Project title:	Container HNS Irrigation: Use of capillary matting under protection
Project number:	HNS 107
Project leader:	C M Burgess, HRI Efford (co-author of report)
Report:	Year 2 Annual Report
Previous reports:	Year 1 Annual Report 2000 / 01
Key workers:	Miss B Long, Project Assistant (co-author of report) Mr S Stagg, Nursery Staff Mr D Joblin, Nursery Staff Mr P Newnham, Site Engineering Supervisor Mr G Evans, Site Engineering
Location of Year 2 work:	Horticulture Research International Efford Lymington Hampshire SO41 0LZ Tel: 01590 673341 Fax: 01590 671553
Project co-ordinators:	Mr John Woodhead, Hillier Nurseries Ltd Mr John Adlam, Dove Associates
Date project commenced:	July 2000
Completion due:	July 2003
Key words:	Capillary matting, irrigation, nursery stock, container.

© 2002 Horticultural Development Council

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.

CONTENTS

GROWER SUMMARY

Headline

Construction and management factors have been identified for 'capillary flow beds' to work effectively with several different capillary mattings. Construction with an engineered 2% gradient across the bed is recommended, with irrigation lines spaced at 1.2m or less and hard-water supplies should be acidified for best results. Time-clock controlled irrigation is currently the most reliable method but needs regular adjustment to match demand. No particular capillary matting tested so far stands out as being clearly better or worse using the system tested, but each requires individual management of irrigation duration and frequency.

Background and Expected Deliverables

A number of capillary mattings are now available on the market; these have the potential to be used as a complete sub irrigation system to increase the efficiency of water usage and improve uniformity of water distribution. Although they are widely available, little independent research into their characteristics and properties has been undertaken. In view of the increase in container nursery stock now spending a proportion of the production cycle under protection, capillary matting may well have a role in achieving efficient irrigation.

Year 1 of this project examined the physical characteristics of capillary matting materials and the construction of a prototype 'capillary flow bed'. Year 1 has been completed and this report looks at the work studied in year 2 of the project.

The expected deliverables from Year 2 were:

1. Test the 'capillary flow bed' system using a range of capillary mattings with water supply operated by automatic and/or semi-automatic control.

2. Determine working tolerances for mattings, ie
   - Sensitivity to different gradients
   - Arrangement and outputs of Irrigation lines
   - Tolerance of "bumps and hollows"

3. Construct a larger scale 'capillary flow bed' under protection comparing this system to overhead sprinkler and Efford Sand Bed irrigation.

Summary of Year 2 Work and Main Conclusions

A number of experiments were carried out using an array of eight small scale 2.4 m x 1.2 m experimental test beds in a glasshouse. They were independently controllable for irrigation regimes and gradients. Automatic control of irrigation was tried using a 'Water Bug' controller (Flowering Plants Ltd) and also time-clock control of watering. *Sambucus* (deciduous) and *Hebe* (evergreen) were grown in 2.0 litre pots on the beds in experiments from October 2001 to July 2002.

Capillary flow bed construction

- A 'capillary flow bed' needs a slight gradient across its width to aid water distribution, to work effectively. This needs to be a reasonably accurately constructed 'engineered slope', although this need not be difficult or expensive to achieve on a raked and firmed soil base.

- A 1% gradient was too slight to improve the spread of water across the bed sufficiently, using the mattings and irrigation line arrangement tested. A gradient of 2% appeared suitable for a range of matting types. Limited tests showed mattings would probably work satisfactorily with a 3% gradient, although a steeper slope reduces the bed width possible using a continuous capillary layer to stay within the vertical lift ability of the mat. For example, a 50 mm lift capacity allows up to a 2.5 m width of bed with a 2% slope.

- The presence of small simulated 'bumps and hollows' of about 10 mm did not cause waterlogging or drying out of pots when tested with two matting types, Florimat 2 and Algon 2H. Tolerance to larger irregularities in the bed surface, and with different mattings, needs testing.

- Water distribution was not markedly affected by the use of either 'low flow' (2.5 litres/m/hr @ 0.55 bar) and 'high flow' (6.8 litres/m/hr) T-tape, although the closer spacing of the emitters on the narrower 'high flow' tape would be expected to be of benefit. Line spacing and arrangement on the bed is more important, and three lines for a 2.5 m width bed (i.e. 0.75 m - 1.0 m spacing) is recommended.

Management

- The use of timeclocks as a semi-automatic irrigation control worked well once plant and capillary matting requirements were established. It was concluded that timeclock control was the safest way of managing the irrigation on a 'capillary flow bed' in the short term pending further development of automatic control.

- In the experiments, it was found that reliable automatic control using the Water Bug device was difficult to achieve. There were specific problems with the device such as it tending to 'stick on' at high settings and cause the beds to flood for example, and this needs more investigation with the manufacturer. However, some problems may have been due to interactions with the other factors examined (bed gradient, line spacing, size of experimental beds etc.). Automatic control of capillary irrigation is a very attractive objective, because manual adjustment of timeclock settings according to the weather is a skilful and often frustrating task. For this reason it is worth pursuing some form of automatic control.

- Achieving a very wide latitude of growing medium wetness (ie running dry regimes or wide wet / dry cycles) does not appear realistic where capillary matting is being used as a primary irrigation system. This is likely to be the case whether automatic or timeclock irrigation control is employed, because of the difficulties of maintaining capillary contact or re-establishing it once broken.

- Mattings need to be wetted up fully and evenly at each watering to maximise effective and rapid uptake into containers. However, significant amounts of irrigation run-off usually means the bed is being run too wet.

- Of the mattings tested in Year 2; Florimat 2, Geobond 300g, SF-250, or Algon 2H or 4H; none were identified as clearly 'better' or 'worse' for nursery stock on the system tested. However, the management of irrigation regimes will need tailoring to individual mattings. Further evaluation is continuing, but matting durability, maintenance and replacement costs will also be factors in determining grower's choice.

- Hard water and fertiliser deposits can rapidly build up on mattings under protection causing them to become water repellant. Acidifying irrigation water to reduce bicarbonate content is recommended.

- Maintaining capillary contact between growing medium and matting is an essential aspect of using a 'capillary flow bed'. The use of a layer such as Mypex over mattings such as Florimat or SF-250, is necessary to give a durable surface to withstand the handling of nursery stock containers, sweeping up debris etc. However, mattings need to be run wetter to avoid losing capillary contact. There must also be sufficient holes in the base of the pot in close contact with the bed, and excessive lifting or re-positioning of pots should be avoided when they or the matting is not well watered.

- Ongoing work on a larger scale under protection is comparing capillary flow beds with Efford Sand Beds and overhead irrigation on gravel, for water consumption and uniformity. Early indications are that water use can be as efficient as with sand beds.

Financial Benefits

The capillary flow bed system offers many of the advantages of an Efford Sand Bed for use under protection, but at a lower capital and set-up cost. Nevertheless, construction and management of capillary beds needs to be carried out with care and attention to detail for good results.

Comparative costs of components of the system, including matting materials, will be considered in the final report.

Action Points for Growers

- It is important to distinguish between the use of capillary matting as a 'secondary' water distribution aid (e.g. to help redistribute surplus water that is otherwise applied by hand or sprinklers from above), and an accurate primary irrigation system to achieve uniform and efficient watering.

- Consider use of capillary flow bed irrigation under protection, where sufficiently large blocks of nursery stock subjects, with similar water demand can be linked to a bed area. This method of sub-irrigation will be particularly appropriate where maximum efficiency of water use is desired, or for subjects where overhead irrigation can encourage disease, affect leaf or flower quality, but where site or financial constraints rule out Efford Drained Sand Beds.

- Unlike Efford Drained Sand Beds, capillary flow beds do not need a dead level site, but they need to be constructed and managed carefully within tolerances as described above.

SCIENCE SECTION

1 INTRODUCTION

Capillary matting irrigation under protection is used widely for watering pot and bedding plants and as a 'secondary distribution system' for overhead watering by hand or sprinklers but is not yet widely used as a primary method of irrigation for container grown nursery stock. A number of capillary mattings are now available on the market; these have the potential to be used as a complete sub irrigation system to increase the efficiency of water use and improve uniformity of water distribution. Although they are widely available, little independent research has been done into the characteristics and properties of different mattings, nor their application for hardy nursery stock.

Sub-irrigation using Efford sand beds is a well proven technique for HNS, both outdoors and under protection, and historical data indicate water savings of at least 50 - 70% compared to overhead irrigation. However, sand beds are relatively costly to set up. Capillary matting systems have most potential under protection, where waterlogging from winter rainfall is not an issue. It is timely because an increasing proportion of nursery stock now spends some of the production cycle under cover.

The project is now in its second year of work and has followed on from the preliminary investigations in Year 1.

The first annual report (Year 1 - 2000 / 01) examined some physical characteristics of capillary matting materials:

- Standard DIN tests for fabrics were used to examine the water holding capacity and the vertical lift of a number of mattings. The visual test for capillary rise was difficult to apply to dark coloured mattings, and there were some significant discrepancies between our results and those quoted by fabric suppliers. Despite these limitations, there was a trend towards water holding capacity being inversely proportional to capillary rise, i.e. that mattings with a high water holding capacity tended to have low capillary rise and vice versa.

- The movement of water between mattings and containers was studied. A method was devised to test both water distribution laterally through the mat and also the delivery of water from the matting into the pot. From using this method the results showed the addition of a permeable ground cover layer (e.g. Mypex or Tex-R), which would be necessary for ground level nursery stock beds, could affect the ability to maintain capillary contact between container and matting, particularly with smaller containers.

- A small prototype 'capillary flow bed' was constructed and showed it was possible to successfully maintain reasonably uniform irrigation to containers over a period of three months. However manual adjustment of time clock control was required according to the weather, and some spot watering of pots on bed edges was necessary. The capillary flow bed technique was first described by Dr Volker Behrens, Geisenheim Institute, Germany (Behrens, 1996). Water is supplied by a trickle or drip line to the upper edge of matting on a gently sloped bed. Gravity helps ensure even distribution of the water across the mat down a 1% - 2% slope, while capillary pull up the slope ensures the mat retains some water. Surplus water runs off the mat into a gutter and can be collected. In the variation examined in this project a slope across the bed, rather than down the bed, was used.

OBJECTIVES

In the second year of the project the objectives were to:

- Test the 'capillary flow bed' system using a range of capillary mattings with water supply operated by automatic and/or semi-automatic control.

- Determine working tolerances for mattings.
  - Sensitivity to different gradients
  - Irrigation lines
  - Tolerance of "bumps and hollows"

- Construct a larger scale 'capillary flow bed' under protection comparing this system to overhead and sand bed irrigation.

GENERAL MATERIALS AND METHODS

3.1 'Capillary flow bed' construction and operation

A capillary flow bed prototype was constructed and developed in Year 1 as a practical irrigation and growing system for HNS under protection. This prototype was then used in Year 2 to construct a total of 8 replicate capillary flow beds.

The 8 capillary flow beds were constructed using 2.4 m x 1.2 m sheets of board supported on a tubular steel framework. It was necessary to reinforce these boards underneath with timber struts and wire cable 'bow bracing' to prevent the boards sagging under the weight of the containers. A sheet of white-on-black polythene was used to seal the bench tops. The steel framework incorporated nut and bolt adjusters along one of the 1.2 m bed edges so the boards could be set on a slope or levelled. A gutter was fixed along the lower 1.2m edge so run-off water could be collected. A T-Tape irrigation line (type 506-20-250) was used across the top (before the first row of pots) and the middle of the bed (after the fifth row of pots). An additional shorter length of T-Tape running into a bucket under the bed was used to record the amount of water applied. Emitters were spaced at 200 mm with the stated flow rate of 2.5 litres/hr/m at 0.55 bar. This gave a total of 12 emitters per bed with a theoretical water delivery of 6 litres/hr or 2.1 litres/m^2/hr (2 mm/hr). Initially the irrigation lines were positioned underneath the capillary mattings.

Capillary matting types included in Year 2 of project

Supplier	Type	Composition
Flowering Plants	Florimat 2 – 'Middle weight'	Synthetic. Black
Tildenet	Geobond 300g	Synthetic / wool blend. White but with bonded black geotextile top layer
Fibertex	SF-250	Synthetic.(Polypropylene/ Polyester/Viscose blends). Grey.
Anglo Felt Ind. Ltd via Geerings	Algon 2H Algon 4H	Wool based. Black with non-woven bonded top layer

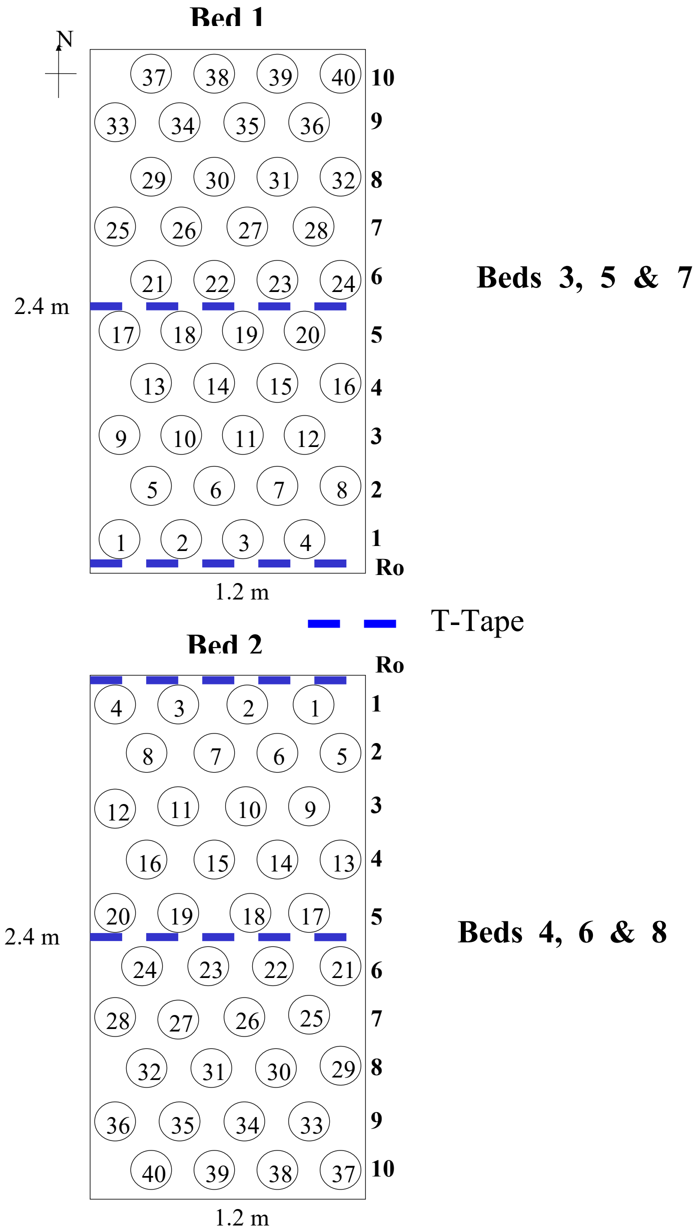
In each case Florimat 2 and SF-250 were used with Mypex 'Red Stripe' ground cover layer over the matting.

After initial observations, the second line of T-tape lines was moved down to after the 6th row of pots, to make sure the bottom of the mat did not dry out. The T-tape lines were also placed on top of the matting as sometimes water channelled down the polythene covered base before the matting at the top of the slope had absorbed it, and that the first row of pots failed to be watered effectively.

From the 5/10/01 – 21/11/01 *Sambucus nigra* 'Black Beauty' plants in 2 litre pots were set out on the bed. From the 22/11/01 onwards *Hebe* 'Mrs Winder' in 2 litre pots replaced the *Sambucus* because a plant species was needed that would continue to grow over the winter months. These were bought in as well established plants in 2 litre containers. The *Hebe* had become large and bushy by mid February 2002, and were pruned back hard so they could be used for further experiments in spring and summer.

There were 10 rows of pots spaced ~ 25cm apart with each row containing 4 pots spaced ~ 30cm apart. So in total, each test bed held 40 plants. This total number of plants decreased to 35 plants when Algon 2H and Algon 4H mattings were tested because these mattings came in a narrower width. There were 4 replicates of the beds on the north side and 4 replicates on the south side of the glasshouse. The bed gradients sloped down from the irrigation feed across the centre of the house to the north or south. Each experimental bed thus represented a cross-section of a 2.4 m wide full size bed running E-W and with a gradient across its width.

Arrangement of experimental capillary flow beds in glasshouse



Mains water was used for irrigation which required acidification to minimise hard water deposits in the capillary mats. A water analysis showed that sufficient bicarbonate was neutralised with a target pH set at 6.2. Water was acidified with nitric acid via an automatic dosing system and held in a tank. A pump and pressure release valve set to 0.55 Bar (approx 8 psi) was used to create a pressurised 'ring main' around the glasshouse from which water to each bed was supplied via individual solenoid valves. This ring main system was necessary to cope with the low flow rates of the small experimental beds and ensure T-Tape pressures remained constant irrespective of how many beds might be irrigated at one time.

The 24v AC solenoid valve on each bed were linked to individually programmable channels on electronic timeclocks, however, automatic irrigation of the 8 beds using proprietary control devices was tried initially from 5/10/01 – 6/02/02 (see 4.1.1 below). From 6/02/02 onwards the irrigation was controlled by the time clocks, and manually adjusted according to the water status of the plants and mattings unless stated otherwise.

The glasshouse compartment was heated to 15 ºC over winter to maintain growth and active transpiration in the *Hebe* crop. Venting throughout the year was set to 18 ºC.

General recording procedure

Pots were weighed during each experiment as a way of recording the weight gain or loss of the pot. On each record, pots from the top (row 1), upper middle (row 4), lower middle (row 7) and bottom (row 10) were weighed.

Water meters capable of recording the very low flow rates to each bed were not available, so the quantity of applied water was estimated by recording the water collected from a third length of T-Tape held under the benches in a pipe running into a bucket. Any surplus run-off water from the gutter at the low edge of the bed was also collected and recorded.

4. EXPERIMENT REPORTS

A series of experiments were undertaken in Year 2 to address the overall objectives set out in Section 2 above. The key findings are reported here under main topic headings, drawing on appropriate results from several experiments rather than presenting a chronological account of each trial.

4.1 Irrigation Control Systems

4.1.1 Automatic Irrigation Using 'Water Bugs'

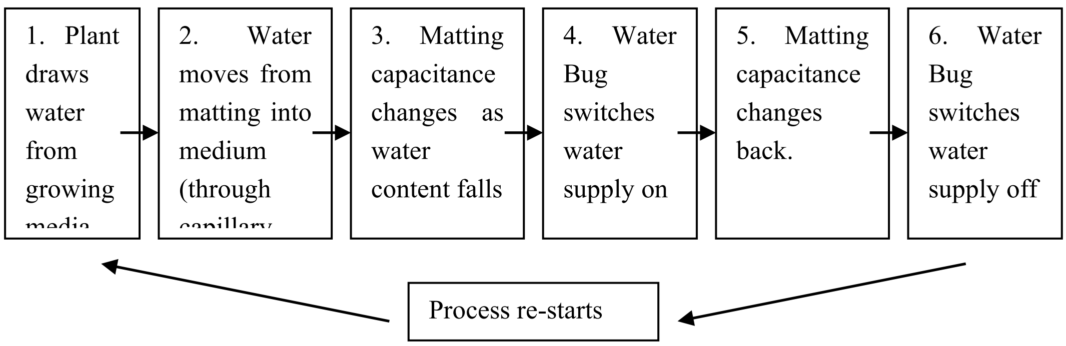
Objective

Test the capillary flow bed system using a range of capillary mattings with irrigation controlled automatically.

Following experience with the single prototype bed at the end of Year 1, fully automatic irrigation control was tried in the early stages of Year 2. This attempted to minimise or eliminate envisaged difficulties of manually adjusting irrigation requirements of 8 treatment / replicate beds individually and in conjunction with the weather. The aim was that if irrigation to suit the needs of the plant could be adjusted for each bed using suitable controllers, water use and uniformity of irrigation using different mattings or other treatments on different beds could be recorded and compared on a standard basis. Type M 'Water Bug' controllers (Flowering Plants Ltd) designed for use with capillary matting and sand beds were installed on each bed linked to each solenoid valve (Appendix, Photo 1).

The Water Bug electronically detects the wetness of capillary matting upon which it is placed, by measuring its 'dielectric constant' or 'capacitance'. The capacitance of the matting changes according to the ratio of water to air held within it. The Water Bug is designed switch on or off the water supply to the matting automatically, according to levels set on 'Min' (0 - 100% scale) and 'Max' (0 - 10 scale) dials. Once calibrated for a crop, in theory it should be possible to set wet or dry regimes, or regimes with a wide or narrow wet/dry cycle. The flow diagram below illustrates the basic process.

<u>Action of Water Bug</u>



Materials and Method

8 capillary flow beds were used for the following experiments involving Water Bugs:

Experiment 1

1) Objective : Compare 2 matting types at 2% flow bed gradient
2) Matting types tested :
    1. Geobond
    2. Florimat 2 and Mypex
3) Flow bed gradient : 2%
4) Water supply control system : Water Bugs
5) Subject : *Sambucus*
6) Trial Design : Randomised block x 4 replicates
7) Dates of experimentation : 5/10/01 – 5/11/01

Experiment 2

1) Objective : Compare 2 matting types at 1% flow bed gradient
2) Matting types tested :
    1. Geobond
    2. Florimat 2 and Mypex
3) Flow bed gradient : 1%
4) Water supply control system : Water Bugs
5) Subject : *Sambucus*
6) Trial Design : Randomised block x 4 replicates
7) Dates of experimentation : 7/11/01 – 13/11/01

Experiment 3

1) Objective : Compare 2 matting types at 1% flow bed gradient
2) Matting types tested :
    1. Geobond
    2. Florimat 2 and Mypex
3) Flow bed gradient : 1%
4) Water supply control system : Water Bugs
5) Subject : *Hebes*
6) Trial Design : Randomised block x 4 replicates
7) Dates of experimentation : 22/11/01 – 30/11/01

Experiment 4

1) Objective : Compare 4 matting types at 2% flow bed gradient
2) Matting types tested :
    1. Florimat 2 and Mypex
    2. Algon 4H
    3. Algon 2H
    4. SF-250 and Mypex
3) Flow bed gradient : 2%
4) Water supply control system : Water Bugs
5) Subject : *Hebes*
6) Trail Design : Randomised block x 2 replicates
7) Dates of experimentation : 24/01/02 – 6/02/02

<u>Assessment Methods</u>

Measurement of the following parameters were used as the key assessment methods:

1. Applied water
2. Run-off water
3. Pots from the top (row 1), upper middle (row 4), lower middle (row 7) and bottom (row 10) were weighed.

Results

Experiment 1: Compare 2 matting types at 2% flow bed gradient.

The Water Bugs were placed adjacent to the 3rd – 4th row of plants down from the top of the bed as recommended by the supplier. Water Bugs were calibrated for each bed so all beds had their own individual settings. This was necessary to account both for minor deviations in each unit's internal calibration as well as treatment and positional factors between beds. The Water Bugs were then adjusted over the next few weeks depending on the dryness/wettness of the plants and mattings.

Some capillary mattings seemed to be running well during the experiment but on others dry patches were occurring. Part of this was due to problems with 'water channelling' under the matting and apparent hydrophobic patches, (see section 4.3.1). However, some controller settings also appeared too low to begin with.

The Water Bug dials were found to be very sensitive, especially the Max dial, which determined how wet the matting became before switching off. On some beds, increasing this setting caused the Water Bugs to 'stick on' leading to flooding of the matting and a large amount of run-off.

This problem of the Water Bugs sticking on lead to further experiments (experiments 2 and 3) being carried out where the Water Bug Max dial was turned up gradually over several days.

Experiment 2 : Compare 2 matting types at 1% flow bed gradient

Figure 1 shows the results of increasing the dial settings by one unit on two occasions on the amount of water applied per day per bed. Quantities of water of 30 litres / bed or over represents flooding. Flooding occurred on one replicate on 9 November, but moderate amounts of water were supplied the following two days. Following a further increase by one unit on 11 Nov, three of the four replicate beds flooded.

Figure 1, Experiment 2

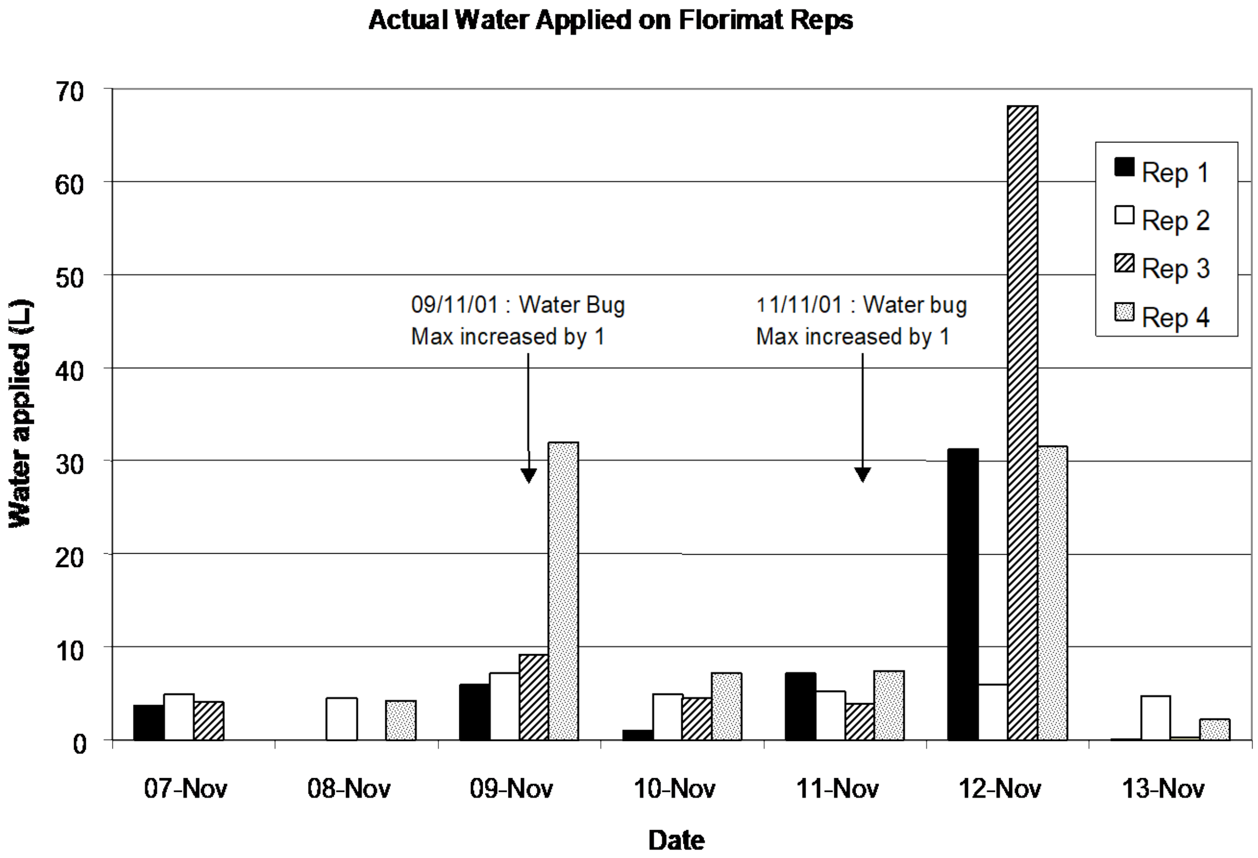
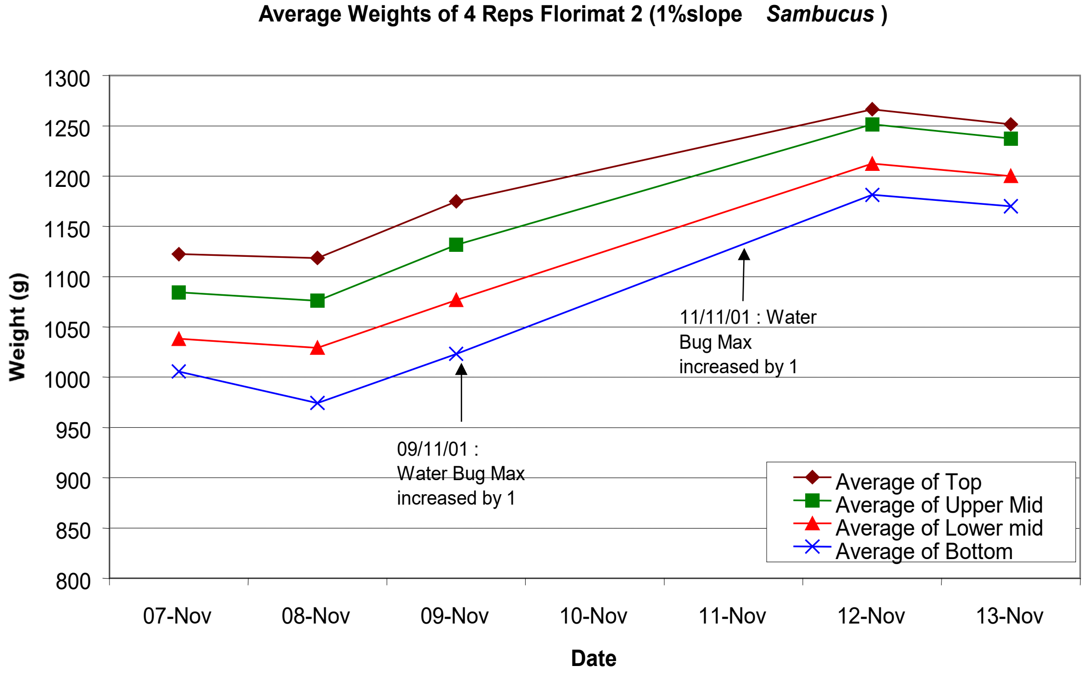


Figure 2 covers the same period as Figure 1, and illustrates the mean total weights of plant + growing media + pots for different sections of the bed. For both Florimat 2 and Geobond matting types, pots on the bottom of the slope were gradually becoming too dry and lost weight, necessitating an increase in Water Bug settings, although this was more marked for Florimat 2 on the 1% slope (see section 4.2.1). The pots at the bottom of the slope were losing weight at the original setting (7 Nov) and increased in weight slightly when the Water Bug Max setting was increased by 1 unit on 9 Nov. Pots were not gaining weight sufficiently by 11 Nov however so settings were increased by a further 1 unit, and the flooding that followed caused the weight gain shown on 12 Nov.

Figure 2, Experiment 2



Experiment 3 : Compare 2 matting types at 1% flow bed gradient

Hebe replaced *Sambucus* for Experiment 3, but otherwise matting treatments and bed gradient settings were the same as for Experiment 2. Experiment 3 was carried out with the same Water Bug settings with the same increase over the recording period as Experiment 2, and the pot weights followed a similar trend. Again, plants on both Geobond and Florimat 2 beds showed decreases in the weights of the pots at the 'low' and 'medium' settings and in some instances became very light/dry. On the 'high' setting, several beds 'stuck on' and flooded. Absolute settings for the Max dial were 6-7.5 for 'low', 7-8.5 for 'medium' and 8-9.5 for 'high'. The ranges within each level reflected the different calibrations appropriate for each controller and the two matting types.

Experiment 4 : Compare 4 matting types at 2% flow gradient

In Experiment 4, four mattings were compared using a steeper 2% gradient. At this time in late January / early February, light levels and plant size were increasing, resulting in greater water demand. The Water Bugs were adjusted to try to meet this demand without them 'sticking on' and overwatering. It was found that it was easier to manage the Water Bug controllers to give even watering on the Algon 2H and 4H mattings which had an integral bonded surface layer than the Florimat 2 and SF-250 mattings with their Mypex surface layer (see also section 4.3.2). Some hand watering of pots on the bottom row of the bed which was furthest from the T-Tape lines was required with the latter two matting types (Figure 3). Over the period of this experiment, the two Algon mattings maintained heavier but even pot weights despite being on 'low' to 'medium' Water Bug settings (Figure 4).

Figure 3, Experiment 4

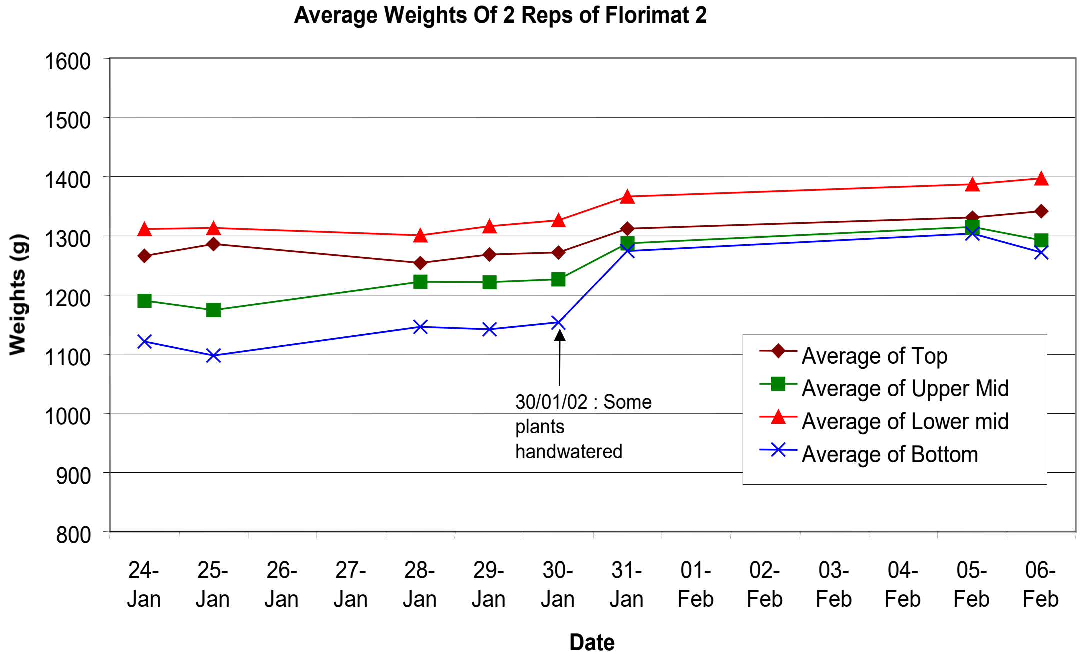
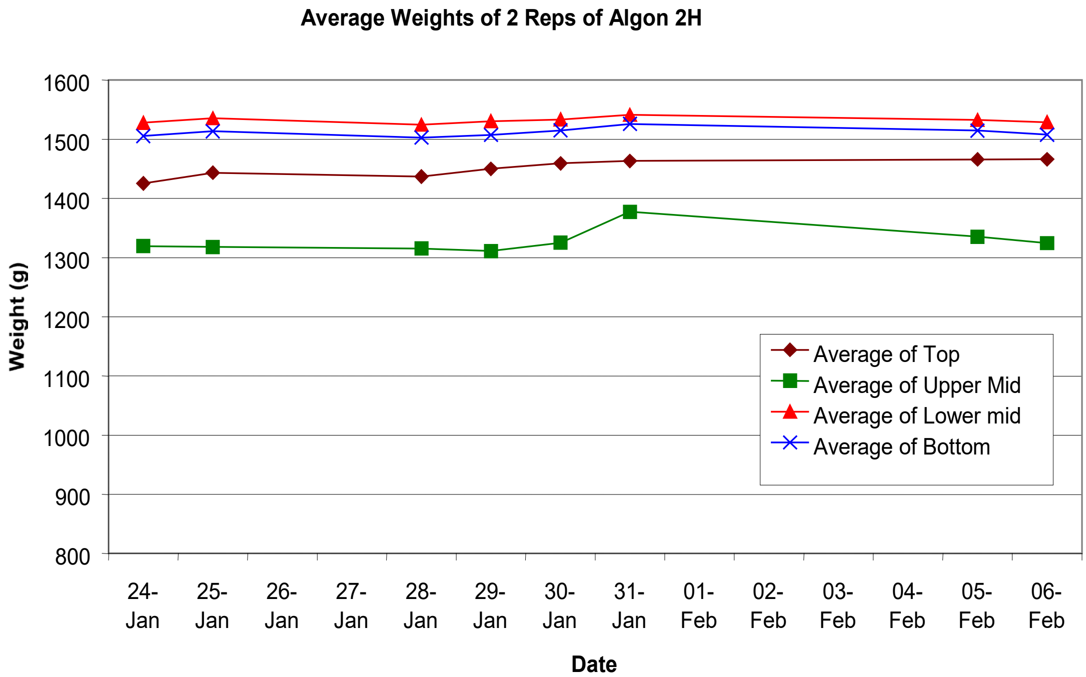


Figure 4, Experiment 4



Discussion

In most of the experiments it was found that the settings of the Water Bugs had to be quite high to wet the mat up sufficiently. However, these high settings lead to a tendency to 'stick on' and flood the bed, with a very fine line between under and over watering. Some of the early problems were possibly due to insufficient initial soaking up of the mattings, but even when mattings had been fully saturated, there were still operational difficulties.

It is also possible that these devices were not well suited to the small size of the test beds. Although uniform irrigation might be expected to be easier to achieve over a small area, the high proportion of plants near the bed edge compared to the centre for example might make this more difficult.

Although details are not reported here, some observations were made after moving the Water Bugs to different areas of the matting (ie closer or further from the irrigation lines), but this did not improve control.

It is difficult to draw reliable conclusions about the relative performance of mattings with Water Bugs from these results. It is true that more pots on Florimat 2 and SF-250 with the Mypex layer did tend to suffer from more drying out than those on the Algon mattings, but this may have been due more to differences in maintaining capillary contact (see Section 4.3.2) than the operation of the Water Bugs *per se*. What was clear, though, is that these experiments did not demonstrate the ability to achieve automatic control of a wide range of irrigation regimes (e.g. running crops with a large wet / dry cycle) using this device on capillary matting.

4.1.2 Semi-Automatic Irrigation Using Timeclock Control

Objective

Test the 'capillary flow bed' system using a range of capillary mattings with water supply operated by semi-automatic control.

Materials and Method

8 capillary flow beds were used for the following experiments with timeclock control:

Experiment 1

1) Objective : Compare 4 matting types at 2% flow bed gradient using T-Tape applying 2 mm/hr.
2) Matting types tested :
    1. Florimat 2 and Mypex
    2. Algon 4H
    3. Algon 2H
    4. SF-250 and Mypex
3) Flow bed gradient : 2%
4) Water supply control system : Timeclocks

   Settings:
    1. 9:30 – 9:50am, 13:00 – 13:20pm, 17:00 – 17:20pm (27 - 28 Feb) (2 mm / day)
    2. 9:30 – 9:40am, 13:00 – 13:10pm, 17:00 – 17:10pm (1 - 11 Mar) (1 mm / day)
    3. 9:30 – 9:35am, 13:00 – 13:05pm, 17:00 – 17:05pm (12 - 15 Mar) (0.5 mm / day)
5) Subject : *Hebes*
6) Trial design : Randomised block x 2 replicates
7) Dates of experimentation : 27/02/02 – 15/03/02

Experiment 2

1) Objective : Compare 4 matting types at 2% flow bed gradient using higher output T-Tape applying 5 mm/hr
2) Matting types tested :
    1. Florimat 2 and Mypex
    2. Algon 4H
    3. Algon 2H
    4. SF-250 and Mypex
3) Flow bed gradient : 2%
4) Water supply control system : Timeclocks

   Settings adjusted with weather and plant / matting requirements:

Florimat 2 + Mypex	1.8 - 2.5 mm/day
Algon 4H	1.7 - 2.3 mm/day
Algon 2H	2.1 - 2.7 mm/day
SF-250	1.7 - 2.3 mm/day

5) Subject : *Hebes*

6) Trial design : Randomised block x 2 replicates
7) Dates of experimentation: 25/06/02 – 16/07/02

Assessment Methods

Measurement of the following parameters were used as the key assessment methods:
1. Applied water
2. Run-off water
3. Pots from the top (row 1), upper middle (row 4), lower middle (row 7) and bottom (row 10) were weighed twice a day. Once in the morning and once in the afternoon.

Results

Experiment 1 Objective: Compare 4 matting types at 2% flow bed gradient using T-Tape applying 2 mm/hr.

To begin with, the timeclocks for all beds were set at 3 x 20 minute watering per day (setting 1). At an application rate of about 2 mm/hr this was equivalent to about 2.0 mm/day. This proved excessive. All pots became fully wet and the mats were saturated, with large amounts of surplus run-off from the capillary beds. The daily run-off is illustrated in Figure 5; gaps are present for days when there was no record taken, but the accumulated run-off was subsequently recorded (i.e. 7 Mar and 12 Mar).

The timeclocks were changed to 3 x 10 minute watering per day (setting 2 = 1 mm/day) for all beds from 1 March. Surplus run-off was reduced, although pots remained fully wet. Pots were also too wet at the bottom of the slope than the top (particularly with the thicker mats such as Algon 4H – Figure 6). The weather from 27 February - 11 March during settings 1 & 2 was sunny, but because the *Hebe* had been pruned about 2 weeks prior to the start of the experiment, overall water requirement was still less than that required.

Figure 5, Experiment 1

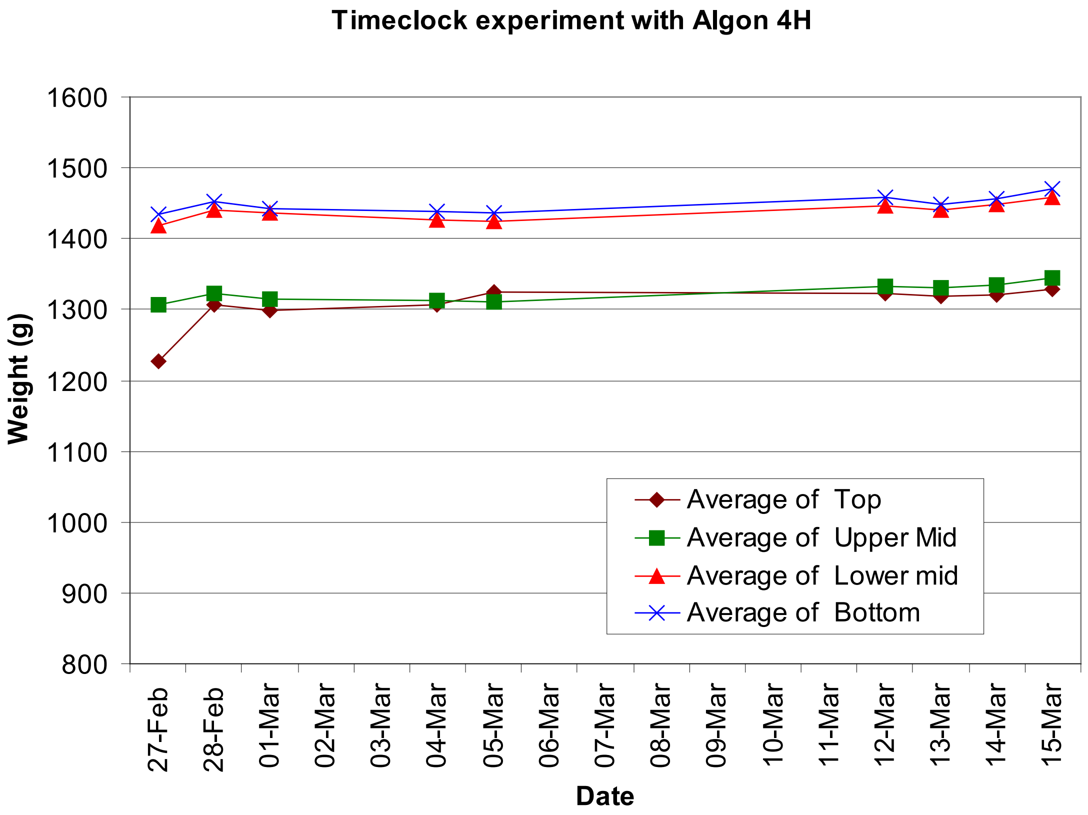
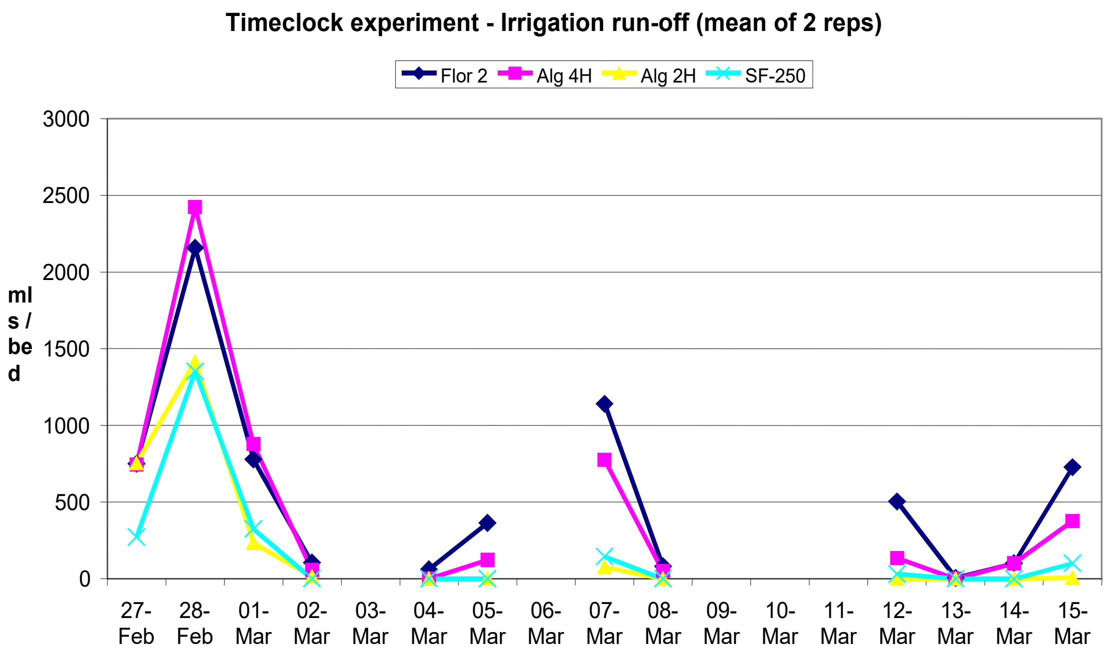


Figure 6, Experiment 1



Irrigation was further reduced to setting 3 (3 x 5 minutes per day equivalent to about 0.5 mm/day) on 12 March. The weather also became overcast during this period, so plant water demand was further reduced. With the reservoir of water in the media and matting from the previous settings, pots weights remained fairly constant, and no drying out of either the mattings, nor pots occurred over this period of dull weather to the end of this assessment period. Because pots did not dry down much between waterings, even this low level of irrigation was slightly excessive, with small amounts of run-off.

Experiment 2 Objective: Compare 4 matting types at 2% flow bed gradient using higher output T-Tape applying 5 mm/hr.

This experiment ran during the summer with larger *Hebe* plants with a higher water demand than in Experiment 1. The type of T-Tape used had been changed by this point to a higher output version (see Section 4.2.2), and irrigation times per day had been adjusted accordingly. Figures 7 and 8 illustrate average pot weights and amount of run-off for each of the four mattings used over the recorded period. The weather was generally bright at the start, and there was little surplus run-off from beds. However, irrigation settings were insufficient for the Florimat 2 beds and some plants were drying out and needed hand watering on 27 June, and the irrigation setting was also increased for this treatment on 2 July. At this time the weather turned dull for a period with some intermittent sunny periods. Irrigation times for all treatments were reduced slightly on 5 July, but some plants, particularly on the Algon mattings, remained too wet (1500+ g). There was some runoff from all treatments over this middle period. The irrigation was switched off completely for two days on 8 and 9 July to allow plants to dry back. Watering was resumed on 10 July and was increased slightly the following day back to 2 July levels. Pot weights and moisture content of media remained at suitable levels for the Algon 2H / 4H and Florimat 2 + Mypex treatments over this period, but pots on the SF-250 + Mypex beds were dryer and a few did require some spot watering. Surplus irrigation runoff was low for the final period of the experiment.

Figure 7, Experiment 2

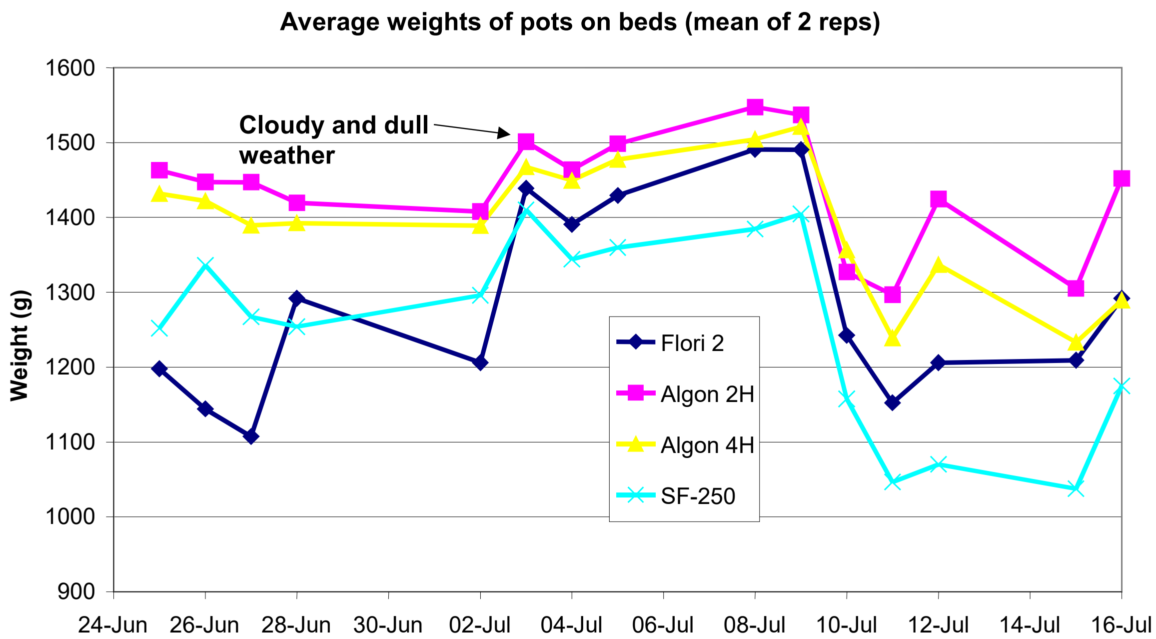
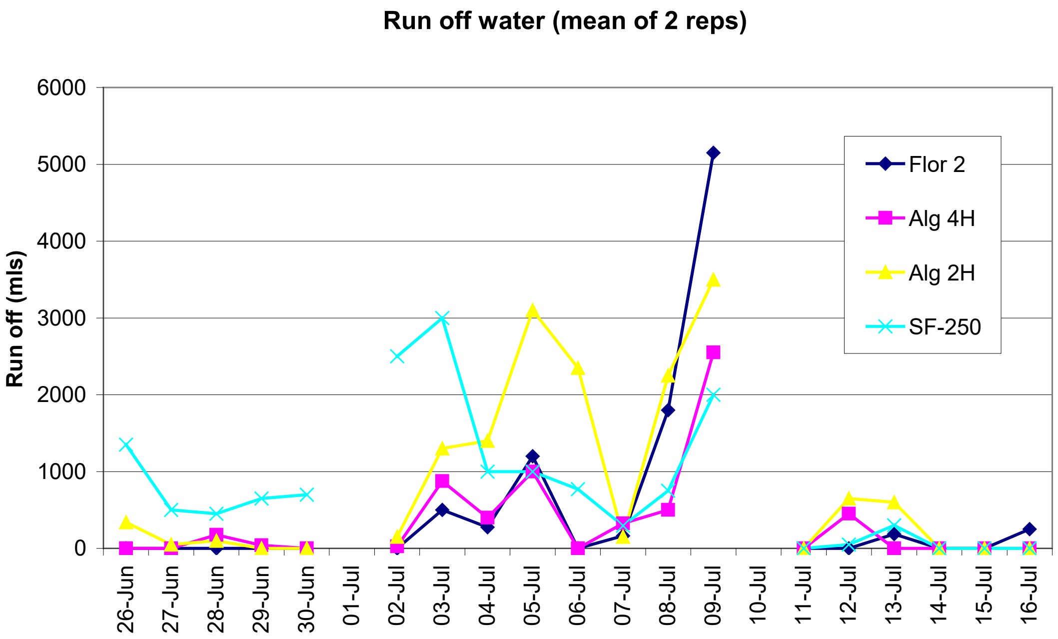


Figure 8, Experiment 2



Discussion

Timeclocks appeared to be more reliable than Water Bugs for irrigating these small-scale experimental units, although the results from both timeclock experiments showed that regular checking and adjustment of settings to suit matting types and the weather was necessary. The Algon mattings maintained wetter pots overall in these experiments, with little drying out, but also some ‘overwet’ pots compared to Florimat and SF-250. It is not possible to separate the influence of the Mypex layer used with these mattings (see Section 4.3.2) from the characteristics of the materials themselves from this experiment. Although not tested in these experiments, it is also possible that thinner mattings such as Florimat 2 and Algon 2H would be managed best with a ‘little and often’ irrigation to keep them more uniformly moist and avoid drying out. Thicker mats, such Algon 4H may be managed best with higher doses of water less frequently.

It is intended that the Water Bug controllers will be re-examined in comparison with timeclock controllers when other operational factors affecting management of the capillary beds have been sorted out.

4.1.3 Measurements of Water Use

In all the experiments carried out the water applied to the matting and the run-off water were recorded with the intention that water use for different capillary matting types could be determined. However, there were a several problems that made it difficult to directly measure water use reliably.

Firstly, the test beds were small with very low flow rates so accurate water meters could not be used. The extra trickle line assembled under the bed, which ran into a bucket, gave a reasonable indication of water use. But even with identical timeclock settings there could be variability of up to 20% or more between volumes collected from different beds. Secondly, the timings of irrigation applications when being controlled by Water Bugs varied between beds which meant that estimates of water use could only be averaged over a long period. This was not possible with the short periods between changing settings during the experiments. Any periods when the controllers 'stuck on' and caused flooding also rendered the records invalid.

With timeclock control also, it was difficult to achieve a long enough period of stable and consistent water use across test beds where plants were neither too wet nor dry across sufficient beds simultaneously to make very reliable comparisons. It is expected that this should be easier with larger scale experiments where fewer beds are being managed and compared at once.

Despite not being able to compare mattings reliably for water use using direct measurments, it was possible to get an indication of the range of rates used based on the stated output of the T-Tape lines and timeclock records. Water use from a crop of well developed *Hebe* in 2 litre containers in summer was up to about 2.5 mm/day in sunny conditions. Early in the year with recently pruned plants, water use was less than 1 mm/day when sunny and less than 0.5 mm/day when overcast. These figures are considerably lower than is typical from crops under overhead systems outdoors in summer where irrigation need is typically at least 5 mm/day when sunny.

4.2 Working Tolerances

4.2.1 Effect of Gradient and "Bumps and Hollows" on Water Distribution

Objective

Determine working tolerances for mattings.

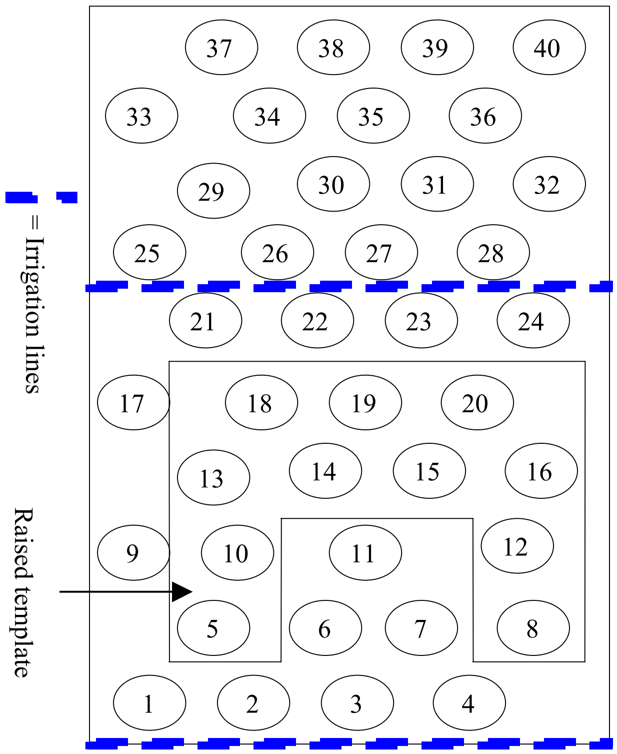
- Sensitivity to different bed gradients
- Tolerance to 'bumps and hollows'

Materials and Method

When constructing a 'capillary flow bed' a very gentle slope is used to help both even distribution of water and to remove any surplus water. The prototype bed used at the end of Year 1 (2000/1) had a 2% gradient. This was equivalent to a 50 mm fall across a bed 2.5 m wide. It was important to assess how critical this gradient needed to be using this flow bed system, so 1% and 3% gradients were also trialled.

Beds would also typically be constructed from raked and levelled soil / sand which was liable to some settling. Thus, the tolerance of different mattings to slight imperfections in the bed, without causing dry spots or waterlogged hollows, needed to be tested. To do this, horseshoe shaped templates were cut from corrugated plastic sheeting. These were designed to fit between the irrigation lines such that the weights of several raised pots could be compared to others nearby. A double layer (9 mm high) was placed under the matting and pots replaced.

Figure 9 Template used for 'bumps and hollows' experiment



Experiment 1

1) Objective : Compare 2 matting types at 1% flow bed gradient
2) Matting types tested :
    1. Geobond
    2. Florimat 2 and Mypex
3) Flow bed gradient : 1%
4) Water supply control system : Water Bugs
5) Subject : *Hebes*
6) Trial Design : Randomised block x 4 replicates
7) Dates of experimentation : 10/12/01 - 14/12/01

Experiment 2

1) Objective : Compare 2 matting types at 3% flow bed gradient
2) Matting types tested :
    1. Geobond
    2. Florimat 2 and Mypex
3) Flow bed gradient : 3%
4) Water supply control system : Water Bugs
5) Subject : Hebes
6) Trial Design : Randomised block x 4 replicates
7) Dates of experimentation : 18/12/01 – 19/12/01

Experiment 3

1) Objective : Compare 2 matting types over simulated "bumps and hollows"
2) Matting types tested :
    1. Florimat 2 and Mypex (templates used)
    2. Algon 2H (templates used)

    Algon 4H and SF-250 beds were also run at this time but without templates.
3) Flow bed gradient : 2%
4) Water supply control system : Timeclocks
5) Subject : Hebes
6) Trial Design : Randomised block x 2 replicates
7) Dates of experimentation : 24/4/02 – 10/5/02

<u>Assessment Methods</u>

Measurement of the following parameters were used as the key assessment methods:

1. Applied water
2. Run-off water
3. Weight of pots from the top (row 1), upper middle (row 4), lower middle (row 7) and bottom (row 10) were three times a day. Early morning, mid-morning and afternoon. For the bumps and hollows experiment, additional pots on top and immediately surrounding the templates were also weighed.

Results

Experiment 1 **-** 1% flow bed gradient

Figure 10, Experiment 1

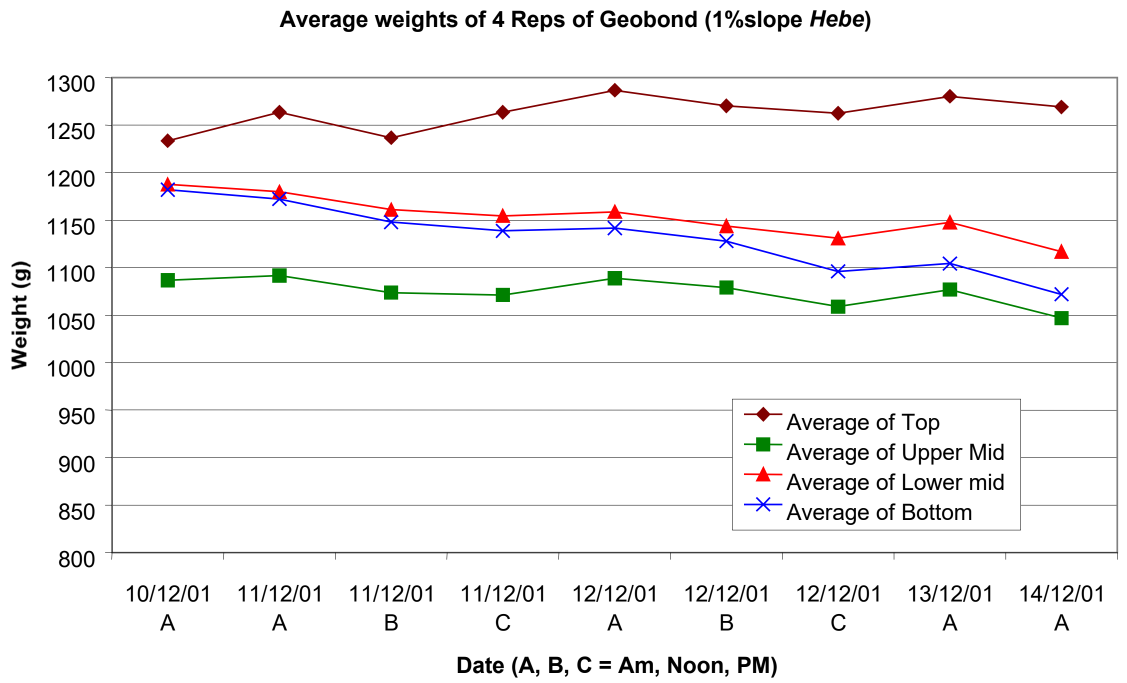
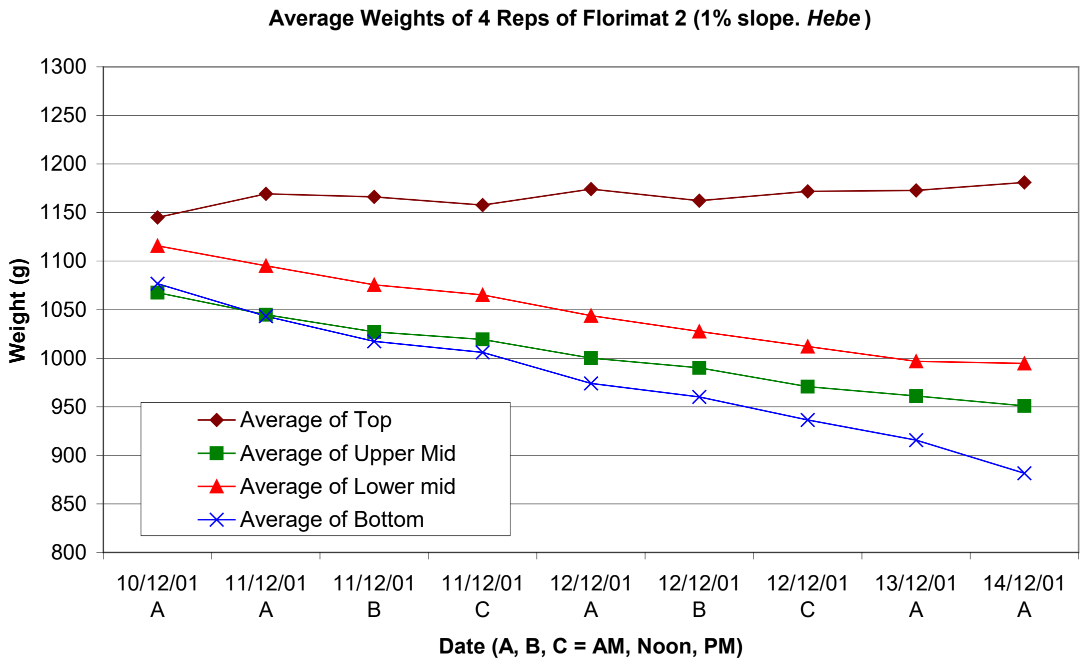


Figure 11, Experiment 1



The 1% slope was too gentle a gradient to achieve sufficiently rapid distribution and flow of water down the slope. Occasionally water would accumulate near the top irrigation line, which was within about 50 mm from the edge of the bed, and some would drip off this edge rather than flow down the bed. The first row of pots at the top of the bed nearest the line remained uniformly moist, but those further down the bed lost weight. Pots on the Geobond matting were generally heavier than on the Florimat 2, but there was still a slight weight loss from the lower rows over the 4 day trial period. The weight loss for these rows of pots on Florimat 2 was more acute, indicating possibly a greater capillary pull from this matting.

Experiment 2 3% flow bed gradient.

Following on from Experiment 1, the bed gradients were increased from 1% - 3% after the weights were recorded on 14 December. Some dry pots on the bottom of the Florimat 2 beds were hand watered at this point, which accounted for the large increase in weight between 14 Dec and 18 Dec (Figure 13). No hand watering was done on the Geobond beds and the slight weight increase for the pots at the bottom of the slope this was due to a redistribution of water from the increased slope. Apart from this, there was very little weight change in the pots on either bed over the five day perod to the 19 December. There were several irrigation applications (from the Water Bugs) over this period, but very little run-off, indicating active water use, but that the 3% slope did not appear to be excessive for the mattings in this experiment.

Figure 12, Experiment 2

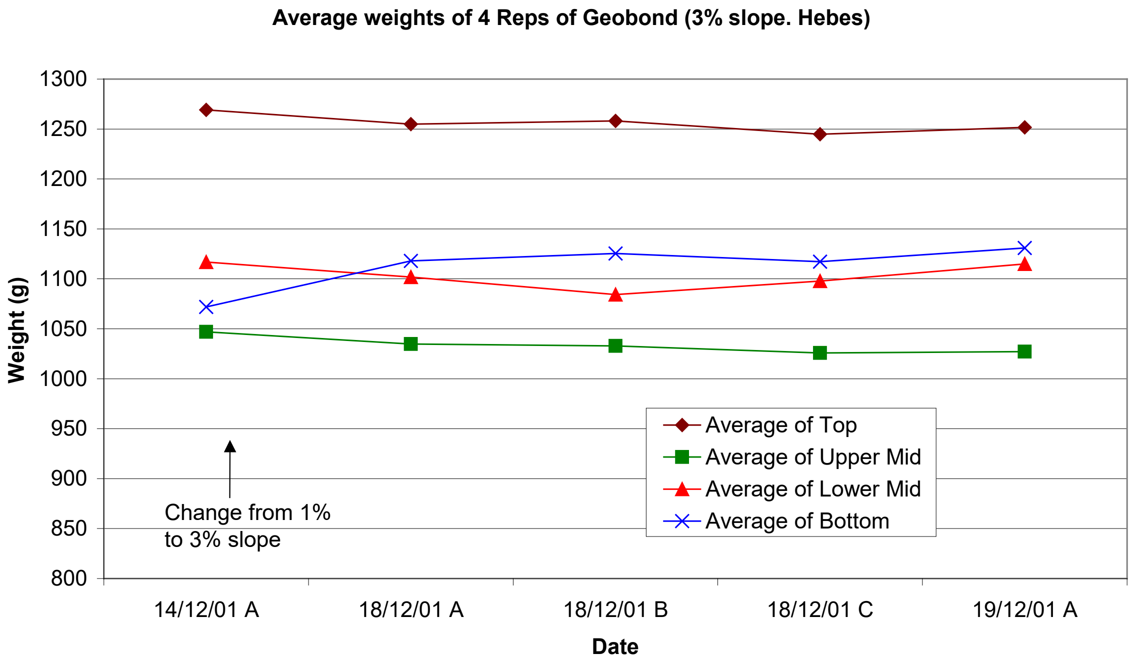
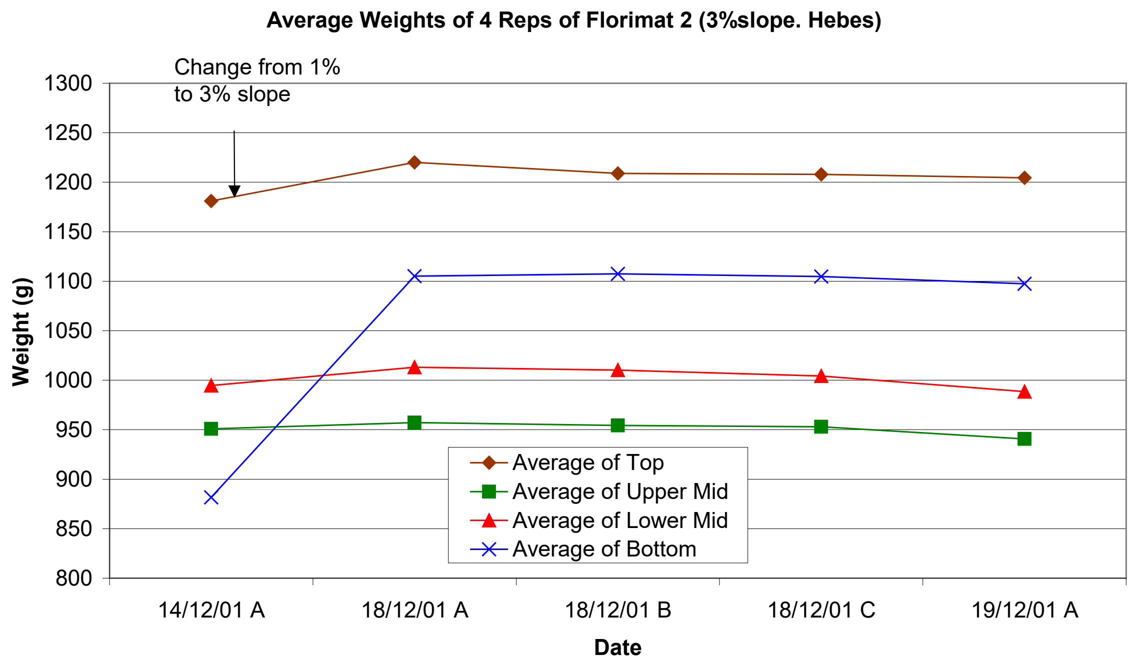


Figure 13, Experiment 2



Experiment 3 Effect of simulated 'bumps' and 'hollows' - 2% gradient

Over the period of the experiment from 24 April - 10 May, there were some differences in pot weights due to overall position on the bed relative to the irrigation lines. However pots were not get significantly dryer on top of the 9 mm raised template area or wetter on the area around the template, including the three pots in the 'hollow' (pots 6, 7 & 11, Fig. 9) for both Florimat 2 and Algon 2H mattings tested (data not shown).

Discussion

A 1% gradient appears to be too gentle a gradient for gravity to improve the distribution of water away from the irrigation lines down the slope. The capillary pull of the matting (particularly with Florimat 2 of those tested) meant that pots away from the T-Tape lines towards the bottom of the bed could dry out. This, coupled with some problems of water flowing off the top of the bed from the first trickle line, means that a steeper slope is advisable.

Although not tested for a long period of time, nor with many mattings, the 3% slope did not appear to be excessive in this trial. However, the steeper the slope, the narrower the bed width that can be accomodated within the overall vertical capillary lift capacity of the matting. Thus, it was decided that a 2% slope should be used for further work including larger scale studies.

The tolerance of mattings to 'bumps and hollows' was not tested to extremes in Experiment 3, but it did give a reassuring indication that some imperfections in the surface of the bed could be accommodated. This will need further testing in future. It is clear that an 'engineered slope' will be required when constructing beds at ground level to give an approximate 2% slope. This should be possible using a spirit levels, straight edges and marker pegs, with raking of soil and firming (preferably mechanically).

4.2.2 Irrigation Trickle lines

Objective

To see whether a higher flow rate T-Tape would improve wetting of mattings and avoid dry patches, and achieve better water distribution between pots.

Materials and Method

Experiment 1

8) Objective : Compare 4 matting types at 2% flow bed gradient using higher output T-Tape applying 5 mm/hr
9) Matting types tested :
    5. Florimat 2 and Mypex
    6. Algon 4H
    7. Algon 2H
    8. SF-250 and Mypex
10) Flow bed gradient : 2%
11) Water supply control system : Timeclocks
    Settings adjusted with weather and plant / matting requirements:

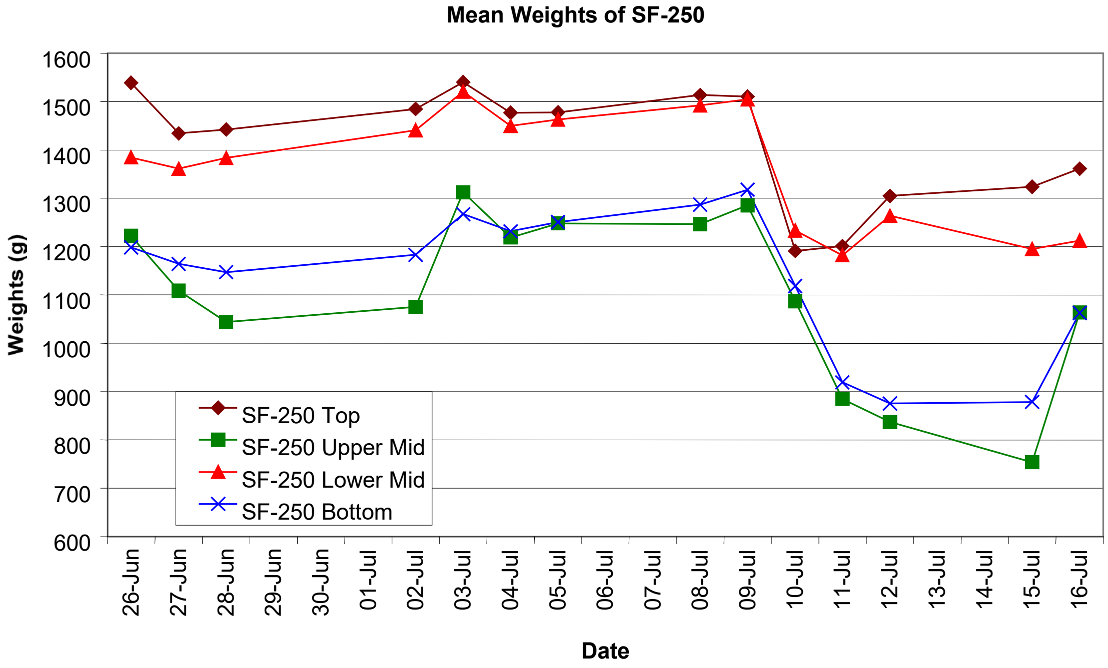
Florimat 2 + Mypex	1.8 - 2.5 mm/day
Algon 4H	1.7 - 2.3 mm/day
Algon 2H	2.1 - 2.7 mm/day
SF-250	1.7 - 2.3 mm/day

12) Subject : *Hebes*
13) Trial design : Randomised block x 2 replicates
14) Dates of experimentation: 25/06/02 – 16/07/02

This was the same experiment as described earlier (Experiment 2) in Section 1.2 describing timeclock control. For most of the experiments, the 506-20-250 T-tape with the flow rate 2.5 litres/m/hr of was used, and worked reasonably well. However, it was though a higher flow rate might improve the water distribution by more rapidly moving the water front down the bed before the pots nearest the lines absorbed too much water. The two lines of a narrower bore T-Tape 306-15-680 but with outlets spaced closer at 15 cm, and a flow rate of 6.8 litres/m/hr was installed.

With the higher flow rate, irrigation times were reduced accordingly compared to the previous 2.5 litres/m/hr T-Tape. Mats wet up well and there were no dry patches, but the higher flow rate did not prevent the pots nearest the trickle lines tending to absorb more water than those pots furthest away. Pots were watered ‘little and often’ with e.g. 4 x 5 minutes watering per day, although times were varied according to needs, with the irrigation turned off for 2 days on 9 July. Figure 14 shows the lower middle and top rows of pots which were immediately ‘downstream’ of the T-Tape lines were wetter than the bottom and upper middle rows of pots. A similar pattern was found with all four mattings tested.

Figure 14 Using higher flow rate T-Tape



Discussion

There are many permutations of output rate of irrigation lines, timing and duration of irrigation, and spacing of irrigation lines, which will all affect the uniformity of water over the matting. Possibly the wetness of the pots and matting at the beginning of an irrigation cycle will also influence the best combination. In any case, altering the irrigation output rate while keeping the line spacing constant, did not improve water distribution to the pots in this instance, but neither did it make it significantly worse. Although the later T-Tape was a higher output specification, it was a narrower bore, which made it easier to manage on the bench, and the closer spacing of emitters were felt to be an advantage. For these reasons, it was decided to keep to this T-Tape for the larger scale beds to be constructed later in the project.

Originally, it was envisaged just a single irrigation line at the top of the capillary flow bed might suffice similar to descriptions of early flow beds from Geisenheim, Germany (Behrens, 1996). Following construction of the prototype bed in Year 1, it was thought that two lines would be necessary to obtain sufficient coverage of the 2.4 m bed at the gentle gradient used. For the Geobond 300g matting, irrigation lines were moved down by one row to between the 6th and 7th rows, giving a gap of about 1.5 m between this and the top line. Experience in Year 2, however, indicates that closer spacings of lines on the irrigation beds (e.g. 3 rather than 2 lines across a 2.4 – 2.5 m bed) would be be advantageous. Three lines per bed was not tried on the small scale beds, but it is likely that line spacings in the range 0.75 m - 1.2 m will give better results.

4.3 Other Findings

4.3.1 Drying out and Re-Wetting of Matting

There were problems with patches of capillary matting drying out, especially in the early stages of the Year 2 work. Re-wetting of these areas proved difficult through the automated irrigation supply and often it was necessary to re-wet these areas by hand. A key factor that caused the mat to become dry and difficult to re-wet was the build up of hard water deposits. These deposits were initially dealt with by soaking and cleaning mats with peroxyacetic acid (as Jet 5 at a dilution of 0.5% or 1:200). The hard water supply was then acidified with nitric acid to remove much of the bicarbonate. It was found that acidifying the water to about pH 6.2 was suitable for our water supply, but the ideal pH can vary with different water sources, and should be checked by analysis.

Dry patches were also exacerbated by exposure of edges and ends of beds to the sun. During sunny periods, this was an additional factor affecting the drying out of pots at the bottom ends of beds on the south side of the glasshouse, in addition to sub-optimal irrigation settings or bed gradient etc. The problem was not restricted to any particular mattings, although Geobond 300g did tend to be more difficult to re-wet once dry. Initial wetting up before placing plants on this matting was also made easier by watering with a weak wetting agent solution. Florimat 2 and Algon, however, wetted up relatively easily when new; it is not clear whether they were dosed with a wetting agent before supply, or whether this was a feature of the materials themselves.

Provided irrigation timing settings were correct, the layer of Mypex used over mattings such as SF-250 and Florimat 2 did appear to help these mattings retain water better and not dry out as quickly when exposed to sun as mattings that had no additional insulating layer. This could be an advantage in facilitating re-wetting during irrigation cycles, whereas completely dry patches often needed hand wetting up. As noted in 4.3.2 below, however, the Mypex could interfere with maintaining capillary contact between pots and matting.

4.3.2 Maintaining Capillary Contact

Irrigation of plants can only be successful when good capillary contact is maintained between the growing medium in the pot and the capillary matting. In addition to the factors already discussed in detail, such as frequency and timing of irrigation, hard water deposits etc., other elements of the system could upset good capillary contact:

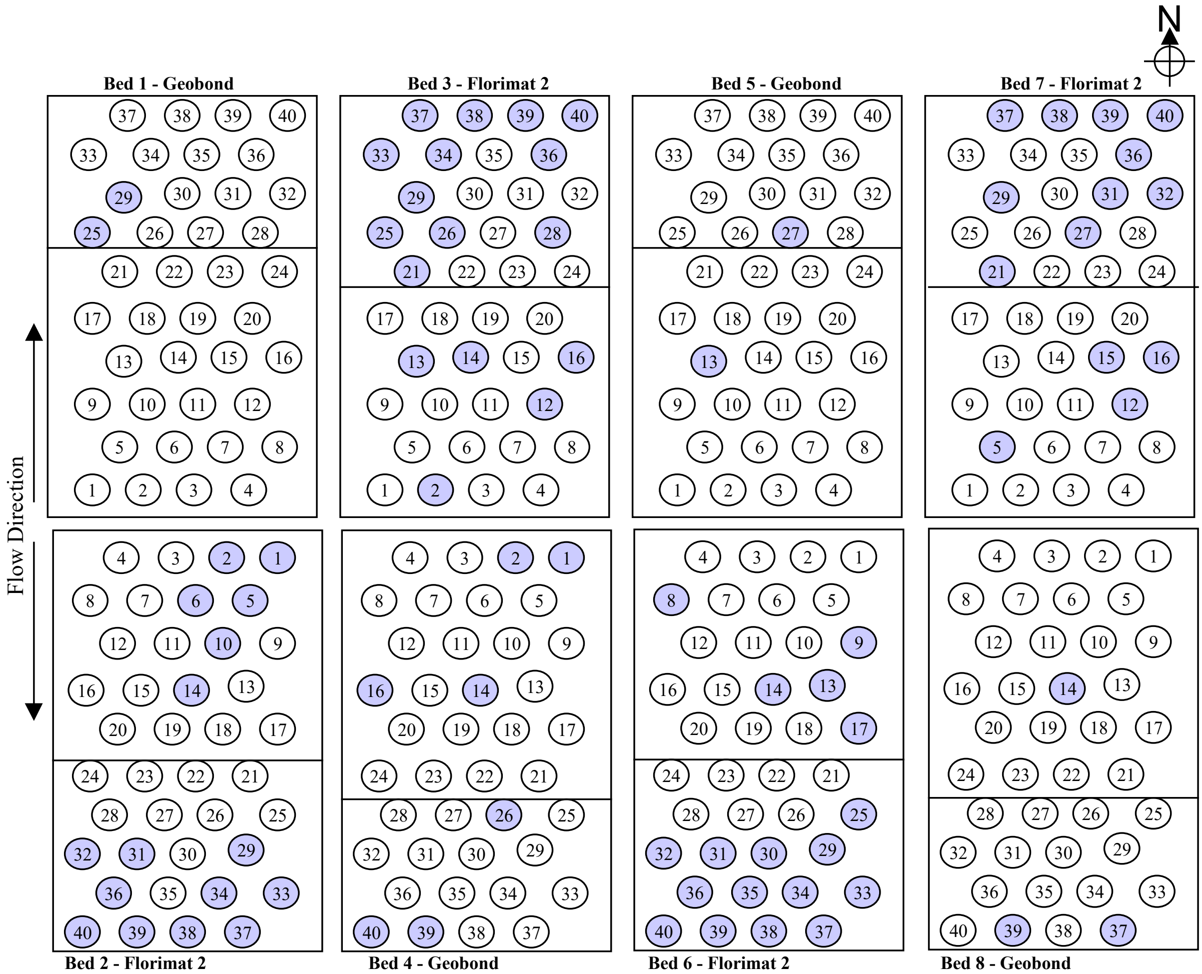
- The need for a hard-wearing surface layer (e.g. Mypex) over some capillary mattings
- Design of pot base
- Excessive re-positioning of pots on the matting

Mypex

Mypex was laid over capillary matting that didn't have a hardwearing upper surface layer already incorporated into it (i.e. Florimat 2 and SF-250 of those investigated in Year 2). In Year 1, it was demonstrated that if Mypex or Tex-R was used, the critical moisture level in the matting at which capillary contact could be maintained was higher than where pots stood directly on the matting. This was most acute with 9 cm pots, but less of a problem with heavier 3 litre containers. In the Year 2 experiments, the problems occurred using intermediate weight 2 litre containers. Figure 15, below, illustrates all the pots requiring at least one hand watering during the experiments in late December 2001 / early January 2002. More pots on the Florimat 2 + Mypex matting needed spot watering than with the Geobond. Better, more consistent results were achieved with Florimat 2 + Mypex once it was 'run wetter', but, along with all the mattings tested, this limited the degree in which pots could be 'dried down' between irrigation cycles.

Apart from Tex-R, other covers for mattings were not tried in the project. There are a range of woven polypropylene ground cover products available similar in appearance to Mypex 'red stripe', but which may give different results. Mypex 'green stripe' for example, is understood to have a poorer permeability, and that a minimum water permeability of 9 litre/m^2/second should be aimed for (Richardson, personal communication). Here, the permeability of a fabric is measured with a 100 mm depth of water passing downwards through the fabric by gravity. Although a layer of very low permeability could restrict upwards capillary flow, a high flow rate is not needed *per se.* Maintenance of a water film between the growing medium and the matting is the most important factor. Even a ground cover material of high permeability, sandwiched between the peat and matting, could break this water film. Cohesion between water molecules, and adhesion between water and the ground cover fabric need to be strong enough to prevent water in the pores of the ground cover being replaced by air. In practice, this applies under 'saturated flow' conditions, i.e. when the matting is relatively wet.

Figure 15 Shaded circles represent dry pots requiring hand spot watering during experiments in late December 2001 / early January 2002



<u>Design of Pot Base</u>

The pot base might have an influence on capillary link between matting and media. Some pots have a flat bottom with a number of holes that allow good capillary contact between media and mat. This was the case with the containers used for the *Sambucus* in the Water Bug experiments 1 and 2. In the case of following experiments with *Hebe,* the pots only had four (of eight) holes allowing direct contact between the capillary matting and growing medium. The remaining holes were set in slightly raised segments of the pot base. In most cases, it appeared as though sufficient contact was made with the lower four holes, provided that the growing medium was settled well to the base of the pot. Breaking of capillarity could occur, however, if plants were removed to examine the rootball, and pots not replaced in the correct orientation. Root growth through the base of the pot into the matting (whether or not covered by Mypex) did also occur to a small extent with undisturbed pots of *Hebe.* This could be beneficial in holding pots securely in contact with the bed, as well as roots directly absorbing some water from the matting. However if pots were lifted, plants turned out and then replaced in the pot, it was again difficult to get the rootball to make close contact with the pot base (Appendix, Photos 2 - 3).

Re-positioning of pots

Finally, removing pots from the matting to record weights was a key experimental procedure. Replacement of pots while mattings were moist, allowed ready re-establishment of capillarity, but if moisture content of the matting was nearing its critical point at the time of weighing, capillary contact could not be re-established without hand watering the pots. This was a frustrating aspect of the experimental procedure that could not be avoided as there was no viable alternative method of obtaining accurate water content records from the large number of pots that needed recording. With the follow-on work on a larger scale (see Section 6), more pots were available for weighing, allowing for rotation of sampled pots between records. This observation concurs with many years experience with Efford sand beds, where the importance of establishing good capillary contact soon after the crop has been set out on the bed, has been emphasised. Under commercial conditions where there is less need to lift plants regularly, less problems would be expected, but care must be taken if plants are moved for any reason.

5 Work in Progress

5.1 Larger scale comparisons of 'Capillary Flow Beds' with other systems

Objective

To construct a larger scale 'capillary flow bed' under protection comparing this system to overhead and sand bed irrigation.

The main objectives of comparing the three irrigation systems was to:

1. Assess and compare water consumption for the crop
2. Measure and compare uniformity of water distribution (uptake by the containers)
3. Compare crop growth and uniformity.

Materials and Methods

Having tested the 'capillary flow bed' using small prototype beds and establishing the working tolerances of a number of capillary mattings, a larger scale 'flow bed' was constructed alongside two other systems in a glasshouse (Appendix, Photos 5 - 8).

<u>3 irrigation systems</u>

- Efford Sand bed
- Capillary flow bed matting
- Overhead sprinklers on a drained gravel base

<u>Plant species</u>

Ceanothus 'Concha' and *C.* 'Pappilosus'

Ceratostigma griffithii

Pittosporum tenuifolium 'Tom Thumb', *P.* 'Wendle Charron' and *P.* 'Abbotsbury Gold'

9 cm liners of these species were pruned and potted into 3.0 litre containers in late April 2002. They were moved onto the comparative production bed systems in June once construction and testing was complete. Pruning of all species was carried out again in late July to maintain shape.

<u>Sand Bed</u>

The sand bed was constructed as 2 half beds 11.25 m long x 1.6 m wide. There were 270 plants consisting of a mixture of species per half bed so a total of 540 plants over all the sand bed. They were spaced 25cm apart. The bed was covered with 'Red Stripe' Mypex to protect the sand and reduce rooting through. The irrigation control was by timeclock with water being applied via 2 trickle lines on each half bed therefore a total of 4 trickle lines over the whole sand bed. Acidified water at 6.2 – 6.5 pH was used on both this and the capillary matting system to avoid hard water problems.

Capillary Flow Bed

The capillary matting bed was 15.9 m long by 2.5 m wide with a 2% cross-width gradient. There was a total of 540 plants on the whole capillary matting bed with 10 rows spaced 250 mm apart. The bed was split into three sections. Each section had a different capillary matting type containing 180 plants each over an area of 5m x 2.5m - Algon 2H, Florimat 2 + Mypex and Geobond 300g. Each section had individual timeclock controlled irrigation via 3 trickle lines, but Water Bug control could be implemented for future experiments if required. The first and second irrigation lines were spaced 3 rows (0.75 m) apart, the third line a further 4 rows (1.0 m) down the bed leaving a final 3 rows before the lower edge. There was a drainage channel into which surplus water can run. The timeclock settings were adjusted according to the individual requirements of the different mattings and plants. Irrigation water was acidified as above.

Overhead Sprinklers on a Gravel Bed

The overhead sprinklers were placed 2 m apart down line x 3.5 m between laterals over 2 gravel half beds of 11.25 m x 1.6 m. The overhead sprinkler irrigation was controlled by a single timeclock and adjusted according to the requirements of the plants. Acidification of the irrigation water was not as practical with the overhead system, so plain mains water was used. There were 270 plants consisting of a mixture of species per half bed so a total of 540 plants over all the gravel bed. They are spaced 25cm apart.

Assessment Methods

Records included the following:

1. Applied water from all three irrigation systems.
2. Run-off water from the capillary matting bed.
3. Pots from a number of different areas of the beds weighed to assess water distribution.
4. Plant growth (e.g. height, bushiness, new growth).

Results

See Appendix, Photos 9 - 12.

Results from this and follow-on experiments will be presented fully in the next report, but interim results look promising. To date, good growth has been achieved on all growing systems, including all three matting types. Once settled in and established, there have not been the problems with dry patches of matting or plants on these larger scale beds as were experienced in the small scale experimental units. *Ceratostigma* initially grew fastest, required more water than the other species and could dry out, but following the summer pruning, all species have been successfully managed as a mixed block. Water use on the capillary matting has been similar or less than the sand bed, and both have used significantly less (approx 1/3) of that on the overhead irrigation.

6 Conclusions and Suggestions for Further Work

The objectives of Year 2 of the project were to test the capillary flow bed system with a range of capillary mattings, under both automatic and semi-automatic irrigation control. Also to determine some working tolerances (e.g. bed gradients, bumps and hollows, irrigation flow rates) for mattings and the bed system. Finally to commence comparisons of the capillary bed system with overhead and Efford Sand Beds on a larger scale under protection.

- The use of timeclocks as semi-automatic irrigation worked well and we were able to control the irrigation according to the plant and capillary matting requirements. It was concluded that timeclock control was the safest way of managing the irrigation on a 'capillary flow bed' in the short term pending further development of automatic control.

- In the experiments, it was found that reliable automatic control using the Water Bug device was difficult to achieve. There were specific problems with the device such as it tending to 'stick on' at high settings and cause the beds to flood for example, and this needs more investigation with the manufacturer. However, some problems may have been due to interactions with the other factors examined (bed gradient, line spacing, scale of experimental beds etc.). Automatic control of capillary irrigation is a very attractive objective, because manual adjustment of timeclock settings according to the weather is a skilful and often frustrating task. For this reason it is worth pursuing some form of automatic control.

- Achieving a very wide latitude of growing medium wetness (ie running dry regimes or wide wet / dry cycles) does not appear realistic where capillary matting is being used as a primary irrigation system. This is likely to be the case whether automatic or timeclock irrigation control is employed, because of the difficulties of maintaining capillary contact or re-establishing it once broken.

- Mattings need to be wetted up fully and evenly at each watering to maximise effective and rapid uptake into containers. However, significant amounts of run-off is usually an indication that the bed is being run 'too wet'.

- A 'capillary flow bed' to work effectively needs a slight cross width gradient to aid water distribution. Experiments have shown that this needs to be an 'engineered slope' constructed reasonably accurately, although this need not be difficult or expensive to carry out on raked and firmed ground base.

- A 1% gradient was insufficient with the mattings and irrigation line arrangement tested to improve the spread of water across the bed sufficiently. A gradient of 2% appeared suitable for a range of matting types. Limited testing showed mattings would probably work satisfactorily with a 3% gradient, although maximum bed width using a continuous capillary layer would be less than with a 2% slope within the vertical lift ability of the matting.

- The presence of small simulated 'bumps and hollows' of about 1 cm did not cause waterlogging or drying out of pots when tested with two matting types, Florimat 2 and Algon 2H. Tolerance to larger irregularities in the bed surface, and with different mattings, needs testing.

- Water distribution was not markedly affected by the use of either 'low flow' (2.5 litres/m/hr @ 0.55 bar) and 'high flow' (6.8 litres/m/hr) T-tape, although the closer spacing of the emitters on the narrower 'high flow' tape would be expected to be of benefit. Line spacing and arrangement on the bed is more important, and three lines for a 2.5 m width bed (i.e. 0.75 m - 1.0 m spacing) is recommended.

- Of the mattings tested in Year 2, Florimat 2, Geobond 300g, SF-250, or Algon 2H or 4H, none were identified as clearly 'better' or 'worse' for nursery stock on the system tested. However, the management of irrigation regimes will need tailoring to individual mattings. Further evaluation is continuing, but matting durability, maintenance and replacement costs will also be factors in determining grower's choice.

- Hard water (and fertiliser) deposits can rapidly build up on mattings under protection causing them to become water repellant. Acidifying irrigation water to reduce bicarbonate content is recommended.

- Maintaining capillary contact between growing medium and matting is an essential aspect of using a 'capillary flow bed'. The use of a layer such as Mypex over mattings such as Florimat or SF-250, is necessary to give a durable surface to withstand the handling of nursery stock containers, sweeping up debris etc. However, mattings need to be run wetter to avoid losing capillary contact. There must also be sufficient holes in the base of the pot in close contact with the bed, and excessive lifting or re-positioning of pots should be avoided when they or the matting is not well watered.

- Ongoing work on a larger scale under protection is comparing capillary flow beds with Efford Sand Beds and overhead irrigation on gravel, for water consumption and uniformity. Early indications are that water use can be as efficient as with sand beds. Management of irrigation regimes with timeclock and automation will also be examined further. Consideration will also be given to ways in which beds can incorporate flexibility to accommodate areas of plants with different irrigation requirements.

Acknowledgements

Thanks to Lees of Portmore, Lymington for the supply of liner plants, growing media and pots for growing on in the large scale experiments in Section 5.

Thanks is also extended to Flowering Plants Ltd for the loan of Water Bug controllers, and their interest and collaboration with technical aspects of the project.

Reference

Behrens, V (1996) Go with the flow *Horticulture Week* 23 May 1996, 25-29

Appendix - Photographs

Photo 1 Waterbug controller (Type M) - Flowering Plants Ltd

Photo 2 - 3 Good capillary contact with base (left) vs poor capillary contact after turning plant out of pot (right)

Photo 4 *Hebe* on small scale test beds - 8 August 2002

Photos 5 - 8 Preparation of demonstration scale capillary flow bed

Photo 9 - 12 Clockwise from top left: Drained sand bed; acidifying unit; capillary flow bed; overhead irrigation on gravel. 8 August 2002.