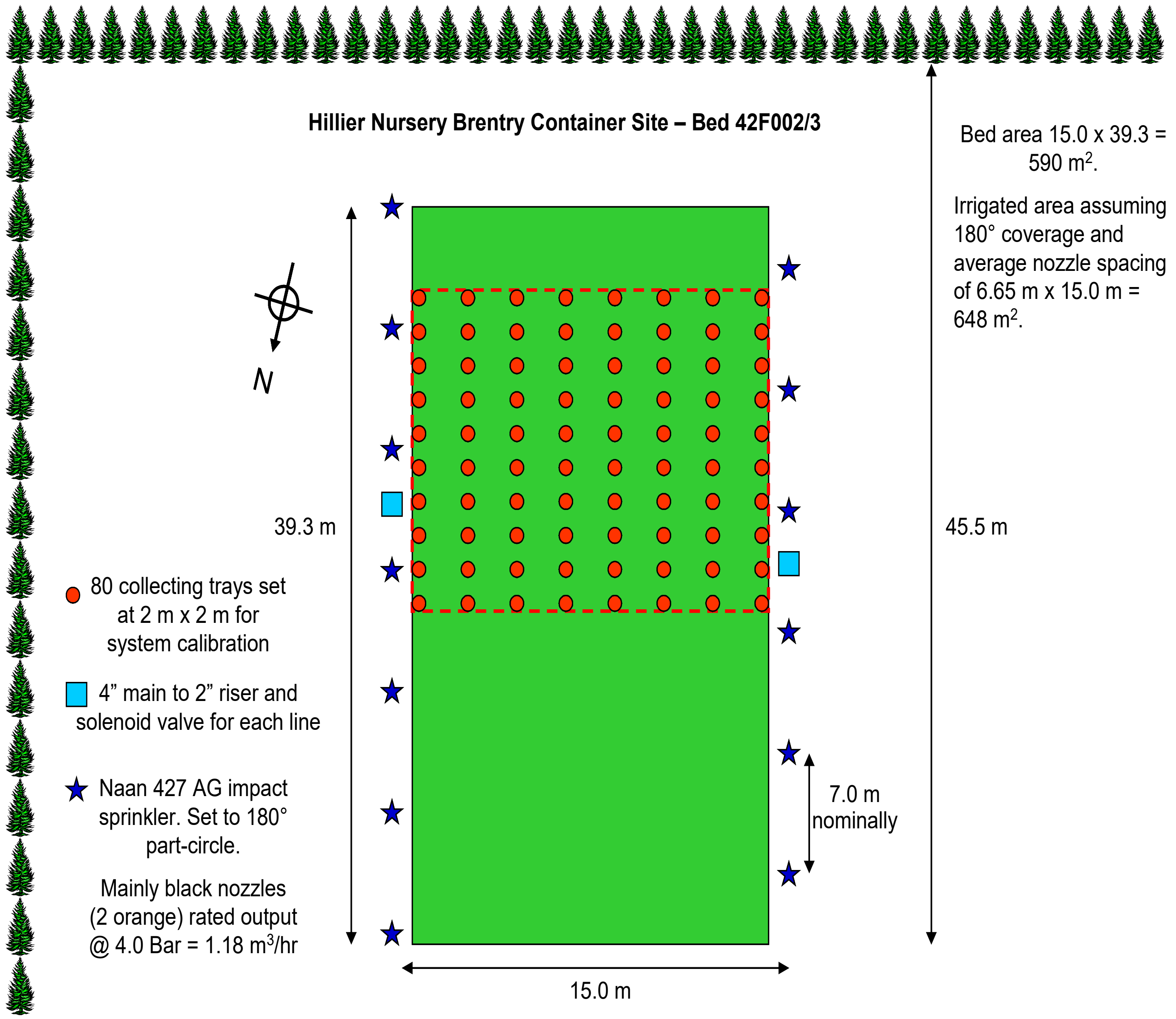
Darbys, Thetford, Norfolk



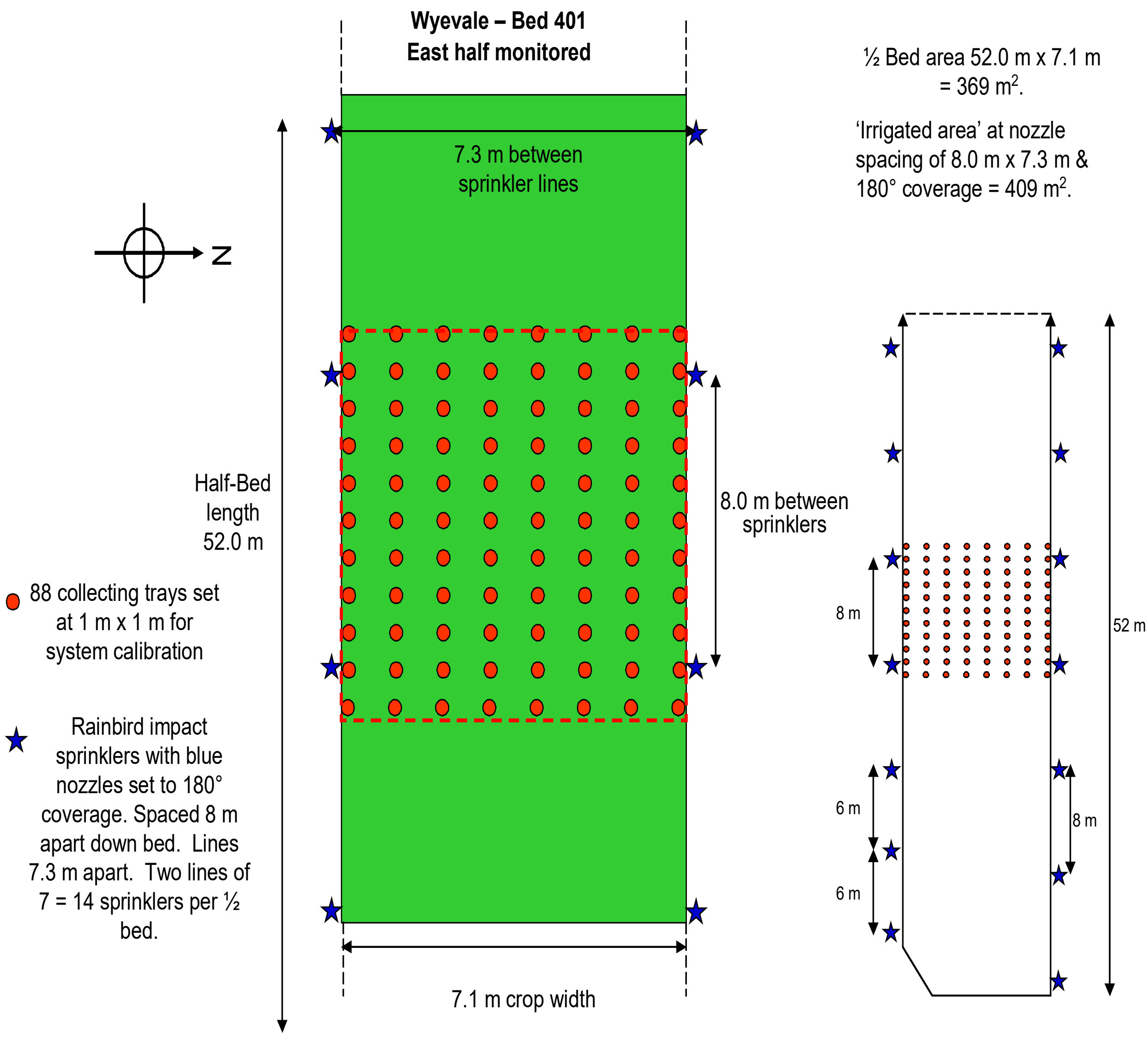
Johnsons of Whixley, Yorkshire



Hilliers, Brentry, Hampshire



Wyevale Nurseries, Hereford



W Godfrey & Sons, Lightwater, Surrey