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CONTRACT REPORT

Water use under different hardy nursery stock container systems

HDC HNS 38
1993-1995

Final Report April 1996

HDC HNS 38

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1993 - 1995

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Key words: Container nursery stock, irrigation, standing areas, gravel beds, sand beds, moisture status, moisture measurement, water meter, water requirements

This report contains the results of two years' work

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

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RELEVANCE TO GROWERS AND PRACTICAL APPLICATION

APPLICATION

This two-year Project over 1993/94 and 1994/95 investigated the potential of improving water efficiency of gravel systems by infilling with 25 or 50 mm of sand and compared their performance against standard gravel and drained sand bed systems. The potential of a simple Rapitest Meter to monitor water status of the growing media and provide a tool to aid crop water management was also investigated. The two seasons provided extremes of weather conditions for the work, with a wet first year and a dry second season, though both had wet winters. The 75 mm of drained sand still provided the most efficient system for economy of water use, especially where low level irrigation was applied directly to the sand, but improved efficiency of water utilisation was obtained on gravel systems by using a sand infill. The importance of having a non-permeable lining when using sand infills on gravel was highlighted. The simple Rapitest Meter proved a useful tool for monitoring differences in water status of growing media between bed systems and as an aid to irrigation management.

SUMMARY

Water shortages, as a result of drier seasons and additional costs over the past few years, have increased awareness of the need to use water more efficiently, especially where extensive overhead irrigation systems are in operation. These problems can mean insufficient water is applied at times and further nursery expansion could be affected, especially where increased abstraction rights from boreholes and rivers are now difficult, if not impossible, to obtain. There is also the public perception of water being 'wasted' from high output overhead irrigation rigs, particularly in areas where hose pipe bans, etc. are in operation. Eastern and South East England have been worst affected, and these areas account for over 50% of the total production of container HNS. At present a large proportion of the industry uses gravel or Mypex standing bases with overhead irrigation, with a relatively large run-off to waste. Drained sand beds offer a practical alternative with a proven record of efficient use of water, and improved growth potential, but capital investment is higher, and they are not readily perceived as the answer, especially where large areas of overhead irrigated gravel systems are already in use. Simple monitoring has already identified that overhead systems can use over 70% more water than 75 mm depth drained sand beds, demonstrating the potential for savings in water bills by making more efficient use of water. However, little information is available on direct comparison of water use between systems, nor on methods of monitoring water requirements based on water relations within the growing media. Many irrigation programmes are based on timeclocks, which can be extremely wasteful of water. The scope of this Project was therefore to:

i. consider cost effective methods of adapting existing gravel systems to achieve more efficient use of applied water, by sand infills. This would not only reduce water use, but also limit leaching of agrochemicals into the ground or surface water supplies.

ii. monitor water applications to a range of different bed systems developed.

iii. look at the practicality of using a simple Rapitest Meter to monitor water status of the growing media, in order to develop 'leaner' watering regimes based on plant requirements rather than watering to excess.

Eighteen small 6 m x 1.5 m wide outdoor beds were used for the work, with two trials run over the 1993/94 and 1994/95 seasons, which had contrasting weather patterns, the first year being relatively wet, but the second very dry over the growing season, though both had wet winters. Bed systems used were as follows:

A. 25 mm gravel over Mypex with overhead irrigation.

B. 75 mm sand (+ drain) over polythene with seephose irrigation.

C. 75 mm sand (+ drain) over polythene with overhead irrigation.

D. 25 mm gravel over Mypex plus 25 mm sand infill with overhead irrigation.

E. 25 mm gravel over Mypex plus 50 mm sand infill with overhead irrigation.

F. 25 mm sand over Mypex with overhead irrigation.

Species included in Year 1 were *Hydrangea* 'Mme J de Schmedt', *Genista hispanica*, *Lavandula* 'Hidcote', *Cytisus kewensis* 'Niki'. In Year 2 a single species was used over the growing season, namely *Hydrangea* 'Mme J de Schmedt' and 'Draps Pink', together with *Lavandula* 'Hidcote' which was brought on to the different beds for winter comparisons since this species is particularly water sensitive.

The 75 mm drained sand beds still proved the most efficient in terms of water use when compared against the 25 mm gravel bed, especially in the drier season where savings of around 70% were made. Savings were greatest where the sand beds were irrigated with low level seephose as compared to overhead irrigation systems. However, the use of sand infill looked a promising method of improving efficiency of water utilisation in gravel systems, but measurement of potential savings over the drier season were confounded by a permeable Mypex lining, which allowed water to be drawn out of the bed down into the drier soil profile beneath. Mypex linings under gravel are commonly used to improve drainage away from the beds, but non-permeable polythene linings would be required if sand infills were being considered as a means of improving their water utilisation. More work is therefore required to determine the depth of sand infill required to achieve the most cost effective savings in water use, together with an assessment of winter drainage.

The Rapitest Meter provided a surprisingly accurate tool in monitoring differences in water status of growing media between species and the different bed systems, as well as providing a means of identifying a set point for when to water, once calibrated to crop requirements. The small hand-held meter proved simple to use with almost instantaneous readings once the probe was inserted into the media, enabling a number of readings to be taken very quickly. The results obtained showed just how responsive the meter was to rapid changes in moisture content of the media either from irrigation or rainfall events. A single meter was used throughout the trial to ensure comparisons between bed systems were valid, since different meters could give varying readouts and each meter would need calibration to crop requirements. The depth of moisture measurement would need to be standardised, since this work showed the marked changes in water status from the drier zones towards the top of the container to the wetter base. In this work two depths were measured and an average taken, though a single measurement at a set depth would probably provide the information required, though a number of readings would need to be taken in different containers to obtain an average for a bed system to aid irrigation management. The measurements also gave the opportunity to investigate a 'lean' water regime by only watering back up to a predetermined level, instead of to excess. Again this needed initial calibration to crop requirements but proved a useful tool in improving efficiency of water use. More work is required to determine the parameters of when and how much water needs to be applied and the influence of these 'leaner' water regimes on plant growth and quality.

As to be expected, variation in species' requirements showed up clearly in the work, and highlighted the problem of mixed cropping on the same bed. Thus in Year 1, when one species with a high water requirement (*Hydrangea*), and three with a low water requirement (*Cytisus*, *Genista*, *Lavandula*) were on the same bed, irrigation applied was a compromise of an average of water measurements over the four species. Thus *Hydrangea* tended to be underwatered, the other three overwatered. This was overcome in the second year by only having one species on the bed (*Hydrangea*).

The different bed systems appeared to have little effect on the quality of plants overwintering in these trials, even though the 75 mm sand beds provided more positive drainage of water from the pots. However, it was noticeable with the *Lavandula* in the second year that new root development in the spring was improved on the sand compared to gravel systems.

In summary the use of a sand infill to existing gravel beds appears a promising method of improving their efficiency of water use, providing a non-permeable lining is used in the base, though the 75 mm drained sand bed still provides the greatest savings in water use, and winter drainage capability. The full potential of the 'infill beds' to conserve water needs further investigation over a dry season, since in this work results were confounded by the permeable lining which allowed water to be pulled from the bed in the drier season. The Rapitest Water Meter appears a useful tool for monitoring water status of growing media and identifying the point at which irrigation is required. However, each meter will need calibration to crop requirements, and further work is needed to develop the 'lean' watering regimes that become possible by such monitoring, since these requirements will vary with species and system of production.

EXPERIMENTAL SECTION

INTRODUCTION

Water shortages, as a result of drier seasons and additional costs over the past few years, have increased awareness of the need to use water more efficiently, especially where extensive overhead irrigation systems are in operation. This has meant insufficient water application at times and constraints on further expansion. Eastern and South East England have been worst affected, and these areas account for over 50% of the total production of container HNS. At present a large proportion of the industry uses gravel or Mypex standing bases with overhead irrigation, with a relatively large run-off to waste. Drained sand beds offer a practical alternative with a proven record of efficient use of water, and improved growth potential, but capital investment is higher, and they are not readily perceived as the answer, especially where large areas of overhead irrigated gravel systems are already in use. Simple monitoring has already identified that overhead systems can use over 70% more water than 75 mm depth drained sand beds, demonstrating the potential for savings in water bills by making more efficient use of water. However, little information is available on direct comparison of water use between systems, nor on methods of monitoring water requirements based on water relations within the growing media. Many irrigation programmes are based on time clocks, which can be extremely wasteful of water.

The scope of this project was fourfold:

i. consider cost effective methods of adapting existing gravel systems to achieve more efficient use of applied water, by sand infills. This would not only reduce water use, but also limit leaching of agrochemicals into the ground or surface water supplies.

ii. monitor water applications to the range of different bed systems developed.

iii. look at the practicality of using a Rapitest Meter to make simple measurements of the water status of the growing media, in order to develop 'leaner' watering regimes based on plant requirements rather than watering to excess.

iv. review and prepare an HDC Fact Sheet on water use for container HNS based on information already available and incorporating results from this project. Monitoring of water applied over a 10 year period to a number of systems was done at HRI Efford and collated in their Station Leaflet No. 10. This would form the basis of the HDC Fact Sheet.

The feasibility and potential benefits of estimating irrigation requirements of containers from physical measurements of evaporative demand on a day to day basis was the subject of a complementary project at HRI East Malling (see Report for HNS 38a).

MATERIALS AND METHODS

Eighteen small 6 m x 1.5 m wide outdoor beds were used for the work, with 2 trials run over the 1993/94 and 1994/95 seasons.

Treatments

Bed Systems:

A. 25 mm gravel over Mypex with overhead irrigation.

B. 75 mm sand (+ drain) over polythene with seephose irrigation.

C. 75 mm sand (+ drain) over polythene with overhead irrigation.

D. 25 mm gravel over Mypex plus 25 mm sand infill with overhead irrigation.

E. 25 mm gravel over Mypex plus 50 mm sand infill with overhead irrigation.

F. 25 mm sand over Mypex with overhead irrigation.

Species:

Year 1 (1993/94)	Year 2 (1994/95)
Hydrangea 'Mme J de Schmedt'	*Hydrangea* 'Mme J de Schmedt'
Genista hispanica	'Draps Pink'
Lavandula 'Hidcote'	*Lavandula* 'Hidcote' (comparisons over winter period only)
Cytisus kewensis 'Niki'	

Design: Trojan Square (see Appendix 1 pages 75 - 76 for trial layout)

6 bed systems
x
3 replicates
—
18 beds
x
4 species
—
72 plants in total

Plot size: 16 plants recorded with surrounding guards

Watering Procedure (based on growing media water status as measured by a ***Rapitest Meter***)

a. *When to water*

i. Each bed checked daily around 7.30 am measuring the water status in 8 containers (2 of each species) at a depth of 4 cm and 8 cm. (Rapitest probe vertically inserted 4 cm from edge of pot on southern side).

ii. Water applied when average meter reading dropped below 6 (mean across 4 and 8 cm depth readings).

b. *Method of watering*

i. 50 litre water/bed (9 m^2) applied initially when average meter reading was below 6.

ii. A further meter reading was taken 2 hours after water applied. If the average reading had not risen to between 8-10, then the amount of water applied the following day was adjusted. If below 8 an additional 5-10 litres/bed was applied at the next watering, above 10 then amount of water applied at next watering was reduced by 5-10 litres/bed. As experience was gained on amount of water needed to bring the moisture status of the growing media back to the required level, the volume of irrigation applied was increased, reducing the need for topping-up at the next watering.

c. *Watermark Moisture Sensors*

Six Watermark Moisture Sensors were obtained, allowing the six bed types within one replicate to be monitored. The probes of these sensors were permanently installed in the containers in the same relative position on each bed. Readings were taken at 8.30 am each day.

Culture

Start Material: 9 cm liners of all material obtained from commercial nurseries, apart from *Hydrangea* which was potted as rooted cuttings from Efford stock, which had been forced under protection (March-April struck cuttings inserted in a 50:50 peat:pine bark rooting media with 1.0 kg/m^3 Osmocote Plus 12-14 months 'Autumn' incorporated, were progagated under intermittent mist.)

Pot size: 3 litre

Growing media: 100% medium Bulrush peat
5.0 kg/m^3 Osmocote Plus 12-14 months 'Spring'
1.5 kg/m^3 Magnesium Limestone
100 ml Cudgel in 40 litres water/m^3

Date potted: Year 1: 15-16 June 1993
Year 2: 24 June 1994 (Lavander), 7-20 July 1994 (*Hydrangea*)

Trial Started: Early July 1993, mid July 1994

Assessments

1. Crop diaries.

2. Records of all water meter readings.

3. Record of amount of water applied, and dates of application.

4. Growth records

   Plant top and root growth assessed at the end of each growing season (November) and again the following spring (April-May). Records varied with species and year and are detailed in the results section.

5. Photographs as appropriate.

Statistical Analysis

Growth record results were analysed using the Standard Analysis of Variance (ANOVA). The degrees of freedom (d.f.), standard error (SED) and least significant difference to 5% (LSD), on which the significance tests were based, are presented in the tables to aid interpretation of the results.

RESULTS

Year 1 (1993-1994)

Because of the volume of data generated in this trial results are presented and discussed under the following headings.

A. Comparison of Rapitest and Watermark meters for monitoring Water Status of growing media (Figure 1, p. 9).

B. Uniformity of media water status measurements across replicates (Figures 2a-f, pp. 11-16).

C. Variation in moisture readings depending on depth taken (Table 1, p. 18).

D. Growing media moisture measurements as influenced by irrigation and rainfall (Figures 3a-f, pp. 20-25).

E. Influence of species on water status of growing media over time (Figures 4a-b, pp. 27-28).

F. Effect of bed system on moisture status of the growing media for *Hydrangea* (Figures 5a-h, pp. 31-38) and Lavender (Figures 6a-d, pp. 39-42) over the growing season and during the winter period, plus irrigation and rainfall data.

G. Total irrigation applied as influenced by bed system (Table 2, p. 43).

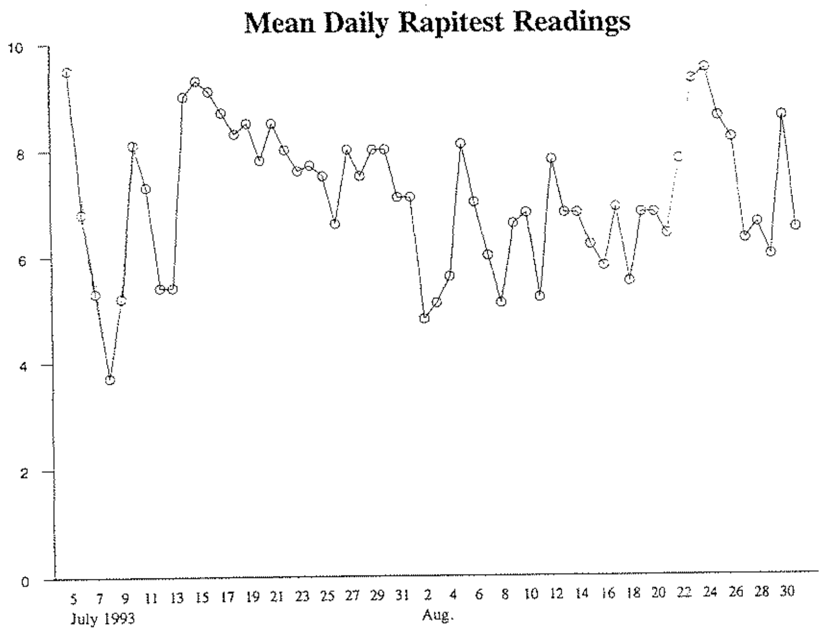
H. Plant growth (Tables 3-4, pp. 45-47).

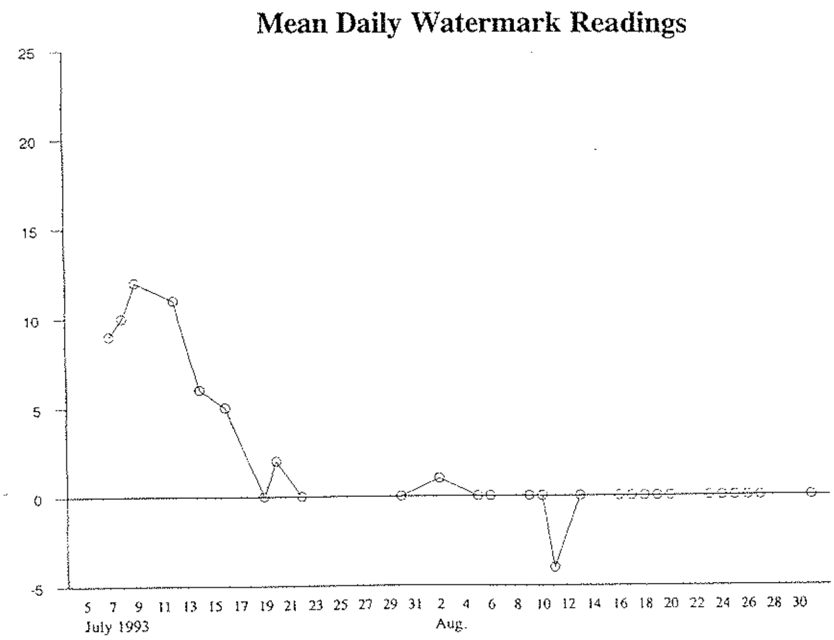
I. Liverwort growth (Table 5, p. 49).

A. Comparison of Rapitest and Watermark meters for monitoring water status of growing media

The Rapitest meter proved more sensitive than the Watermark meter in monitoring changes in water status of the growing media, as demonstrated in Figure 1. This example was from the 25 mm gravel + 50mm sand infill bed, but similar patterns of results were seen in the other bed systems. In view of these results use of the Watermark meter was discontinued after the first period of measurements in favour of the more flexible Rapitest meter.

Figure 1



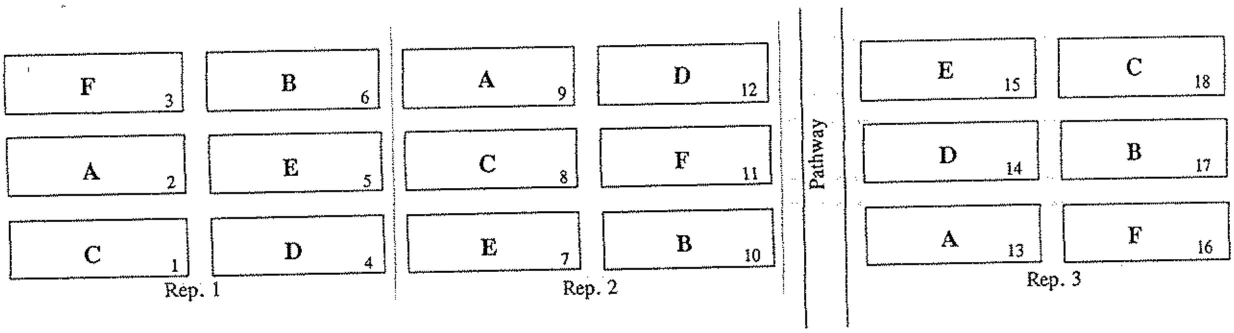


B. Uniformity of growing media water status measurements across replicates

Figures 2a-2f show the variation in water status of the growing media between replicates over the period of the trial. Overall, taking bed position and potential variability due to overhead irrigation into account, the readings between replicates are remarkably close.

An influence of bed position on the results can be seen. For example in Replicate 1 Treatment C (Figure 2c) is on the South-West corner and would catch the prevailing south-westerly winds to a greater degree than the other two replicates, and pots on this bed were generally dryer. However, Treatment E (Figure 2e) was surrounded by other beds and the moisture readings between the three replicates was far less variable.

Bed Layout



Key to Treatments:

A: 25mm Gravel + Overhead Irrigation

B: 75mm Sand + Seephose

C: 75mm Sand + Overhead Irrigation

D: 25mm Gravel + 25mm Sand Infill

E: 25mm Gravel + 50mm Sand Infill

F: 25mm Sand + Overhead Irrigation

N

Figure 2a: Year 1 (1993-94): 25mm Gravel Bed + Overhead Irrigation (Trt. A)

Mean daily Rapitest moisture measurements

(average across 4 species)

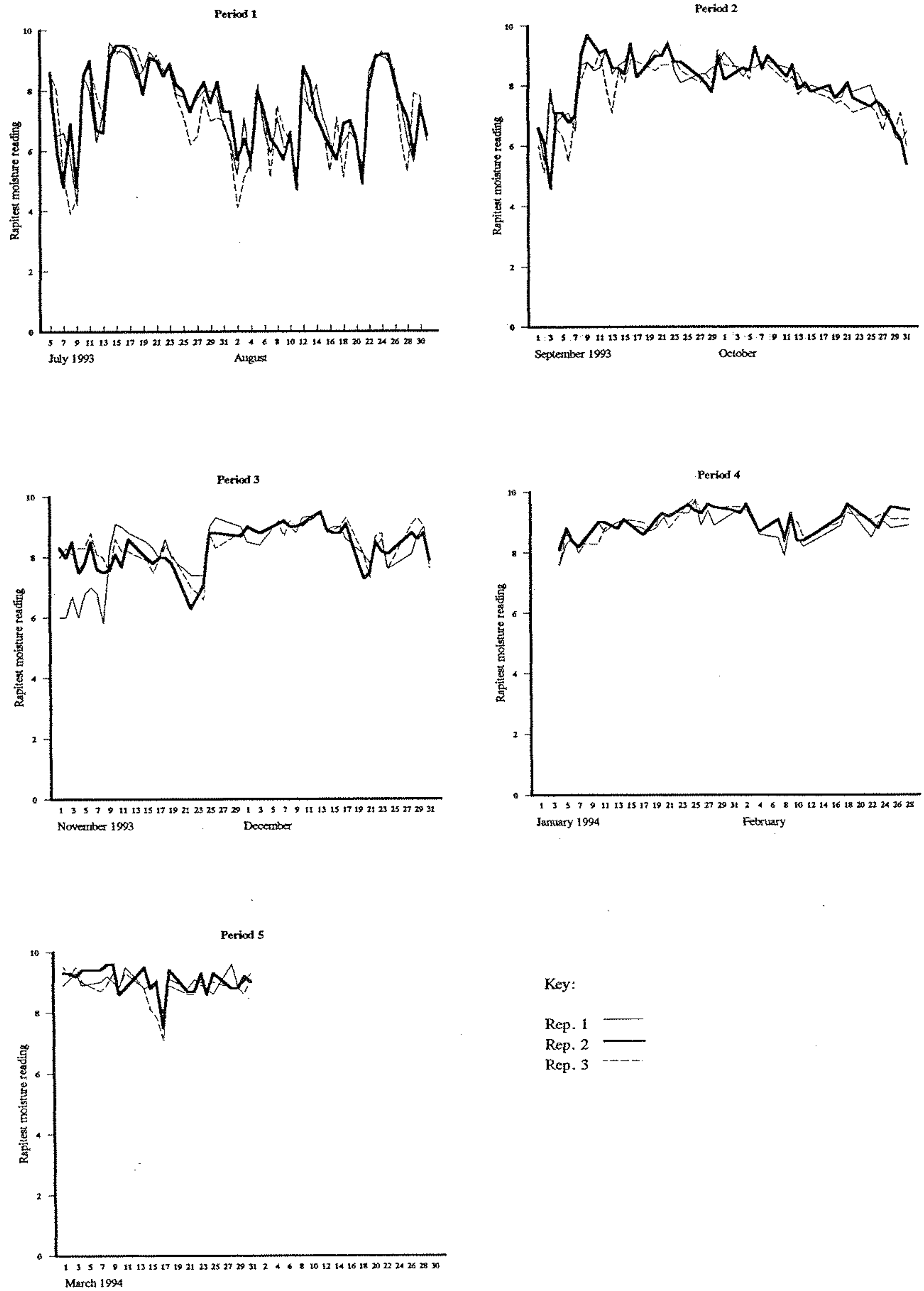


Figure 2b: Year 1 (1993-94): 75mm Sand Bed + Seephose (Trt. B)

Mean daily Rapitest moisture measurements

(average across 4 species)

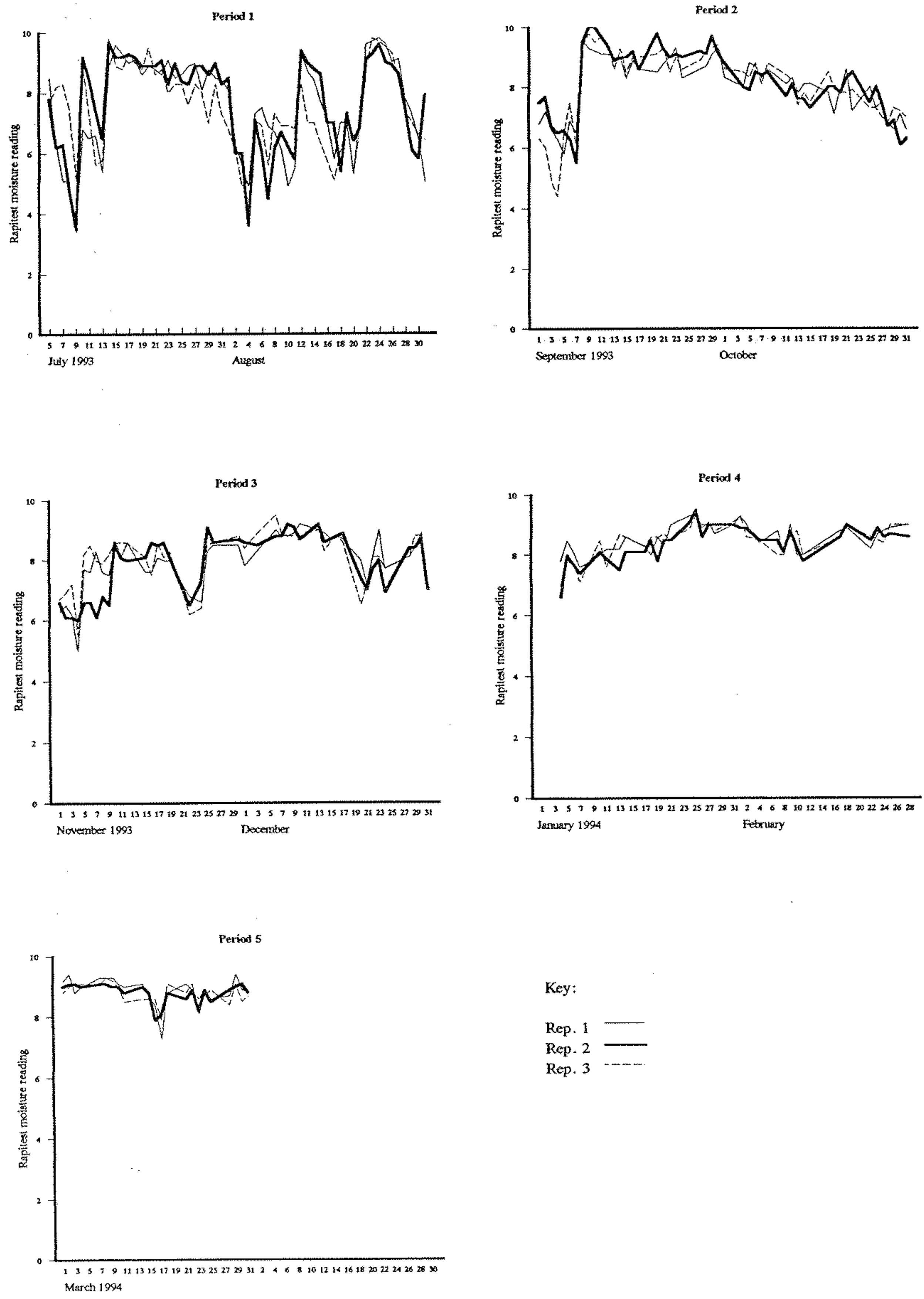


Figure 2c: Year 1 (1993-94): 75mm Sand Bed + Overhead Irrigation (Trt. C)

Mean daily Rapitest moisture measurements

(average across 4 species)

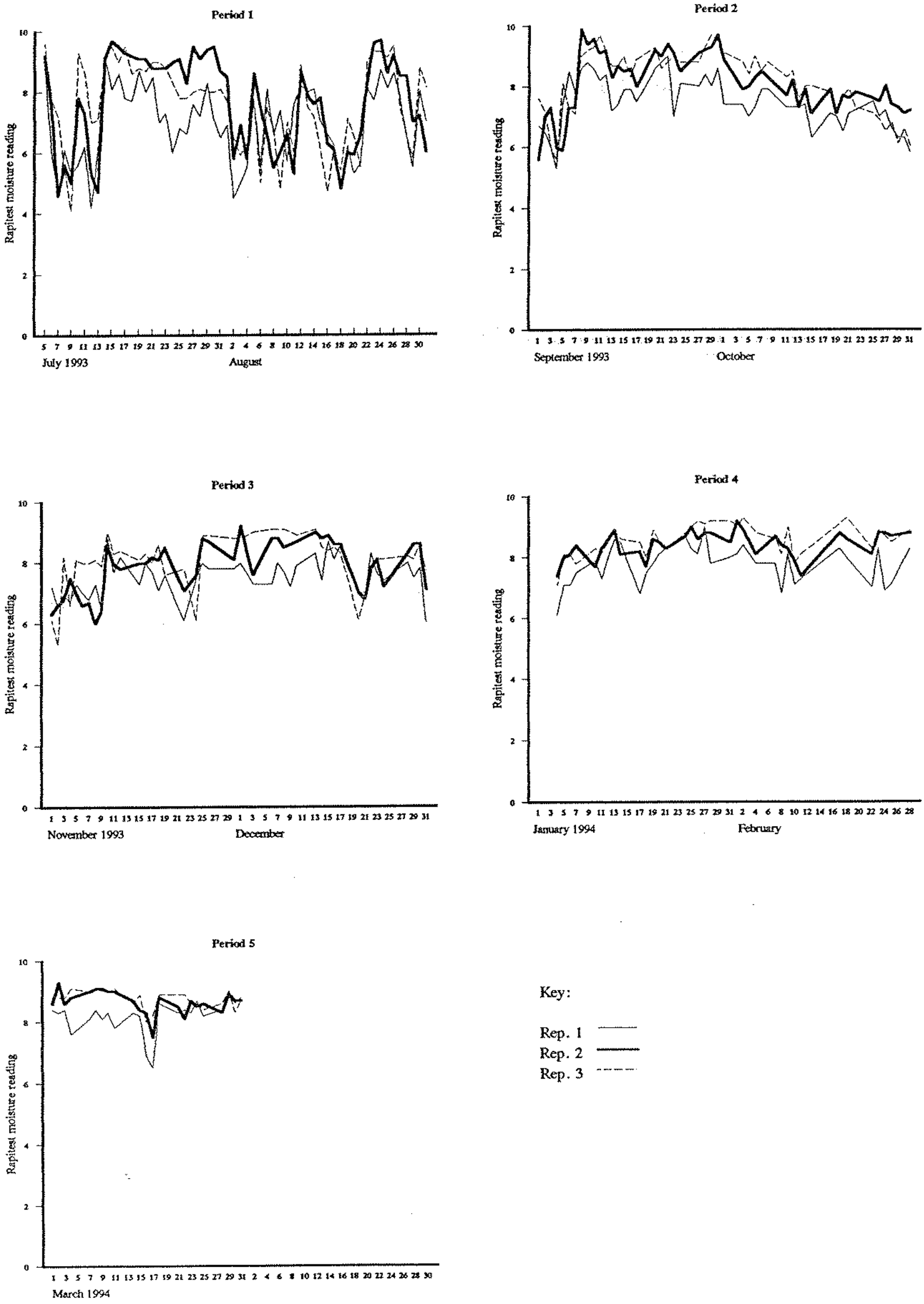


Figure 2d: Year 1 (1993-94): 25mm Gravel + 25mm Sand Infill (Trt. D)

Mean daily Rapitest moisture measurements

(average across 4 species)

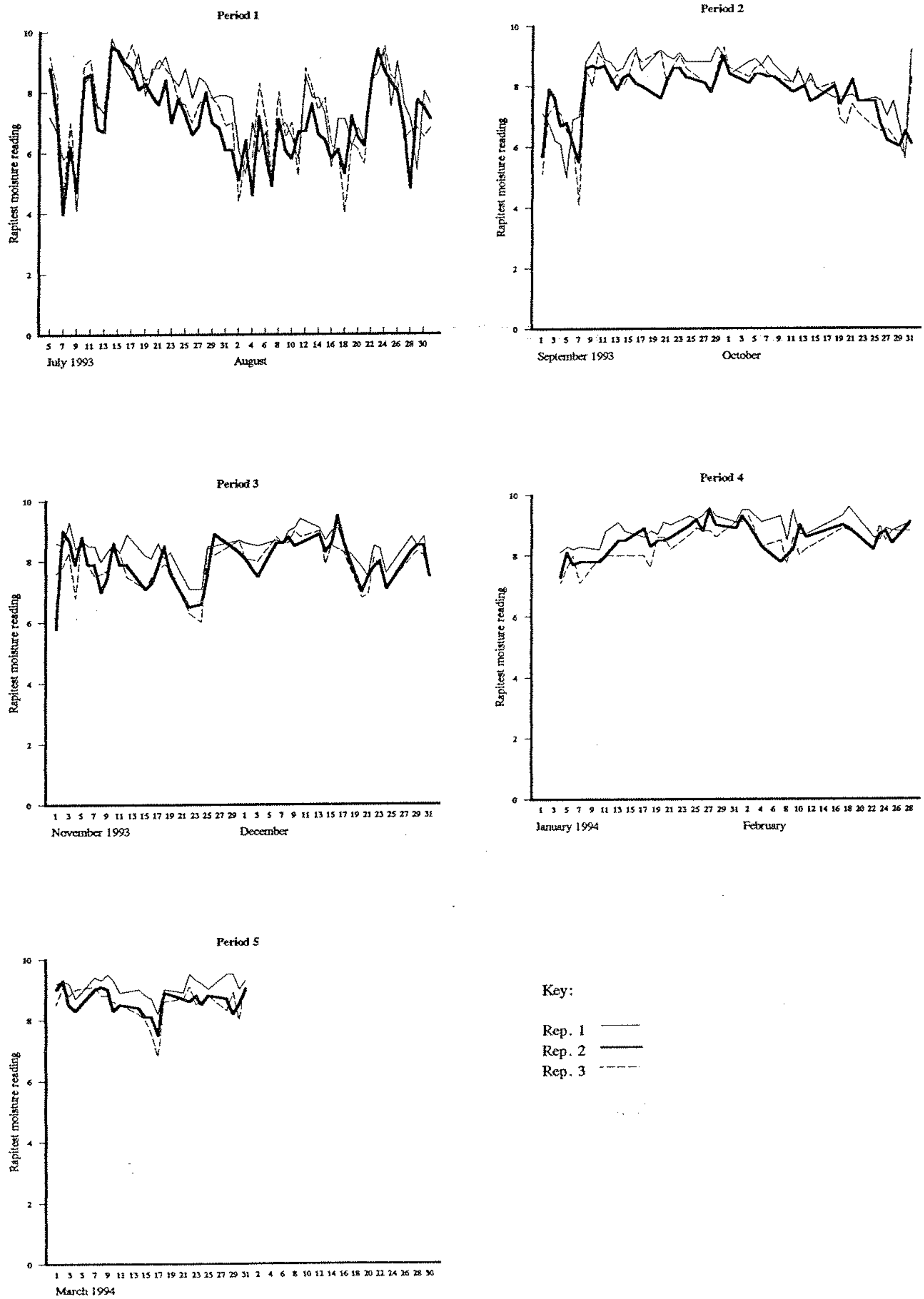


Figure 2e: Year 1 (1993-94): 25mm Gravel + 50mm Sand Infill (Trt. E))

Mean daily Rapitest moisture measurements

(average across 4 species)

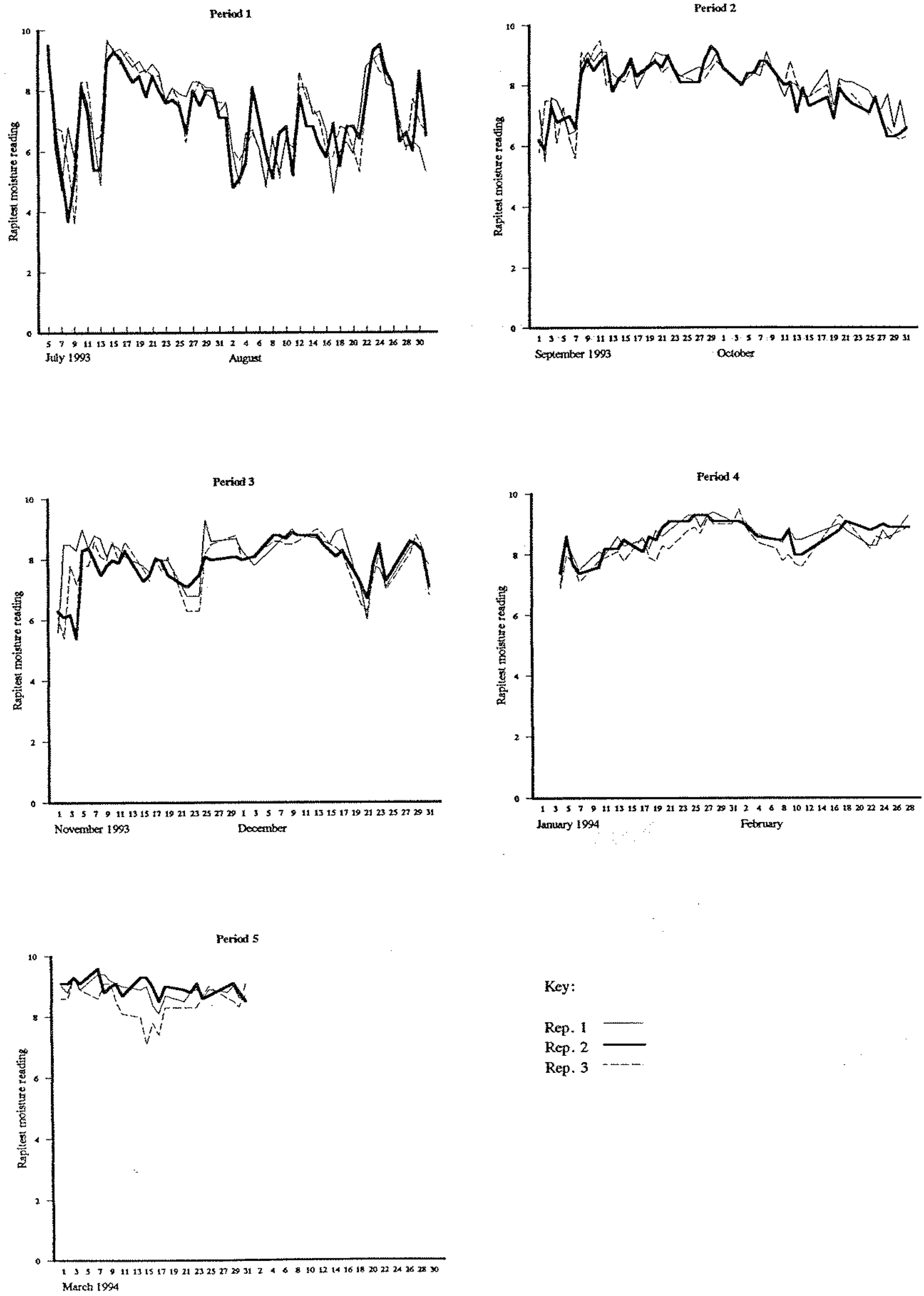
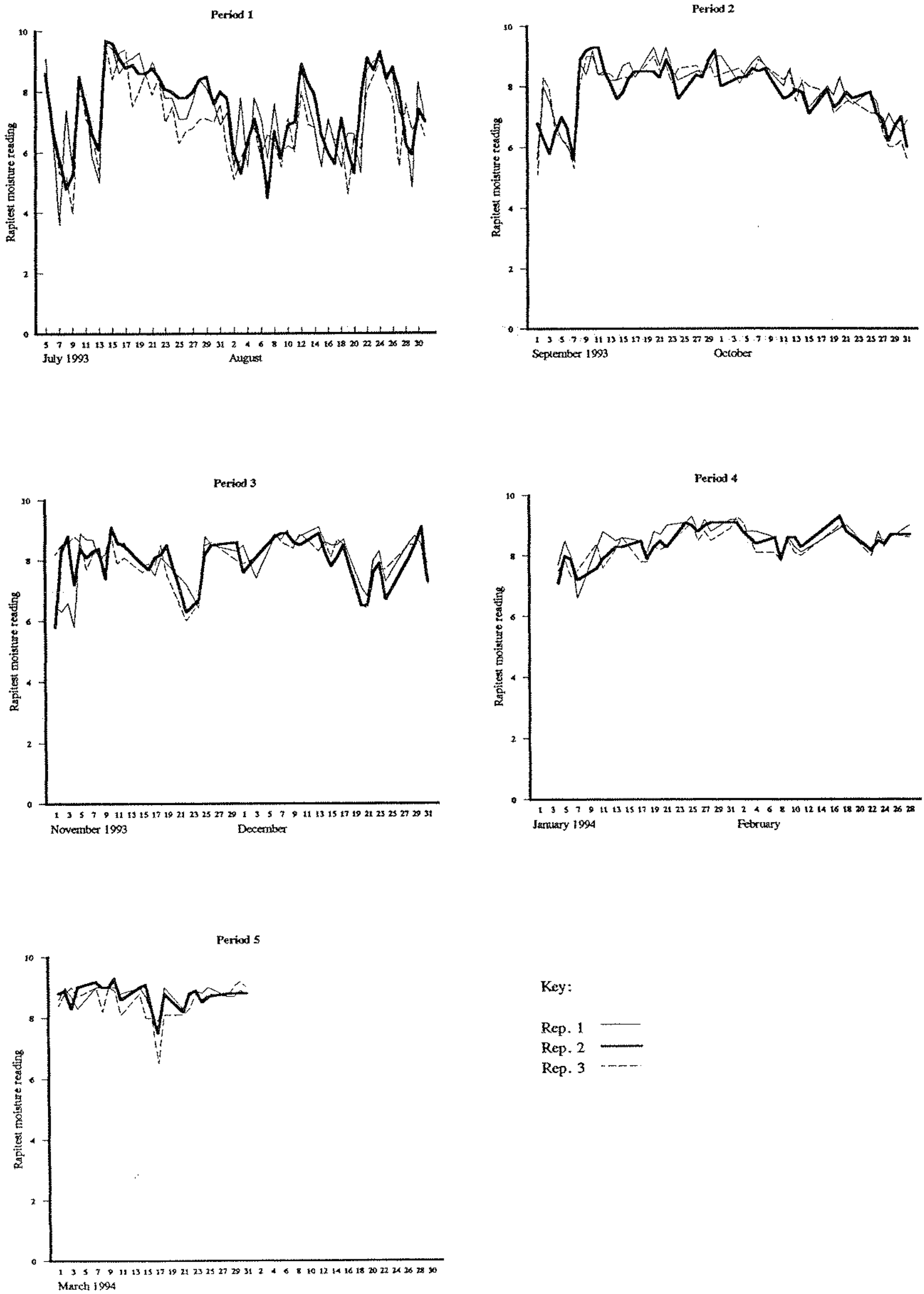


Figure 2f: Year 1 (1993-94): 25mm Sand Bed + Overhead Irrigation (Trt. F)1

Mean daily Rapitest moisture measurements

(average across 4 species)



C. Variation in moisture readings depending on depth taken

Table 1 shows the Rapitest moisture readings taken over the first fortnight in August 1993 for the 4 and 8 cm depths across the six bed types.

As expected there was a clear pattern of the lower horizon of the pot remaining wetter than the upper horizon, showing the importance of taking the measurements at a standard depth, 'calibrated' to ensure irrigation is applied according to plant requirements.

The drier top zone of the container on low level irrigated sand compared with gravel beds was also apparent over time when not interrupted by irrigation or rainfall events.

Preliminary observations before the start of the trial suggested that watering when the Rapitest meter measurements reached 5 would be a useful starting point. However, under the trial conditions *Hydrangea* suffered unacceptable stress (starting to wilt) at these levels. Consequently irrigation was applied when the meter readings fell below 6.

The frequency of irrigation (plus any rainfall) is also indicated in the table, and even over the relatively short period of time in August, the 25 mm gravel bed required 4 irrigations compared to 3 on the low level irrigated sand, where plants were slower to dry due to the reservoir of water held in this depth of sand. Pots on the 75 mm depth of sand with overhead irrigation appeared to dry out faster than the bed with low level irrigation. This, however, could be a reflection of less water reaching the bed from the metered dose applied, due to wind drift or over-spill onto pathways.

The results with the 'infill' beds and 25 mm of sand were more variable, but the 25 mm of sand appeared to enable pots to maintain higher moisture levels over time than the gravel with a 25 mm sand infill, despite both being lined with Mypex.

Table 1 **Rapitest meter moisture measurements at 4 and 8 cm depths in 3 litre containers**

(figures are an average across the 4 species)

® = Rainfall * = Irrigation

Date	Depth	25 mm Gravel	75 mm Sand + Seephose	75 mm Sand + Overhead	25 mm Gravel + 25 mm Sand	25 mm Gravel + 50 mm Sand	25 mm Sand + Overhead
1 Aug 93	4	6.5	8.1	7.8	5.3	6.1	7.0
	8	8.1	9.0	9.4	7.1	8.3	8.8
	Mean	*7.3*	*8.6*	*8.6*	*6.2*	*7.2*	*7.9*
2 Aug 93	4	4.6	5.1	4.5	3.8	3.8	4.6
	8	6.9	6.9	7.1	6.5	6.0	7.8
	Mean	*5.8* *	*6.0*	*5.8* *	*5.1* *	*4.9* *	*6.2*
3 Aug 93	4	5.8	4.8	6.4	5.8	4.3	3.9
	8	7.1	7.3	7.5	7.1	6.1	6.8
	Mean	*6.4*	*6.0*	*7.0*	*6.4*	*5.2* *	*5.3* *
4 Aug 93	4	4.9	2.6	5.0	3.0	4.9	5.8
	8	6.6	4.6	6.8	6.4	6.5	6.9
®	*Mean*	*5.8* *	*3.6* *	*5.9* *	*4.7* *	*5.7* *	*6.3*
5 Aug 93	4	6.5	6.6	7.6	5.9	7.1	6.5
	8	9.5	6.9	9.8	8.6	9.3	7.9
	Mean	*8.0*	*6.8*	*8.7*	*7.3*	*8.2*	*7.2*
6 Aug 93	4	6.6	4.8	6.8	5.1	6.3	5.3
	8	8.1	7.3	8.3	7.0	7.8	7.5
	Mean	*7.3*	*6.0*	*7.5*	*6.1*	*7.1*	*6.4*
7 Aug 93	4	5.8	3.0	5.9	4.0	5.3	3.5
	8	7.1	6.1	7.4	5.9	6.8	5.6
	Mean	*6.4*	*4.6* *	*6.6*	*4.9* *	*6.1*	*4.6* *
8 Aug 93	4	4.9	4.4	4.1	6.4	4.5	5.5
	8	7.4	8.1	6.9	7.9	7.0	8.0
	Mean	*6.1*	*6.3*	*5.5* *	*7.1*	*5.8* *	*6.8*
9 Aug 93	4	4.5	4.9	5.1	5.4	5.9	4.8
	8	7.0	8.6	6.9	7.0	7.5	7.0
	Mean	*5.8* *	*6.8*	*6.0*	*6.2*	*6.7*	*5.9*
10 Aug 93	4	5.9	4.3	5.9	4.9	6.1	6.1
	8	7.4	8.3	7.4	6.9	7.6	7.8
	Mean	*6.6*	*6.3*	*6.6*	*5.9* *	*6.9*	*6.9*
11 Aug 93	4	3.9	4.4	4.3	6.3	4.4	6.3
	8	5.6	7.3	6.5	7.3	6.1	7.9
®	*Mean*	*4.8* *	*5.8* *	*5.4* *	*6.8*	*5.3* *	*7.1*
12 Aug 93	4	8.1	9.1	8.1	5.9	7.5	8.3
	8	9.5	9.8	9.4	7.6	8.1	9.6
	Mean	*8.8*	*9.4*	*8.8*	*6.8*	*7.8*	*8.9*
13 Aug 93	4	8.1	8.8	7.1	6.9	5.9	7.4
	8	8.6	9.3	8.8	8.4	7.9	9.3
	Mean	*8.4*	*9.0*	*7.9*	*7.6*	*6.9*	*8.3*
14 Aug 93	4	6.1	8.5	6.9	5.8	5.8	6.8
	8	8.4	9.3	8.5	7.6	8.0	9.1
	Mean	*7.3*	*8.9*	*7.7*	*6.7*	*6.9*	*7.9*

D. Growing media moisture measurements as influenced by irrigation and rainfall

Figures 3a - 3f show the timing of irrigation and amount applied on each occasion, together with rainfall, linked to water status of the growing media.

The sensitivity of the Rapitest meter in monitoring moisture status of the growing media was again demonstrated by the rapid response achieved in increased water availability immediately following irrigation or rainfall events.

The amount of rainfall during the summer of 1993 meant that occasions on which irrigation was required were relatively limited and occurred in the main during August and early September. The frequency and amount of irrigation applied reflected the influence of bed type on moisture status of the growing media and when rainfall occurred.

The potential of an infill of sand to a gravel bed, particularly the 50mm depth, in making more efficient use of water was demonstrated, compared with the standard 25 mm gravel system, as was the benefit of 75 mm of sand compared with 25 mm.

Heavy rain precluded the need for any irrigation during the rest of September through to the end of October, when a final irrigation was needed following a dry period in late October. At this point in time less water was required on the 75 mm sand beds.

Figure 3a: Year 1 (1993-94): 25mm Gravel Bed + Overhead Irrigation (Trt. A)

Mean daily Rapitest moisture measurements
(average across 4 species x 3 replicates)

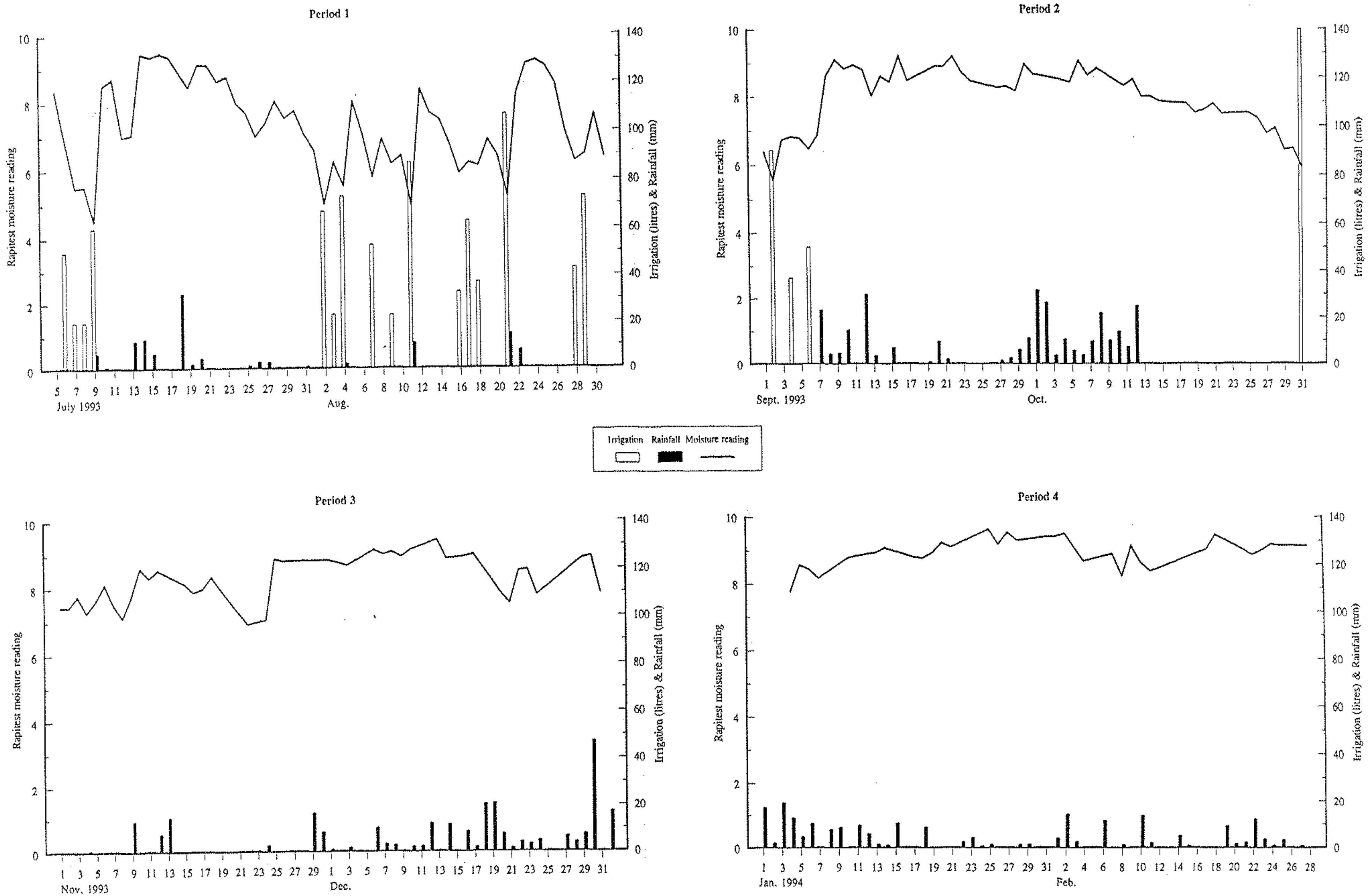


Figure 3b: Year 1 (1993-94): 75mm Sand + Seephose (Trt. B)

Mean daily Rapitest moisture measurements

(average across 4 species x 3 replicates)

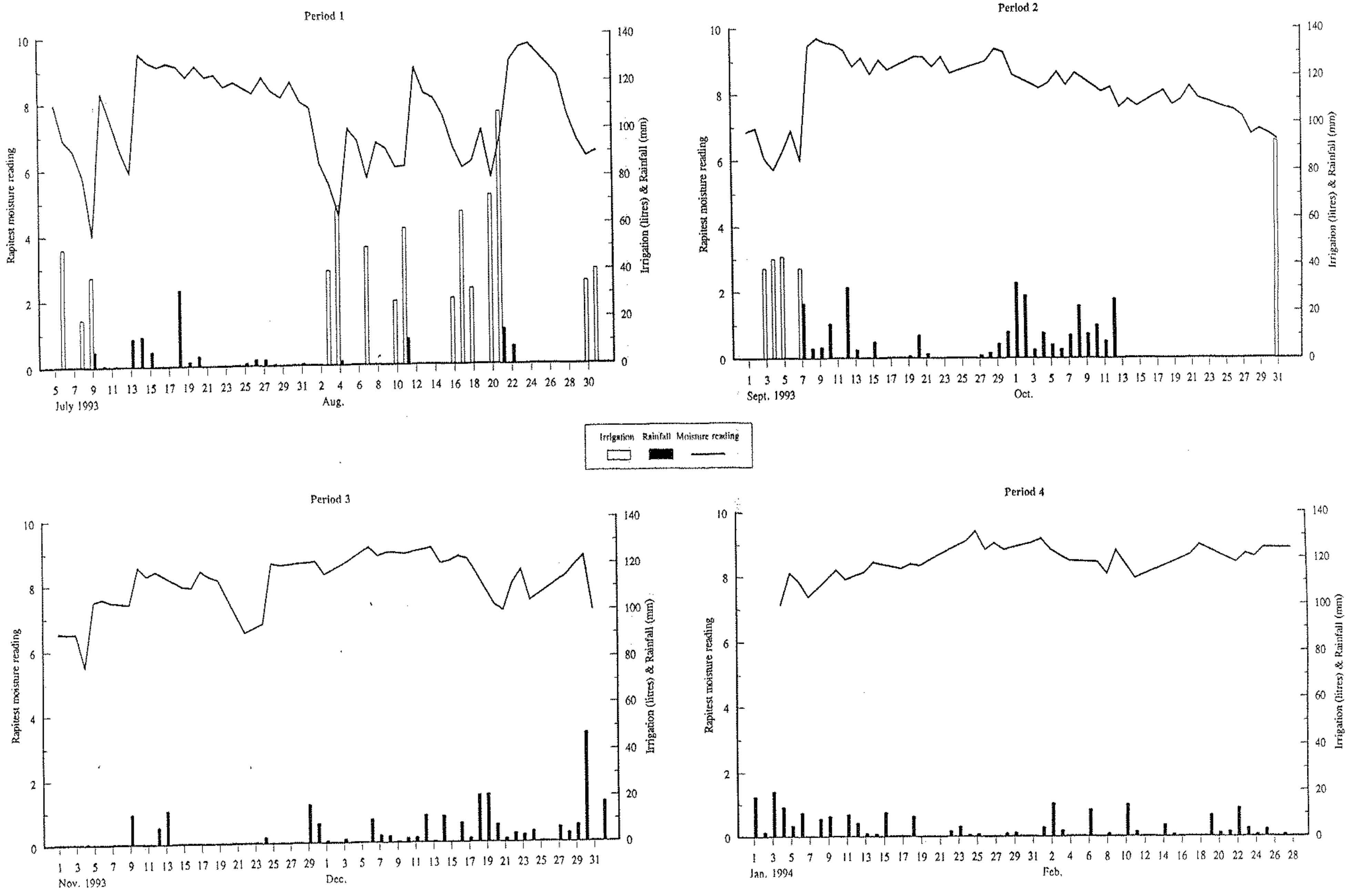


Figure 3c: Year 1 (1993-94): 75mm Sand Bed + Overhead Irrigation (Trt. C)

Mean daily Rapitest moisture measurements

(average across 4 species x 3 replicates)

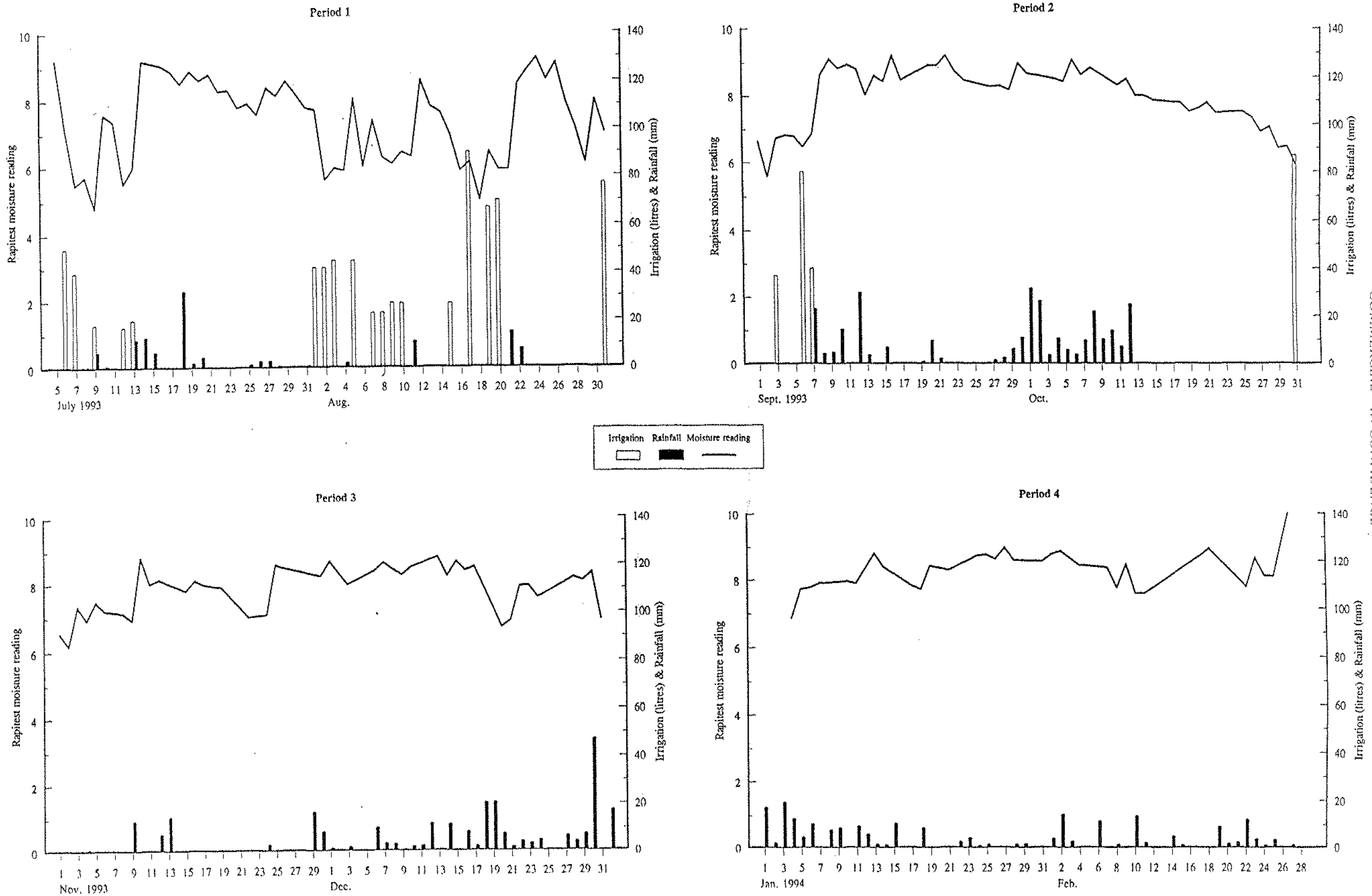


Figure 3d: Year 1 (1993-94): 25mm Gravel + 25mm Sand Infill (Trt. D)

Mean daily Rapitest moisture measurements
(average across 4 species x 3 replicates)

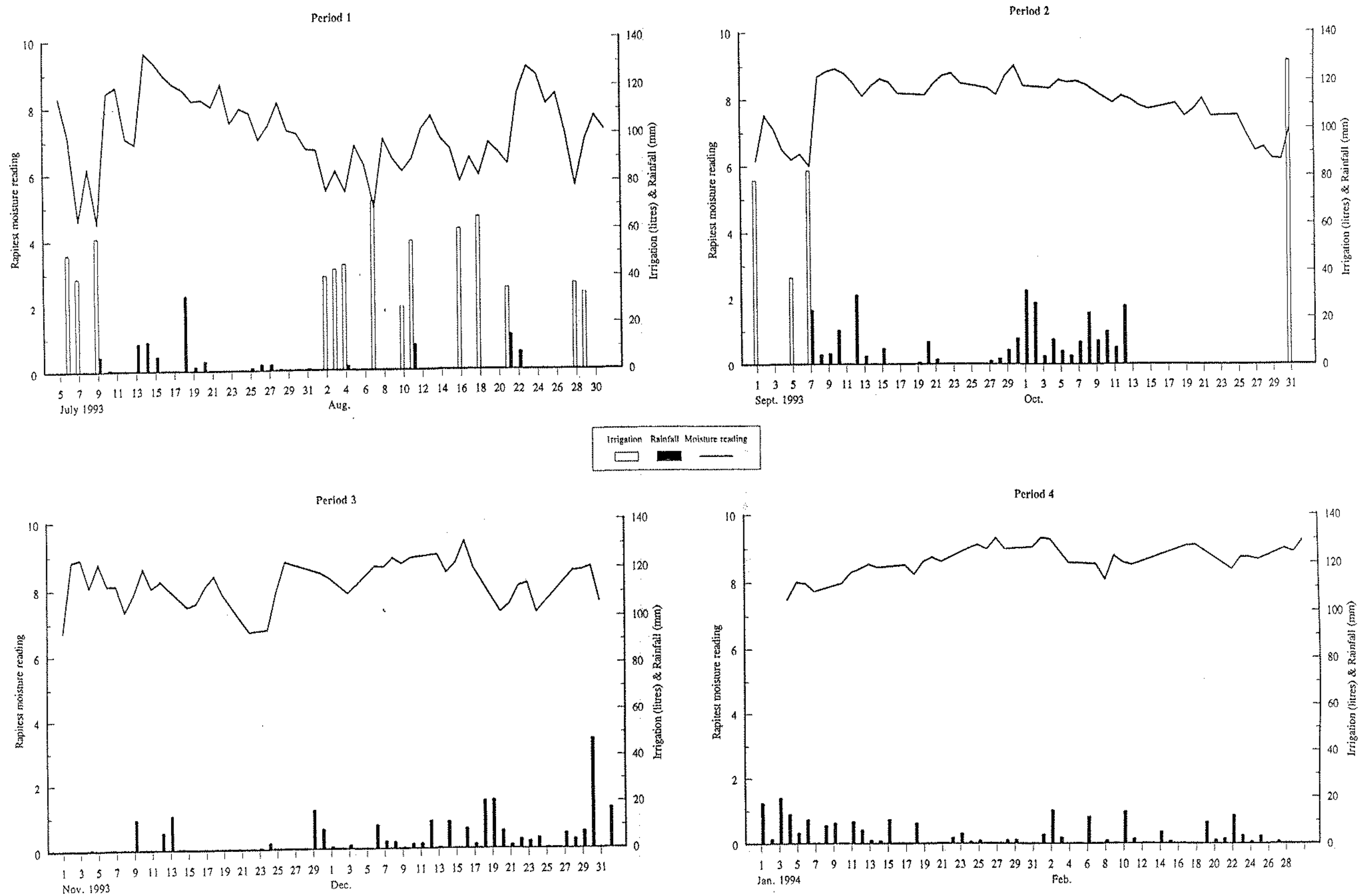


Figure 3e: Year 1 (1993-94): 25mm Gravel + 50mm Sand Infill (Trt. E)

Mean daily Rapitest moisture measurements

(average across 4 species x 3 replicates)

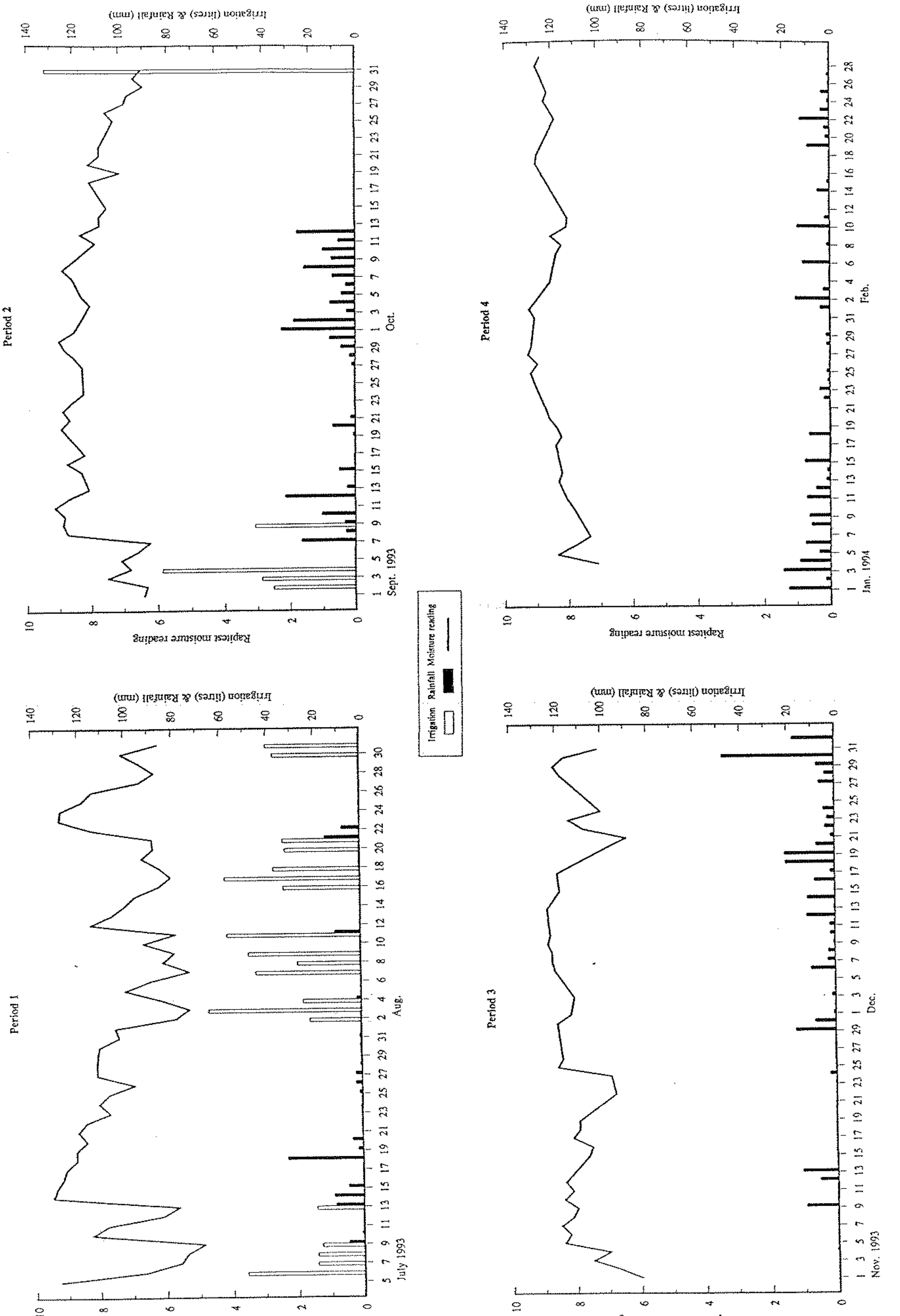
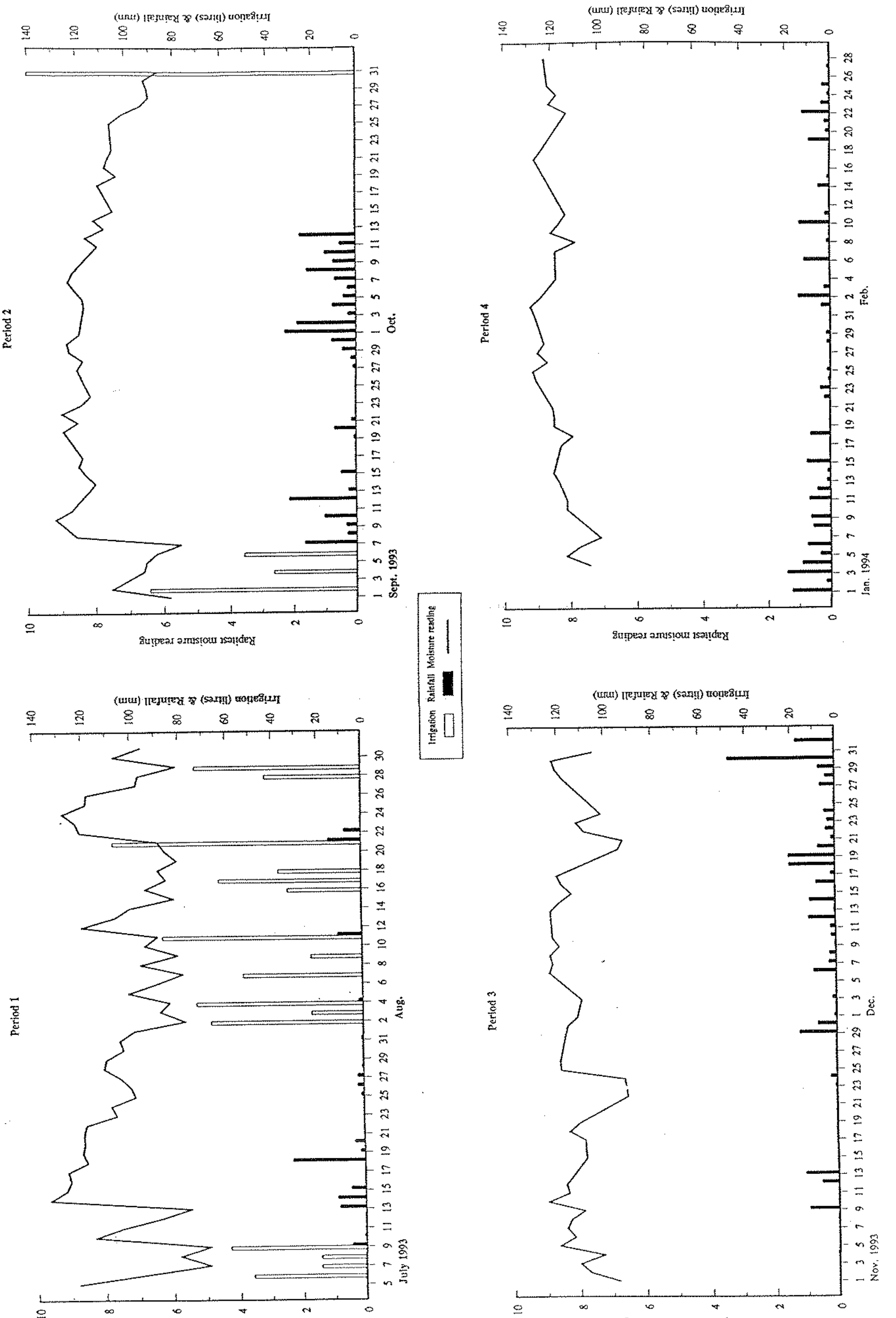


Figure 3f: Year 1 (1993-94): 25mm Sand + Overhead Irrigation (Trt. F)

Mean daily Rapitest moisture measurements

(average across 4 species x 3 replicates)



E. Influence of species on water status fluctuations over time in growing media

The 25 mm of gravel + overhead irrigation and 75 mm of sand with low level irrigation systems are used as illustrations of the influence of species on water status within the growing media (figures 4a and 4b).

The increased water requirement of *Hydrangea*, compared with *Lavandula*, *Genista* and *Cytisus* is clearly shown in both bed systems, with the greater degree of drying out occurring in the gravel bed. The drier upper horizons of the growing media are also clearly defined.

In contrast to *Hydrangea*, the species requiring less water had similar water status readings over time at the 8 cm depth regardless of bed systems. However, when measured at a depth of 4 cm plants on the sand appeared drier, reflecting the drainage pull of the sand and low level irrigation keeping the surface of the container drier.

Since all species were on the same bed, irrigation had to be a compromise of average readings across species. Consequently *Hydrangea* received less than its optimum requirement, while the other species would have been 'over-watered' to some extent. This was adjusted in the second year by only having one species on the bed during the growing season.

Figure 4a: Year 1 (1993-94): 25mm Gravel Bed + Overhead Irrigation (Trt. A)

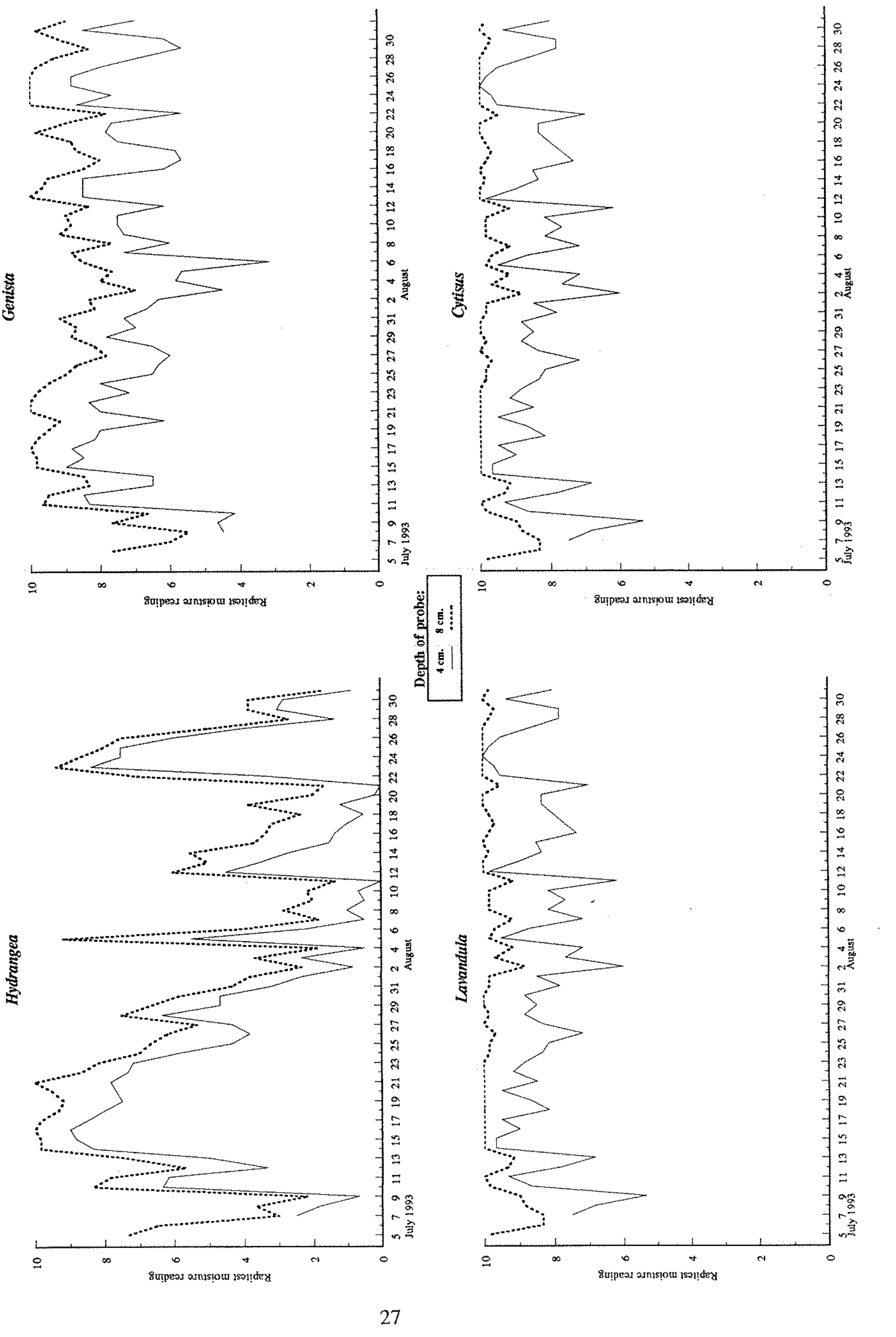
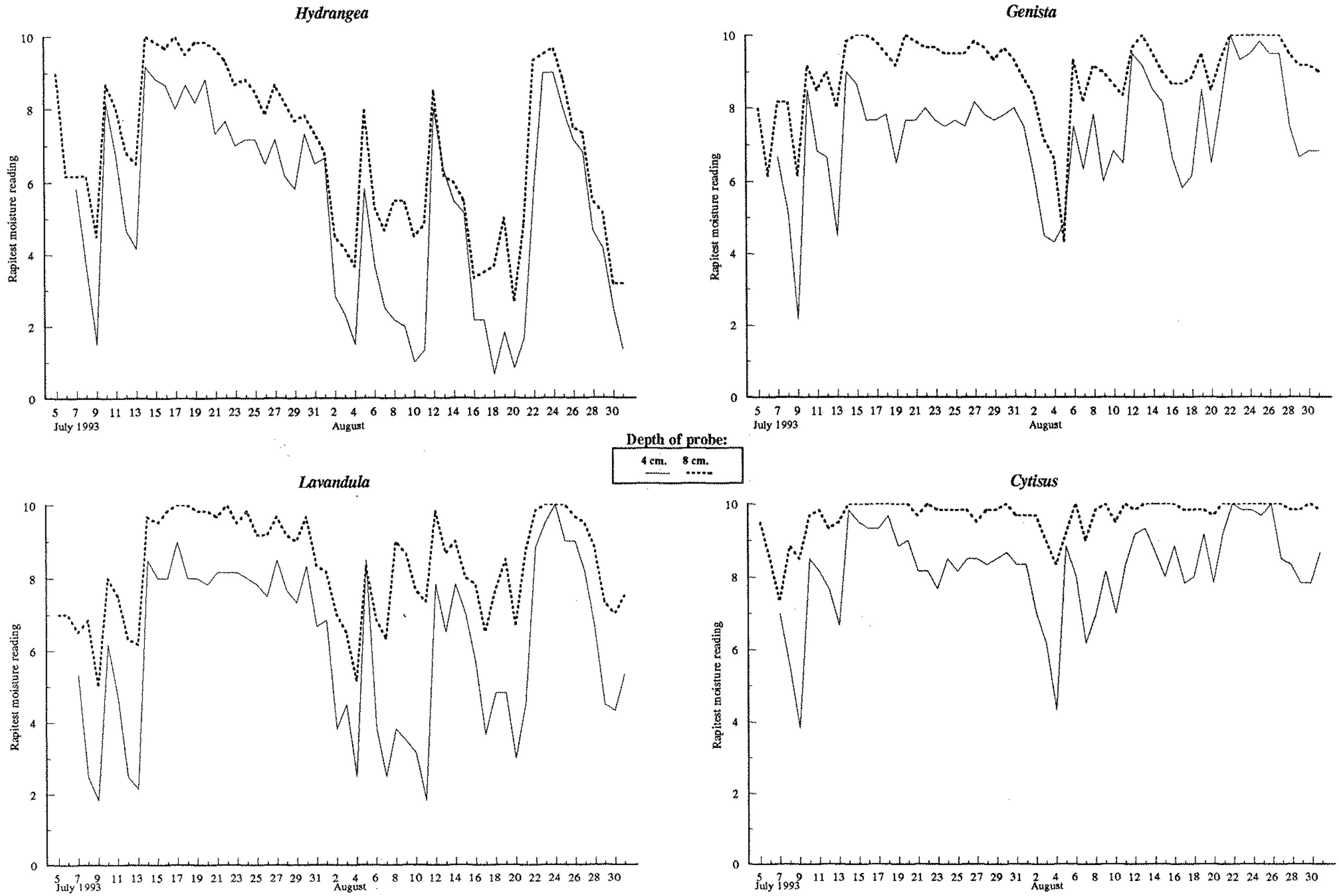


Figure 4b: Year 1 (1993-94): 75mm Sand Bed + Low Level Irrigation (Trt. B)



F. Effect of bed system on moisture status of the growing media for *Hydrangea* and *Lavandula*

In order to consider the influence of bed systems on moisture retention in the growing media in more detail, two species were selected, *Hydrangea* with a high water need and *Lavandula* as a species with a low water requirement. The data is presented in graphic format in Figures 5a-h (*Hydrangea*) and 6a-d (*Lavandula*). The two control treatments, 25 mm gravel and 75 mm sand with seephose have been repeated in each graph for reference against one of the other treatments (4 graphs in total/occasion). In addition, rainfall and irrigation applied are presented in tabular form adjacent to each graph. The full set of results are given for *Hydrangea*, encompassing four periods, July-August and September-October 1993 for the growing season and November-December 1993 and January-February 1994 for the overwintering period. *Lavandula* data covers the July-August 1993 and January-February 1994 periods only for comparison of growing season and overwintering conditions.

Hydrangea

During the first part of the growing season (July-August) the most moisture retentive system overall, which required least irrigation, was the 75 mm sand bed with seephose irrigation (bold line). At the other end of the spectrum containers dried out fastest on the 25 mm gravel system with overhead irrigation.

The closest system to the 75 mm sand + seephose system was the 75 mm sand plus overhead irrigation, though as discussed earlier, this system required more water to compensate that lost by wind drift or into pathways. The 25 mm sand bed with overhead irrigation gave intermediate results between the 75 mm sand and 25 mm gravel systems.

Infilling a 25 mm gravel bed with either 25 or 50mm of sand improved water retention giving similar results to the 25 mm of sand on its own.

During the latter part of the growing season (September-October) a similar pattern of results was observed, though with more rainfall occurring differences between the two 75 mm sand beds with either seephose or overhead irrigation were reduced. As previously, the 25 and 50mm sand infills gave intermediate results between the 75 mm sand and 25 mm gravel systems.

With the onset of autumn rainfall became the dominant influence and moisture status of the growing media was similar across bed systems. However, by January-February the property of the 75 mm drained sand beds to 'pull' water from the container was evident, growing media on these beds having less moisture retained when compared with those on the 25 mm gravel bed, though still well above the irrigation set point.

The 25 mm sand and 25 mm sand infill on gravel were achieving some pot drainage, with moisture readings intermediate between the 25 mm gravel and 75 mm sand beds. The 50mm sand infill on gravel appeared to be achieving a similar pot drainage to the 75 mm sand systems.

Lavandula

The pattern of results with *Lavandula* appeared to be opposite to that seen with *Hydrangea* in that during the growing season, the 75 mm of sand appeared to have drier containers than the gravel or other beds with sand included. This could have been in part due to these plants receiving more water than required, due to irrigation being based on average moisture figures across four species, one of which had a high water requirement (*Hydrangea*). A possible result of the excess water availability could have been increased drainage from the 75 mm sand beds.

Over the winter period (January-February) moisture content of the media from the various systems was remarkably similar, though as with *Hydrangea* the ability of the drained sand to 'pull' water from the container was seen to a limited extent.

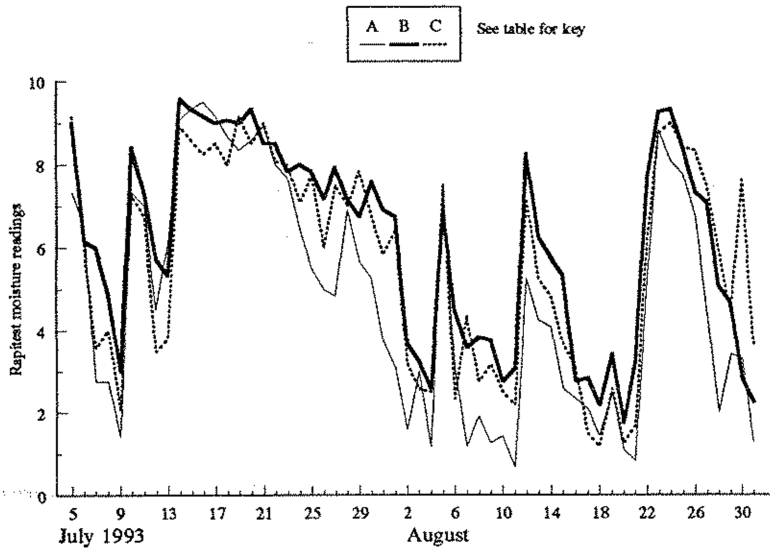
Figure 5a: Year 1 (1993-94): *Hydrangea*

Comparison of Bed Systems: July - August 1993

(figures are an average of 3 replicates)

Irrigation in litres applied/bed ($9m^2$)

Date	A 25mm Gravel	B 75mm Sand +LL irrigation	C 75mm Sand with over-head irrigation	Rainfall (mm)
5-8 July '93	22.5	17.5	22.5	0
9-12 July '93	15	9.6	12	1.85
13-16 July '93	0	0	5	7.85
17-20 July '93	0	0	0	9.65
21-24 July '93	0	0	0	.025
25-28 July '93	0	0	0	1.8
29 -1 Aug. '93	0	0	0	.0375
2-5 Aug. '93	40.8	27.1	32.1	.5
6-9 Aug. '93	19.2	12.5	5.8	0
10-13 Aug. '93	21.8	21.3	13.3	2.75
14-17 Aug. '93	24.2	23.3	6.7	0
18-21 Aug. '93	35.8	25.8	56.7	3.725
22-25 Aug. '93	0	0	0	1.975
26-29 Aug. '93	29.2	0	19.2	0
30-31 Aug. '93	0	37.5	0	0



Irrigation in litres applied/bed ($9m^2$)

Date	A 25mm Gravel	B 75mm Sand +LL irrigation	F 25mm Sand	Rainfall (mm)
5-8 July '93	22.5	17.5	22.5	0
9-12 July '93	15	9.6	12	1.85
13-16 July '93	0	0	0	7.85
17-20 July '93	0	0	0	9.65
21-24 July '93	0	0	0	.025
25-28 July '93	0	0	0	1.8
29 -1 Aug. '93	0	0	0	.0375
2-5 Aug. '93	40.8	27.1	32.1	.5
6-9 Aug. '93	19.2	12.5	17.9	0
10-13 Aug. '93	21.8	21.3	20.4	2.75
14-17 Aug. '93	24.2	23.3	15	0
18-21 Aug. '93	35.8	25.8	16.7	3.725
22-25 Aug. '93	0	0	0	1.975
26-29 Aug. '93	29.2	0	17.5	0
30-31 Aug. '93	0	37.5	0	0

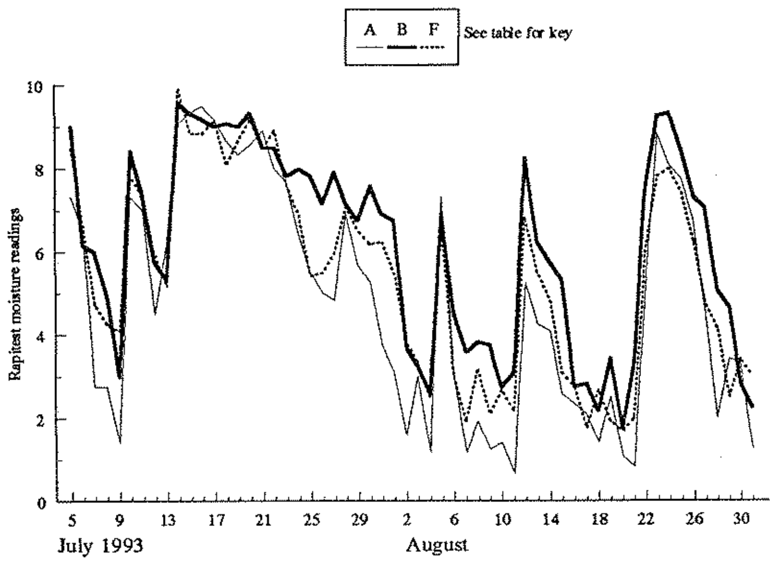


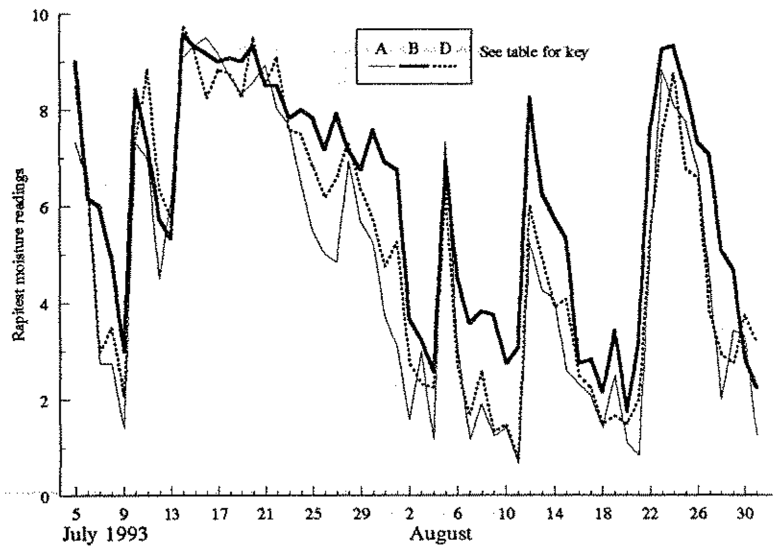
Figure 5b: Year 1 (1993-94): *Hydrangea*

Comparison of Bed Systems: July - August 1993

(figures are an average of 3 replicates)

Irrigation in litres applied/bed (9m²)

Date	A 25mm Gravel	B 75mm Sand +LL irrigation	D 25mm Gravel + 25mm sand	Rainfall (mm)
5-8 July '93	22.5	17.5	22.5	0
9-12 July '93	15	9.6	12	1.85
13-16 July '93	0	0	0	7.85
17-20 July '93	0	0	0	9.65
21-24 July '93	0	0	0	.025
25-28 July '93	0	0	0	1.8
29 -1 Aug. '93	0	0	0	.0375
2-5 Aug. '93	40.8	27.1	32.1	.5
6-9 Aug. '93	19.2	12.5	17.9	0
10-13 Aug. '93	21.8	21.3	20.4	2.75
14-17 Aug. '93	24.2	23.3	15	0
18-21 Aug. '93	35.8	25.8	16.7	3.725
22-25 Aug. '93	0	0	0	1.975
26-29 Aug. '93	29.2	0	17.5	0
30-31 Aug. '93	0	37.5	0	0



Irrigation in litres applied/bed (9m²)

Date	A 25mm Gravel	B 75mm Sand +LL irrigation	E 25mm Gravel + 50mm Sand	Rainfall (mm)
5-8 July '93	22.5	17.5	22.5	0
9-12 July '93	15	9.6	4.6	1.85
13-16 July '93	0	0	5	7.85
17-20 July '93	0	0	0	9.65
21-24 July '93	0	0	0	.025
25-28 July '93	0	0	0	1.8
29 -1 Aug. '93	0	0	0	.0375
2-5 Aug. '93	40.8	27.1	27.9	.5
6-9 Aug. '93	19.2	12.5	30	0
10-13 Aug. '93	21.8	21.3	12	2.75
14-17 Aug. '93	24.2	23.3	22.9	0
18-21 Aug. '93	35.8	25.8	25.4	3.725
22-25 Aug. '93	0	0	0	1.975
26-29 Aug. '93	29.2	0	19.2	0
30-31 Aug. '93	0	37.5	17.5	0

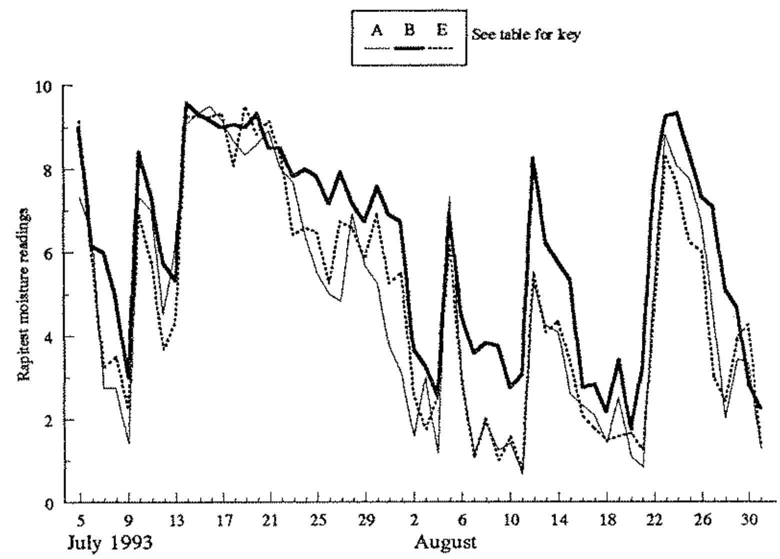


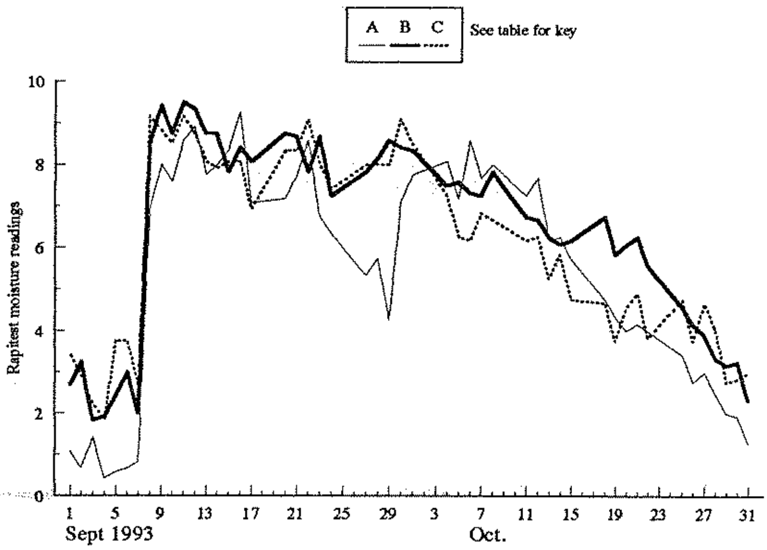
Figure 5c: Year 1 (1993-94): *Hydrangea*

Comparison of Bed Systems: September - October 1993

(figures are an average of 3 replicates)

Irrigation in litres applied/bed (9m²)

Date	A 25mm Gravel	B 75mm Sand +LL irrigation	C 75mm Sand with over-head irrigation	Rainfall (mm)
1-4 Sept '93	31.7	20	29.2	0
5-8 Sept '93	12.5	20.4	10	6.825
9-12 Sept '93	0	0	0	12.275
13-16 Sept '93	0	0	0	2.65
17-20 Sept '93	0	0	0	2.65
22-24 Sept '93	0	0	0	.525
22-28 Sept. '93	0	0	0	.95
29-2 Oct. '93	0	0	0	18.775
3-6 Oct. '93	0	0	0	5.925
7-10 Oct. '93	0	0	0	13.85
11-14 Oct. '93	0	0	0	8.025
15-18 Oct. '93	0	0	0	0
19-22 Oct. '93	0	0	0	.05
23-26 Oct. '93	0	0	0	0
27-31 Oct. '93	18.7	0	11.7	0



Irrigation in litres applied/bed (9m²)

Date	A 25mm Gravel	B 75mm Sand +LL irrigation	F 25mm sand	Rainfall (mm)
1-4 Sept '93	31.7	20	28.8	0
5-8 Sept '93	12.5	20.4	31.25	6.825
9-12 Sept '93	0	0	0	12.275
13-16 Sept '93	0	0	0	2.65
17-20 Sept '93	0	0	0	2.65
22-24 Sept '93	0	0	0	.525
22-28 Sept. '93	0	0	0	.95
29-2 Oct. '93	0	0	0	18.775
3-6 Oct. '93	0	0	0	5.925
7-10 Oct. '93	0	0	0	13.85
11-14 Oct. '93	0	0	0	8.025
15-18 Oct. '93	0	0	0	0
19-22 Oct. '93	0	0	0	.05
23-26 Oct. '93	0	0	0	0
27-31 Oct. '93	18.7	0	11.3	0

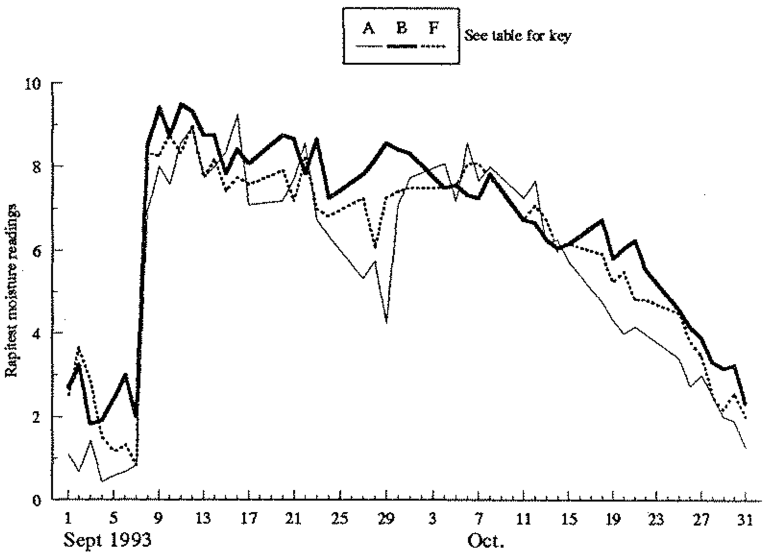


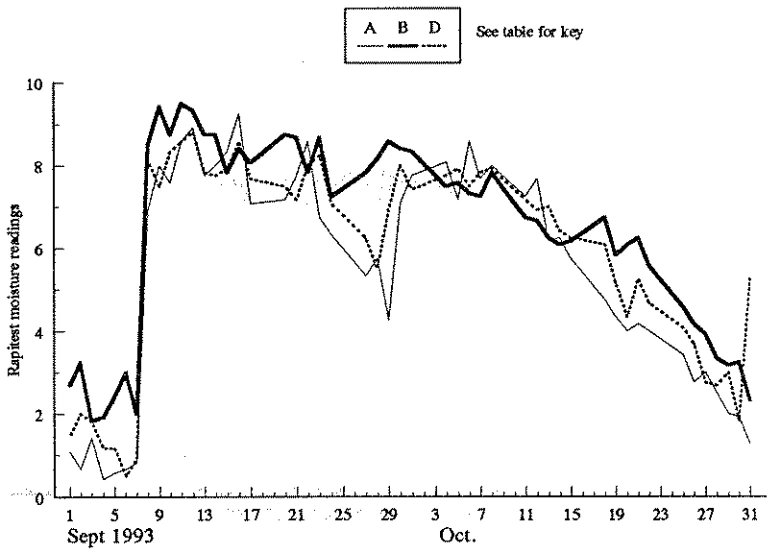
Figure 5d: Year 1 (1993-94): *Hydrangea*

Comparison of Bed Systems: September - October 1993

(figures are an average of 3 replicates)

Irrigation in litres applied/bed ($9m^2$)

Date	A 25mm Gravel	B 75mm Sand +LL irrigation	D 25mm Gravel + 25mm sand	Rainfall (mm)
1-4 Sept '93	31.7	20	19.6	0
5-8 Sept '93	12.5	20.4	29.6	6.825
9-12 Sept '93	0	0	0	12.275
13-16 Sept '93	0	0	0	2.65
17-20 Sept '93	0	0	0	2.65
22-24 Sept '93	0	0	0	.525
22-28 Sept. '93	0	0	0	.95
29-2 Oct. '93	0	0	0	18.775
3-6 Oct. '93	0	0	0	5.925
7-10 Oct. '93	0	0	0	13.85
11-14 Oct. '93	0	0	0	8.025
15-18 Oct. '93	0	0	0	0
19-22 Oct. '93	0	0	0	.05
23-26 Oct. '93	0	0	0	0
27-31 Oct. '93	18.7	0	20.4	0



Irrigation in litres applied/bed ($9m^2$)

Date	A 25mm Gravel	B 75mm Sand +LL irrigation	E 25mm Gravel + 50mm sand	Rainfall (mm)
1-4 Sept '93	31.7	20	30.4	0
5-8 Sept '93	12.5	20.4	10.8	6.825
9-12 Sept '93	0	0	0	12.275
13-16 Sept '93	0	0	0	2.65
17-20 Sept '93	0	0	0	2.65
22-24 Sept '93	0	0	0	.525
22-28 Sept. '93	0	0	0	.95
29-2 Oct. '93	0	0	0	18.775
3-6 Oct. '93	0	0	0	5.925
7-10 Oct. '93	0	0	0	13.85
11-14 Oct. '93	0	0	0	8.025
15-18 Oct. '93	0	0	0	0
19-22 Oct. '93	0	0	0	.05
23-26 Oct. '93	0	0	0	0
27-31 Oct. '93	18.7	0	0	0

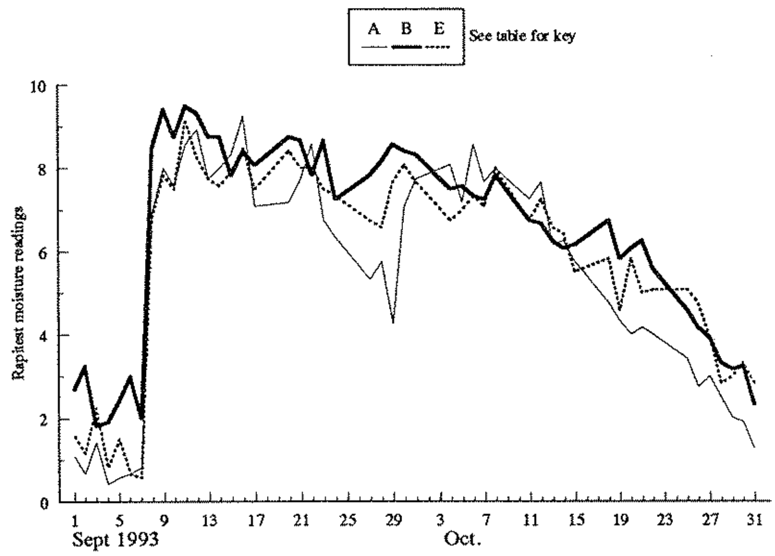


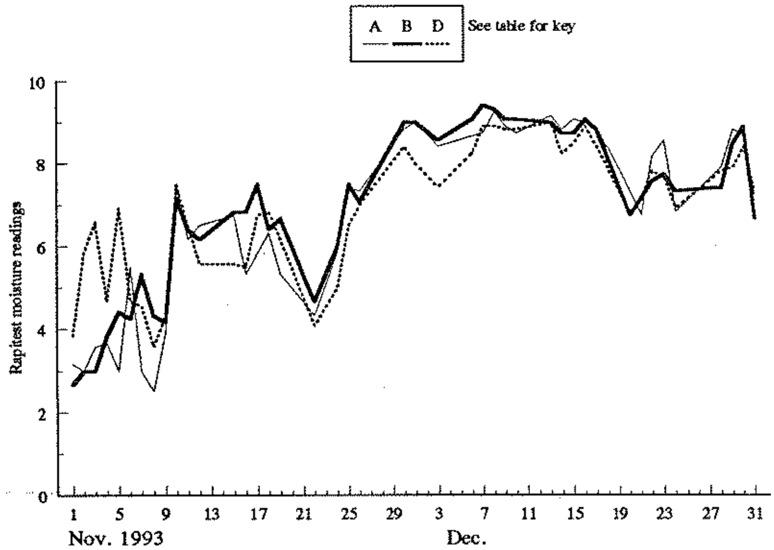
Figure 5e Year 1 (1993-94): *Hydrangea*

Comparison of Bed Systems: November - December 1993

(figures are an average of 3 replicates)

Irrigation in litres applied/bed (9m²)

Date	A 25mm Gravel	B 75mm Sand +LL irrigation	D 25mm Gravel + 25mm sand	Rainfall (mm)
1-4 Nov. '93	0	22.9	11.7	0.25
5-8 Nov. '93	11.7	0	0	0
9-12 Npv. '93	0	0	0	5.1
13-16 Nov. '93	0	0	0	3.65
17-20 Nov. '93	0	0	0	0
21-24 Nov. '93	0	0	0	.775
25-28 Nov. '93	0	0	0	.05
29-2 Dec. '93	0	0	0	6.5
3-6 Dec. '93	0	0	0	2.975
7-10 Dec. '93	20	0	0	2.075
11-14 Dec. '93	0	0	0	6.5
15-18 Dec. '93	0	0	0	7.725
19-22 Dec. '93	0	0	0	8.425
23-26 Dec '93	0	0	0	2.05
27 31 Dec. '93	0	0	0	13.02



Irrigation in litres applied/bed (9m²)

Date	A 25mm Gravel	B 75mm Sand +LL irrigation	E 25mm Gravel + 50mm sand	Rainfall (mm)
1-4 Nov. '93	0	22.9	32.9	0.25
5-8 Nov. '93	11.7	0	0	0
9-12 Npv. '93	0	0	0	5.1
13-16 Nov. '93	0	0	0	3.65
17-20 Nov. '93	0	0	0	0
21-24 Nov. '93	0	0	0	.775
25-28 Nov. '93	0	0	0	.05
29-2 Dec. '93	0	0	0	6.5
3-6 Dec. '93	0	0	0	2.975
7-10 Dec. '93	20	0	0	2.075
11-14 Dec. '93	0	0	0	6.5
15-18 Dec. '93	0	0	0	7.725
19-22 Dec. '93	0	0	0	8.425
23-26 Dec '93	0	0	0	2.05
27 31 Dec. '93	0	0	0	13.02

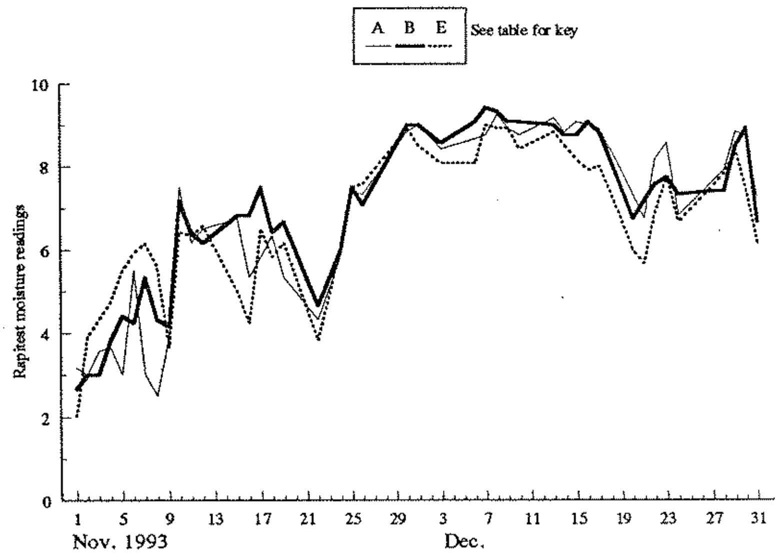


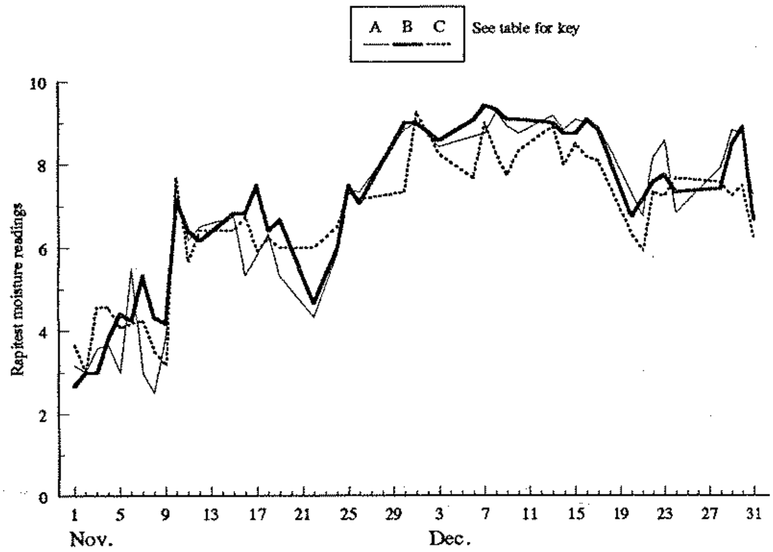
Figure 5f: Year 1 (1993-94): *Hydrangea*

Comparison of Bed Systems: November - December 1993

(figures are an average of 3 replicates)

Irrigation in litres applied/bed ($9m^2$)

Date	A 25mm Gravel	B 75mm Sand +LL irrigation	C 75mm Sand with over-head irrigation	Rainfall (mm)
1-4 Nov. '93	0	22.9	10	0.25
5-8 Nov. '93	11.7	0	0	0
9-12 Npv. '93	0	0	0	5.1
13-16 Nov. '93	0	0	0	3.65
17-20 Nov. '93	0	0	0	0
21-24 Nov. '93	0	0	0	.775
25-28 Nov. '93	0	0	0	.05
29-2 Dec. '93	0	0	0	6.5
3-6 Dec. '93	0	0	0	2.975
7-10 Dec. '93	20	0	0	2.075
11-14 Dec. '93	0	0	0	6.5
15-18 Dec. '93	0	0	0	7.725
19-22 Dec. '93	0	0	0	8.425
23-26 Dec '93	0	0	0	2.05
27 31 Dec. '93	0	0	0	13.02



Irrigation in litres applied/bed ($9m^2$)

Date	A 25mm Gravel	B 75mm Sand +LL irrigation	F 25mm sand	Rainfall (mm)
1-4 Nov. '93	0	22.9	22.5	0.25
5-8 Nov. '93	11.7	0	0	0
9-12 Npv. '93	0	0	0	5.1
13-16 Nov. '93	0	0	0	3.65
17-20 Nov. '93	0	0	0	0
21-24 Nov. '93	0	0	0	.775
25-28 Nov. '93	0	0	0	.05
29-2 Dec. '93	0	0	0	6.5
3-6 Dec. '93	0	0	0	2.975
7-10 Dec. '93	20	0	0	2.075
11-14 Dec. '93	0	0	0	6.5
15-18 Dec. '93	0	0	0	7.725
19-22 Dec. '93	0	0	0	8.425
23-26 Dec '93	0	0	0	2.05
27 31 Dec. '93	0	0	0	13.02

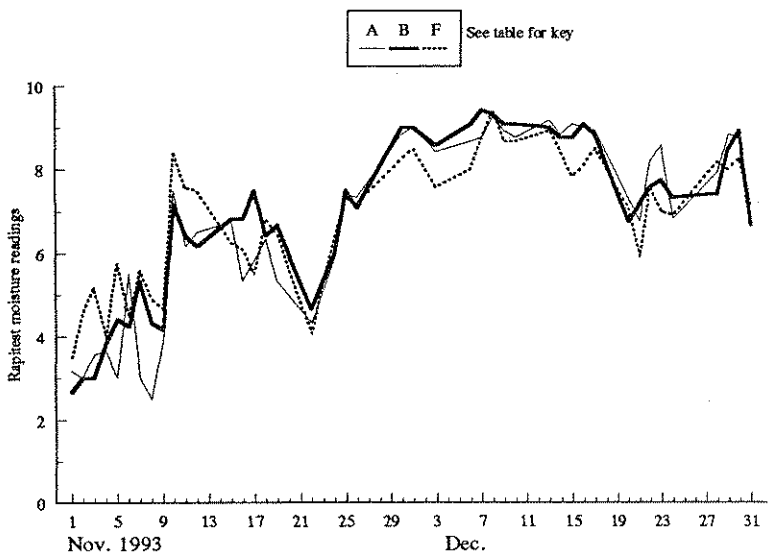


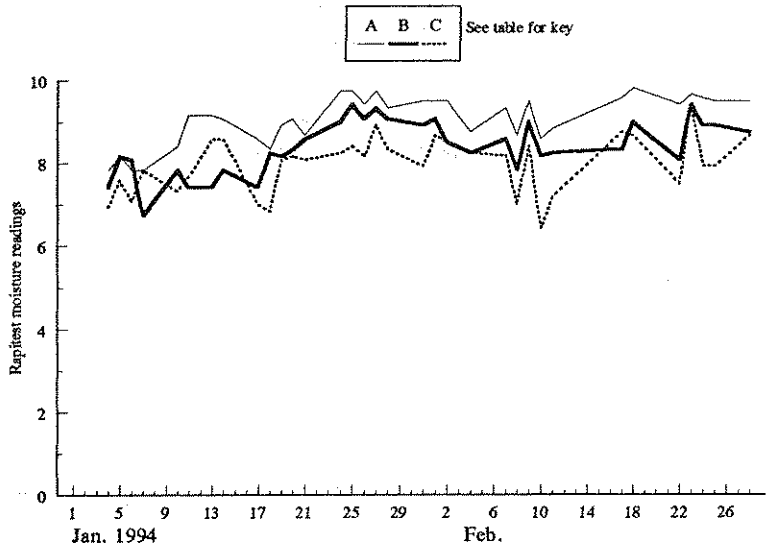
Figure 5g: Year 1 (1993-94): *Hydrangea*

Comparison of Bed Systems: January - February 1994

(figures are an average of 3 replicates)

Irrigation in litres applied/bed ($9m^2$)

Date	A 25mm Gravel	B 75mm Sand +LL irrigation	C 75mm sand with over-head irrigation	Rainfall (mm)
1-4 Jan. '94	0	0	0	12.875
5-8 Jan. '94	0	0	0	5.7
9-12 Jan.. '95	0	0	0	6.05
13-16 Jan. '94	0	0	0	3.275
17-20 Jan. '94	0	0	0	2.2
21-24 Jan. '94	0	0	0	1.85
25-28 Jan. '94	0	0	0	0.7
29-1 Feb. '94	0	0	0	1.375
2-5 Feb. '94	0	0	0	4.25
6-9 Feb. '94	0	0	0	3.175
10-13 Feb. '94	0	0	0	3.925
14-17 Feb. '94	0	0	0	1.525
18-21 Feb. '94	0	0	0	3.25
22-25 Feb. '94	0	0	0	4.975
26-28 Feb. '94	0	0	0	.37



Irrigation in litres applied/bed ($9m^2$)

Date	A 25mm Gravel	B 75mm Sand +LL irrigation	F 25mm sand	Rainfall (mm)
1-4 Jan. '94	0	0	0	12.875
5-8 Jan. '94	0	0	0	5.7
9-12 Jan.. '95	0	0	0	6.05
13-16 Jan. '94	0	0	0	3.275
17-20 Jan. '94	0	0	0	2.2
21-24 Jan. '94	0	0	0	1.85
25-28 Jan. '94	0	0	0	0.7
29-1 Feb. '94	0	0	0	1.375
2-5 Feb. '94	0	0	0	4.25
6-9 Feb. '94	0	0	0	3.175
10-13 Feb. '94	0	0	0	3.925
14-17 Feb. '94	0	0	0	1.525
18-21 Feb. '94	0	0	0	3.25
22-25 Feb. '94	0	0	0	4.975
26-28 Feb. '94	0	0	0	.37

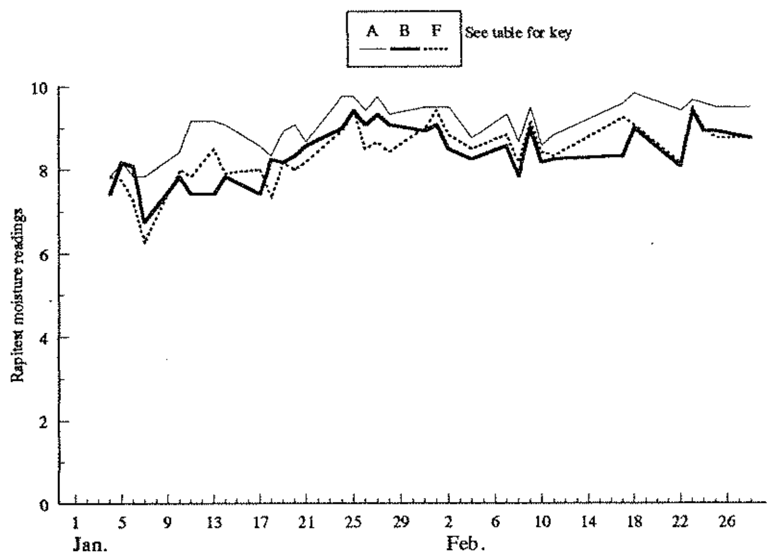


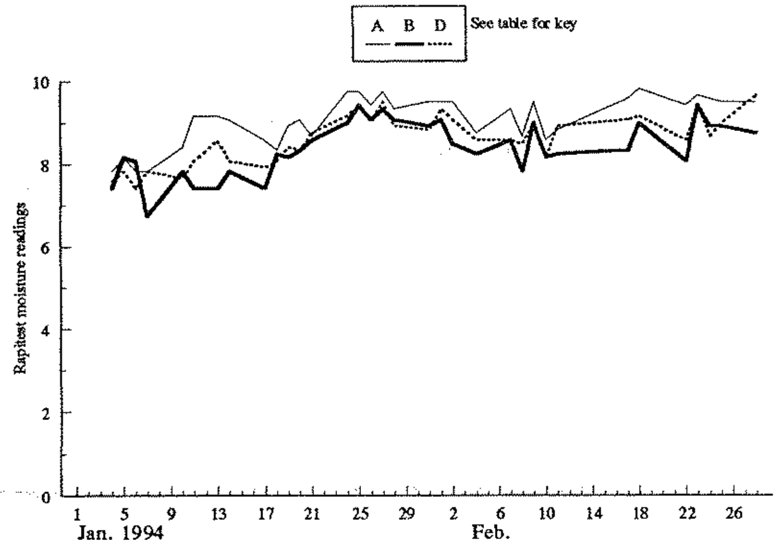
Figure 5h: Year 1 (1993-94): *Hydrangea*

Comparison of Bed Systems: January - February 1994

(figures are an average of 3 replicates)

Irrigation in litres applied/bed ($9m^2$)

Date	A 25mm Gravel	B 75mm Sand +LL irrigation	D 25mm Gravel + 25mm sand	Rainfall (mm)
1-4 Jan. '94	0	0	0	12.875
5-8 Jan. '94	0	0	0	5.7
9-12 Jan. '9$	0	0	0	6.05
13-16 Jan. '94	0	0	0	3.275
17-20 Jan. '94	0	0	0	2.2
21-24 Jan. '94	0	0	0	1.85
25-28 Jan. '94	0	0	0	0.7
29-1 Feb. '94	0	0	0	1.375
2-5 Feb. '94	0	0	0	4.25
6-9 Feb. '94	0	0	0	3.175
10-13 Feb. '94	0	0	0	3.925
14-17 Feb. '94	0	0	0	1.525
18-21 Feb. '94	0	0	0	3.25
22-25 Feb. '94	0	0	0	4.975
26-28 Feb. '94	0	0	0	.37



Irrigation in litres applied/bed ($9m^2$)

Date	A 25mm Gravel	B 75mm Sand +LL irrigation	E 25mm Gravel + 50mm sand	Rainfall (mm)
1-4 Jan. '94	0	0	0	12.875
5-8 Jan. '94	0	0	0	5.7
9-12 Jan. '9$	0	0	0	6.05
13-16 Jan. '94	0	0	0	3.275
17-20 Jan. '94	0	0	0	2.2
21-24 Jan. '94	0	0	0	1.85
25-28 Jan. '94	0	0	0	0.7
29-1 Feb. '94	0	0	0	1.375
2-5 Feb. '94	0	0	0	4.25
6-9 Feb. '94	0	0	0	3.175
10-13 Feb. '94	0	0	0	3.925
14-17 Feb. '94	0	0	0	1.525
18-21 Feb. '94	0	0	0	3.25
22-25 Feb. '94	0	0	0	4.975
26-28 Feb. '94	0	0	0	.37

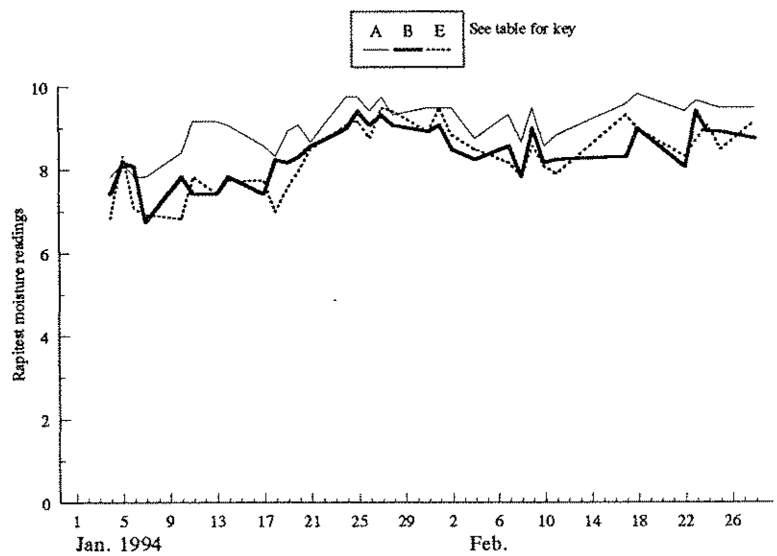


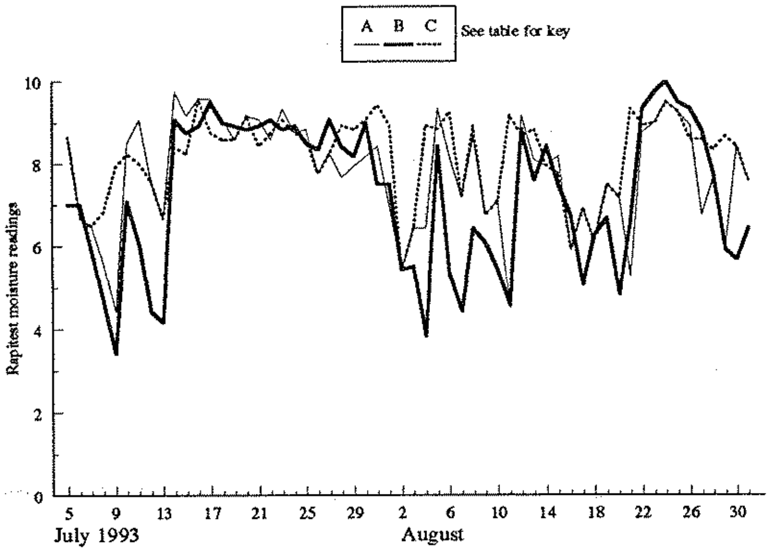
Figure 6a: Year 1 (1993-94): *Lavandula*

Comparison of Bed Systems: July - August 1993

(figures are an average of 3 replicates)

Irrigation in litres applied/bed (9m²)

Date	A 25mm Gravel	B 75mm Sand +LL irrigation	C 75mm Sand with over-head irrigation	Rainfall (mm)
5-8 July '93	22.5	17.5	22.5	0
9-12 July '93	15	9.6	12	1.85
13-16 July '93	0	0	5	7.85
17-20 July '93	0	0	0	9.65
21-24 July '93	0	0	0	.025
25-28 July '93	0	0	0	1.8
29 -1 Aug. '93	0	0	0	.0375
2-5 Aug. '93	40.8	27.1	32.1	.5
6-9 Aug. '93	19.2	12.5	5.8	0
10-13 Aug. '93	21.8	21.3	13.3	2.75
14-17 Aug. '93	24.2	23.3	6.7	0
18-21 Aug. '93	35.8	25.8	56.7	3.725
22-25 Aug. '93	0	0	0	1.975
26-29 Aug. '93	29.2	0	19.2	0
30-31 Aug. '93	0	37.5	0	0



Irrigation in litres applied/bed (9m²)

Date	A 25mm Gravel	B 75mm Sand +LL irrigation	F 25mm Sand	Rainfall (mm)
5-8 July '93	22.5	17.5	22.5	0
9-12 July '93	15	9.6	12	1.85
13-16 July '93	0	0	0	7.85
17-20 July '93	0	0	0	9.65
21-24 July '93	0	0	0	.025
25-28 July '93	0	0	0	1.8
29 -1 Aug. '93	0	0	0	.0375
2-5 Aug. '93	40.8	27.1	32.1	.5
6-9 Aug. '93	19.2	12.5	17.9	0
10-13 Aug. '93	21.8	21.3	20.4	2.75
14-17 Aug. '93	24.2	23.3	15	0
18-21 Aug. '93	35.8	25.8	16.7	3.725
22-25 Aug. '93	0	0	0	1.975
26-29 Aug. '93	29.2	0	17.5	0
30-31 Aug. '93	0	37.5	0	0

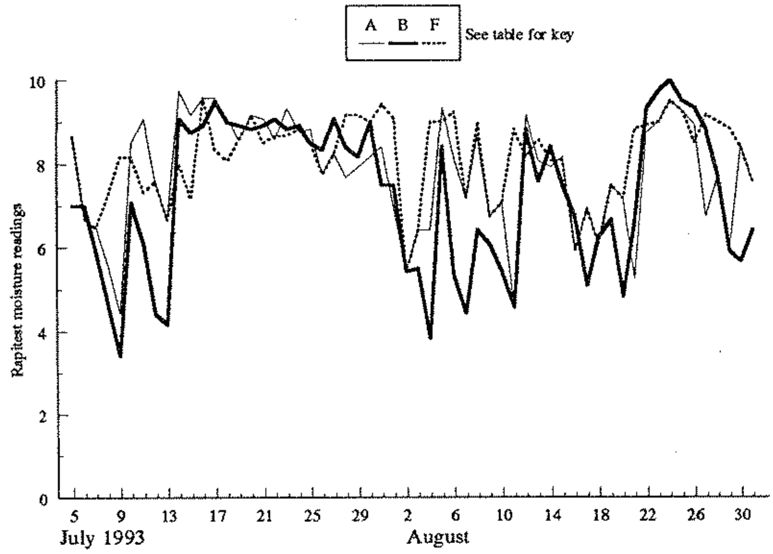


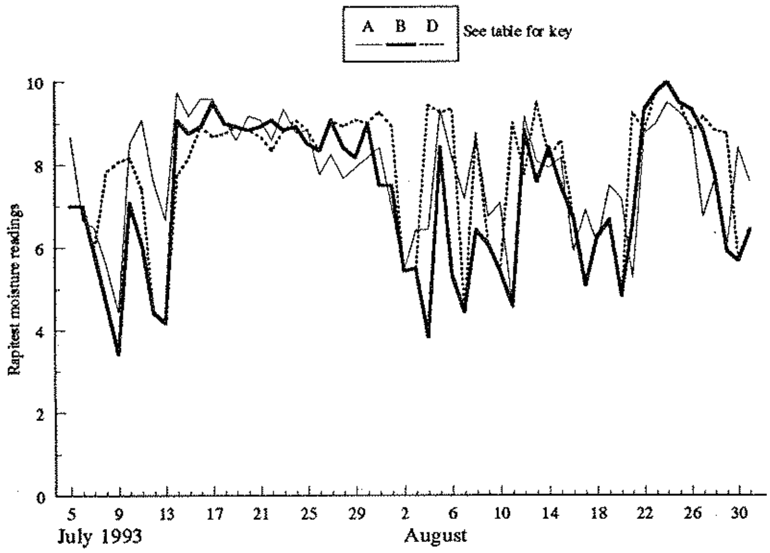
Figure 6b: Year 1 (1993-94): *Lavandula*

Comparison of Bed Systems: July - August 1993

(figures are an average of 3 replicates)

Irrigation in litres applied/bed ($9m^2$)

Date	A 25mm Gravel	B 75mm Sand +LL irrigation	D 25mm Gravel + 25mm sand	Rainfall (mm)
5-8 July '93	22.5	17.5	22.5	0
9-12 July '93	15	9.6	12	1.85
13-16 July '93	0	0	0	7.85
17-20 July '93	0	0	0	9.65
21-24 July '93	0	0	0	.025
25-28 July '93	0	0	0	1.8
29 -1 Aug. '93	0	0	0	.0375
2-5 Aug. '93	40.8	27.1	32.1	.5
6-9 Aug. '93	19.2	12.5	17.9	0
10-13 Aug. '93	21.8	21.3	20.4	2.75
14-17 Aug. '93	24.2	23.3	15	0
18-21 Aug. '93	35.8	25.8	16.7	3.725
22-25 Aug. '93	0	0	0	1.975
26-29 Aug. '93	29.2	0	17.5	0
30-31 Aug. '93	0	37.5	0	0



Irrigation in litres applied/bed ($9m^2$)

Date	A 25mm Gravel	B 75mm Sand +LL irrigation	E 25mm Gravel + 50mm Sand	Rainfall (mm)
5-8 July '93	22.5	17.5	22.5	0
9-12 July '93	15	9.6	4.6	1.85
13-16 July '93	0	0	5	7.85
17-20 July '93	0	0	0	9.65
21-24 July '93	0	0	0	.025
25-28 July '93	0	0	0	1.8
29 -1 Aug. '93	0	0	0	.0375
2-5 Aug. '93	40.8	27.1	27.9	.5
6-9 Aug. '93	19.2	12.5	30	0
10-13 Aug. '93	21.8	21.3	12	2.75
14-17 Aug. '93	24.2	23.3	22.9	0
18-21 Aug. '93	35.8	25.8	25.4	3.725
22-25 Aug. '93	0	0	0	1.975
26-29 Aug. '93	29.2	0	19.2	0
30-31 Aug. '93	0	37.5	17.5	0

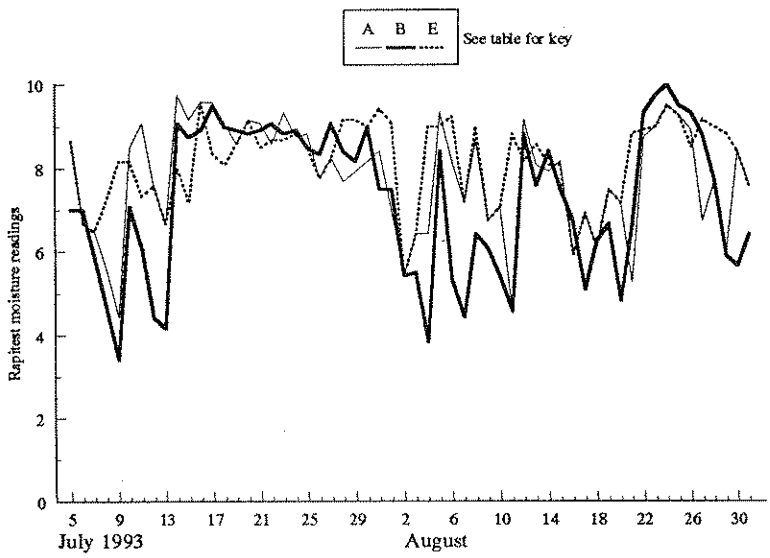


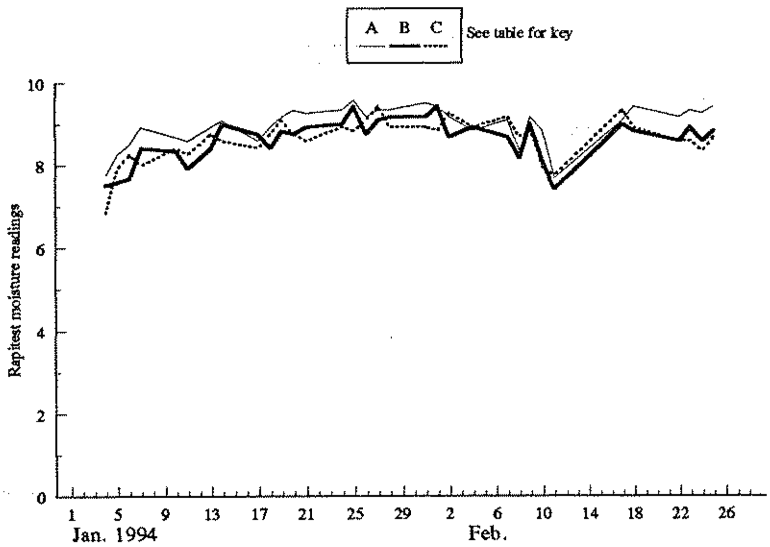
Figure 6c: Year 1 (1993-94): *Lavandula*

Comparison of Bed Systems: January - February 1994

(figures are an average of 3 replicates)

Irrigation in litres applied/bed ($9m^2$)

Date	A 25mm Gravel	B 75mm Sand +LL irrigation	C 75mm sand with over-head irrigation	Rainfall (mm)
1-4 Jan. '94	0	0	0	12.875
5-8 Jan. '94	0	0	0	5.7
9-12 Jan. '9$	0	0	0	6.05
13-16 Jan. '94	0	0	0	3.275
17-20 Jan. '94	0	0	0	2.2
21-24 Jan. '94	0	0	0	1.85
25-28 Jan. '94	0	0	0	0.7
29-1 Feb. '94	0	0	0	1.375
2-5 Feb. '94	0	0	0	4.25
6-9 Feb. '94	0	0	0	3.175
10-13 Feb. '94	0	0	0	3.925
14-17 Feb. '94	0	0	0	1.525
18-21 Feb. '94	0	0	0	3.25
22-25 Feb. '94	0	0	0	4.975
26-28 Feb. '94	0	0	0	.37



Irrigation in litres applied/bed ($9m^2$)

Date	A 25mm Gravel	B 75mm Sand +LL irrigation	F 25mm sand	Rainfall (mm)
1-4 Jan. '94	0	0	0	12.875
5-8 Jan. '94	0	0	0	5.7
9-12 Jan. '9$	0	0	0	6.05
13-16 Jan. '94	0	0	0	3.275
17-20 Jan. '94	0	0	0	2.2
21-24 Jan. '94	0	0	0	1.85
25-28 Jan. '94	0	0	0	0.7
29-1 Feb. '94	0	0	0	1.375
2-5 Feb. '94	0	0	0	4.25
6-9 Feb. '94	0	0	0	3.175
10-13 Feb. '94	0	0	0	3.925
14-17 Feb. '94	0	0	0	1.525
18-21 Feb. '94	0	0	0	3.25
22-25 Feb. '94	0	0	0	4.975
26-28 Feb. '94	0	0	0	.37

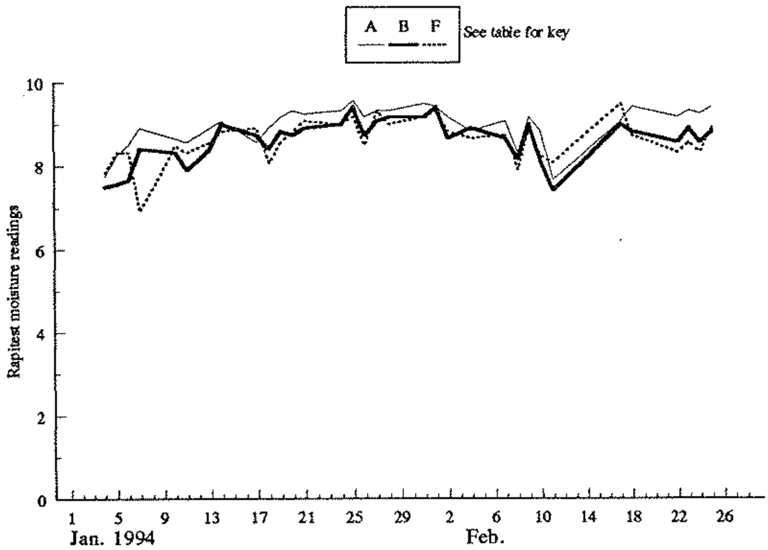


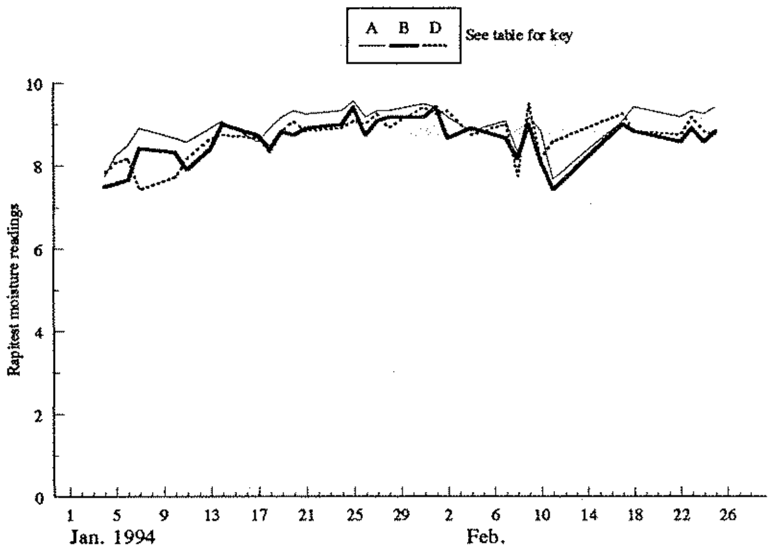
Figure 6d: Year 1 (1993-94): *Lavandula*

Comparison of Bed Systems: January - February 1994

(figures are an average of 3 replicates)

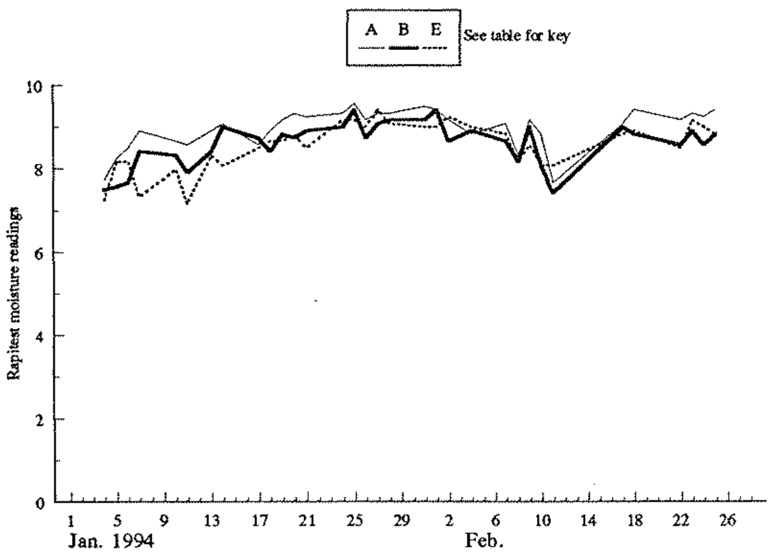
Irrigation in litres applied/bed (9m²)

Date	A 25mm Gravel	B 75mm Sand +LL irrigation	D 25mm Gravel + 25mm sand	Rainfall (mm)
1-4 Jan. '94	0	0	0	12.875
5-8 Jan. '94	0	0	0	5.7
9-12 Jan.. '9$	0	0	0	6.05
13-16 Jan. '94	0	0	0	3.275
17-20 Jan. '94	0	0	0	2.2
21-24 Jan. '94	0	0	0	1.85
25-28 Jan. '94	0	0	0	0.7
29-1 Feb. '94	0	0	0	1.375
2-5 Feb. '94	0	0	0	4.25
6-9 Feb. '94	0	0	0	3.175
10-13 Feb. '94	0	0	0	3.925
14-17 Feb. '94	0	0	0	1.525
18-21 Feb. '94	0	0	0	3.25
22-25 Feb. '94	0	0	0	4.975
26-28 Feb. '94	0	0	0	.37



Irrigation in litres applied/bed (9m²)

Date	A 25mm Gravel	B 75mm Sand +LL irrigation	E 25mm Gravel + 50mm sand	Rainfall (mm)
1-4 Jan. '94	0	0	0	12.875
5-8 Jan. '94	0	0	0	5.7
9-12 Jan.. '9$	0	0	0	6.05
13-16 Jan. '94	0	0	0	3.275
17-20 Jan. '94	0	0	0	2.2
21-24 Jan. '94	0	0	0	1.85
25-28 Jan. '94	0	0	0	0.7
29-1 Feb. '94	0	0	0	1.375
2-5 Feb. '94	0	0	0	4.25
6-9 Feb. '94	0	0	0	3.175
10-13 Feb. '94	0	0	0	3.925
14-17 Feb. '94	0	0	0	1.525
18-21 Feb. '94	0	0	0	3.25
22-25 Feb. '94	0	0	0	4.975
26-28 Feb. '94	0	0	0	.37



G. Total irrigation applied to different bed systems

The total amount of irrigation applied is shown in Table 2. 1993 had a particularly wet growing season (Appendix III, p. 78), significantly reducing the irrigation requirements. As a result differences between bed systems were small, though the 75 mm sand bed with seephose irrigation used the least water, and the 25 mm gravel with overhead watering the most. The sand infill on a gravel bed gave some reduction in water use, similar in this work to the 75 and 25 mm sand beds with overhead irrigation. Further comparisons under drier conditions are required to obtain a more accurate assessment.

Table 2 Total amount of irrigation applied/bed over 1993/94 season

	System	Replicate/ Bed No.	No. Occasions Irrigated	Total Applied (litres)	% of Gravel
A.	25 mm Gravel	1 (Bed 2)	11	1025	
		2 (Bed 9)	12	965	
		3 (Bed 13)	15	1460	
	Mean		*12.7*	*1150*	
B.	75 mm Sand + Seephose	1 (Bed 6)	11	1010	
		2 (Bed 10)	9	715	
		3 (Bed 17)	10	905	
	Mean		*10.0*	*877*	*76.3%*
C.	75 mm Sand + Overhead	1 (Bed 1)	14	1200	
		2 (Bed 8)	11	870	
		3 (Bed 18)	11	910	
	Mean		*12.0*	*993*	*86.3%*
D.	25 mm Gravel + 25 mm Sand	1 (Bed 4)	9	745	
		2 (Bed 12)	13	1130	
		3 (Bed 14)	13	1075	
	Mean		*11.7*	*983*	*85.5%*
E.	25 mm Gravel + 50 mm Sand	1 (Bed 5)	11	905	
		2 (Bed 7)	12	1080	
		3 (Bed 15)	12	1070	
	Mean		*11.7*	*1018*	*88.5%*
F.	25 mm Sand + Overhead	1 (Bed 3)	12	1080	
		2 (Bed 11)	11	930	
		3 (Bed 16)	12	1035	
	Mean		*11.7*	*1015*	*88.3%*

H. Plant Growth

By Autumn 1993 (Table 3)

Hydrangea demonstrated a significant improvement in growth on the 75 mm sand beds compared to the 25 mm sand and gravel systems. While the 50 mm sand infill on gravel appeared to give some improvement in growth this did not prove to be significantly different to other systems.

Growth of the slower growing species was similar regardless of bed system.

By Spring 1994 (Table 4)

Hydrangea: As in the autumn record, spring growth appeared to be slightly better on the sand systems, particularly the 75 mm sand + seephose system, but these differences did not prove to be significant compared with the gravel bed. Visible root growth over the pot-ball was significantly better on the 75 mm sand beds compared with the other sand systems, but these differences were small and not considered to be commercially significant.

Lavandula: As with *Hydrangea*, while there appeared to be an improvement in growth on the sand beds, this did not prove to be significantly different to that achieved on the gravel bed. Root growth was similar regardless of bed system.

Cytisus: Plants on the 25 mm gravel bed were significantly smaller than those on the sand beds. While the 75 mm sand+ seephose system produced the largest plants, differences between the various depths of sand and sand infills did not prove significant. Root growth was similar across bed types.

Genista: Plant growth was similar across all systems, though visible root over the pot-ball was significantly better on the gravel bed.

Table 3 Year 1 (1993-94): Plant Growth by Autumn 1993

Mean Size Score (Visual score of 1-5, 5 = largest)
(figures are a mean of 3 replicates, 10 plants/plot)

Hydrangea recorded 22 October 1993, other species on 3 November 1993

	System	*Hydrangea*	*Lavandula*	*Cytisus*	*Genista*
A.	**25 mm Gravel**	2.69	3.02	9.83	3.33
B.	**75 mm Sand + Seephose**	3.40	3.38	10.85	3.52
C.	**75 mm Sand + Overhead**	3.58	3.13	9.58	3.51
D.	**25 mm Gravel + 25 mm Sand**	2.52	3.08	9.48	3.27
E.	**25 mm Gravel + 50mm Sand**	3.02	3.46	10.73	3.06
F.	**25 mm Sand + Overhead**	2.52	3.17	11.06	3.15
d.f. = 8	*SED ±*	*0.263*	*0.184*	*1.011*	*0.285*
	LSD 5% ±	*0.61*	*0.42*	*2.33*	*0.66*

Table 4 Year 1 (1993-94): Plant Growth by Spring 1994

(figures are a mean of 3 replicates, 16 plants/plot)

a. ***Hydrangea*** (Assessed 19 May 1994)

	System	Size Score 1-5 (5 = largest)	Vigour Score 1-5 (5 = most vigorous)	% Visible Root Cover over Root Ball
A.	**25 mm Gravel**	2.09	3.18	74.5
B.	**75 mm Sand + Seephose**	3.18	4.38	77.2
C.	**75 mm Sand + Overhead**	2.77	3.46	75.8
D.	**25 mm Gravel + 25 mm Sand**	2.43	3.10	68.9
E.	**25 mm Gravel + 50mm Sand**	2.83	4.33	70.5
F.	**25 mm Sand + Overhead**	2.55	3.45	70.5
d.f. = 8	*SED ±*	*0.519*	*0.625*	*1.24*
	LSD 5% ±	*1.20*	*1.44*	*2.9*

b. ***Lavandula*** (Assessed 6 April 1994)

	System	Size Score 1-5 (5 = largest)	Vigour Score 1-5 (5 = most vigorous)	% Visible Root Cover over Root Ball
A.	**25 mm Gravel**	3.13	4.08	47.4
B.	**75 mm Sand + Seephose**	3.43	3.86	45.5
C.	**75 mm Sand + Overhead**	3.31	4.04	47.3
D.	**25 mm Gravel + 25 mm Sand**	3.42	4.25	45.0
E.	**25 mm Gravel + 50mm Sand**	3.62	4.32	46.8
F.	**25 mm Sand + Overhead**	3.57	4.32	50.2
d.f. = 8	*SED ±*	*0.229*	*0.318*	*1.01*
	LSD 5% ±	*0.53*	*0.73*	*2.33*

Table 4 Continued

c. ***Cytisus and Genista*** (Assessed 19 May and 6 April 1994 respectively)

	System	*Cytisus*		*Genista*	
		Size Score 1-5 (5 = largest)	**% Root Cover over Pot Ball**	**Size Score 1-5** (5 = largest)	**% Root Cover over over Pot Ball**
A.	**25 mm Gravel**	2.58	17.2	3.42	64.9
B.	**75 mm Sand + Seephose**	3.88	17.2	3.31	50.7
C.	**75 mm Sand + Overhead**	3.50	17.8	3.62	47.5
D.	**25 mm Gravel + 25 mm Sand**	3.33	17.1	3.08	44.6
E.	**25 mm Gravel + 50mm Sand**	3.75	16.5	3.04	43.4
F.	**25 mm Sand + Overhead**	3.42	17.6	3.22	46.0
d.f. = 8	*SED ±*	*0.287*	*1.23*	*0.330*	*2.892*
	LSD 5% ±	*0.66*	*2.84*	*0.76*	*6.67*

I. Liverwort growth

Presence of liverwort was assessed at the end of the first growing season and the following spring (Table 5). Variability in occurrence of liverwort between plants gave large standard errors (SED) and correspondingly high least significant differences (LSD) for comparison between treatments.

By December 1993, while there appeared to be a marked reduction in liverwort on the 75 mm sand bed with seephose irrigation, this only proved to be significant with *Cytisus*.

Following a very wet winter period, liverwort had increased by March 1994 and development was similar regardless of bed type. Even the *Cytisus*, which had only a minimal presence of liverwort in December 1993, had in excess of 75% pot cover by the spring record.

Table 5 Year 1 (1993-94): % Liverwort cover/pot

(figures are a mean of 3 replicates, 16 plants/plot)

	System	*Hydrangea*	*Lavandula*	*Cytisus*	*Genista*
By December 1993					
A.	**25 mm Gravel**	0.0	46.7	90.0	80.0
B.	**75 mm Sand + Seephose**	0.0	20.0	4.3	63.3
C.	**75 mm Sand + Overhead**	0.3	46.7	73.3	83.3
D.	**25 mm Gravel + 25 mm Sand**	0.0	33.3	50.0	73.3
E.	**25 mm Gravel + 50mm Sand**	0.0	33.3	53.3	73.3
F.	**25 mm Sand + Overhead**	0.3	46.7	50.0	86.7
d.f. = 8	*SED ±*	-	*12.51*	*23.8*	*9.43*
	LSD 5% ±	-	*28.9*	*53.7*	*21.8*
By March 1994					
A.	**25 mm Gravel**	2.0	63.3	100.0	91.7
B.	**75 mm Sand + Seephose**	4.0	61.7	76.7	98.3
C.	**75 mm Sand + Overhead**	5.0	73.3	88.3	96.7
D.	**25 mm Gravel + 25 mm Sand**	2.0	56.7	91.7	83.3
E.	**25 mm Gravel + 50mm Sand**	2.7	60.0	98.3	86.7
F.	**25 mm Sand + Overhead**	2.7	80.0	83.3	98.3
d.f. = 8	*SED ±*	-	*15.37*	*9.94*	*3.33*
	LSD 5% ±	-	*35.4*	*22.9*	*7.7*

Year 2 (1994-1995)

The trial was repeated in 1994-95, but with only a single species/bed during the growing season to allow targeting of irrigation to that species' requirements. Since *Hydrangea* showed a marked response in changes in moisture status of the growing media, having a high water requirement, this species was used as the indicator for the 1994 growing season.

Over the winter period the main concern was influence of bed type in draining excess water from the container in order to reduce the risk of waterlogging and consequent loss in quality. *Hydrangea* can be sensitive to waterlogging, but a further highly sensitive species, *Lavandula*, was also included for the overwintering assessment. These plants had been grown on a gravel system with overhead irrigation during the growing season, and were moved to the different bed types in early December 1994.

The 1994 season proved much drier than the previous year and considerably more irrigation was required, enabling a better comparison between bed systems for their efficiency of water use. However, it became apparent as the season progressed that the 25 mm sand and 25 and 50 mm sand infill on gravel beds were using far more water than the gravel control. A Mypex lining had been used as a standard under the gravel systems to achieve better drainage of excess water from the bed, and this had remained when the sand infills were applied. A Mypex lining was also used under the 25 mm sand bed to obtain a direct comparison with the sand infill beds. Consequently, as the season progressed and the drier conditions lowered the soil water table, capillary movement of water occurred ***out*** of the bed through the permeable Mypex lining.

Comparisons of water use between the 75 mm sand beds with the 25 mm gravel bed were valid, since the drained sand beds had a polythene lining.

As in Year 1, results are divided into a number of areas:

J. Uniformity of growing media water status measurements.

K. Effects of bed system on media water status.

L. Total irrigation applied to different bed systems.

M. Plant growth.

J. Uniformity of growing media water status measurements

The uniformity of water measurements by the Rapitest Meter in Year 2 proved as consistent as those obtained in Year 1 (Figures 7a-f and 8a-c). The drier 1994 season meant more frequent irrigation, as reflected by the marked peaks and troughs of the media water status measurements, and it was necessary to apply more water at each application to bring plants back up to a reasonable moisture level.

However, three of the beds showed erratic moisture levels in comparison with the other two replicates in the same treatment. Both Replicate 2 of the 25 mm gravel (Bed 2) and Replicate 1 of the 25 mm gravel + 50 mm sand (Bed 5) used far less water than their counterparts, while Replicate 1 of the 75 mm sand + overhead system (Bed 1) used considerably more water than the other replicates. This shows clearly in the graphs for the 25 mm gravel + 50 mm sand bed where Replicate 1 appears to have remained wetter (Figure 7e), while on the 75 mm sand + overhead bed of Replicate 1 the growing media is considerably drier. Why these differences have occurred in Year 2 but not in Year 1 is unclear. The 75 mm sand + overhead irrigation was an enclosed system lined with polythene. A possible explanation here was the puncturing of the lining from weed or animal activity underground, leading to continuous loss of water into the drier soil beneath. The anomaly with the Mypex lined gravel and gravel + 50 mm sand beds requiring less water is more difficult to account for, unless there were variations in the soil/sub soil structure under the beds, reducing the downward capillary pull of water from them. Whatever the reason, these replicates have been omitted from the data where systems were compared.

The pattern of moisture status of the growing media overwinter was similar for both *Hydrangea* and *Lavandula*.

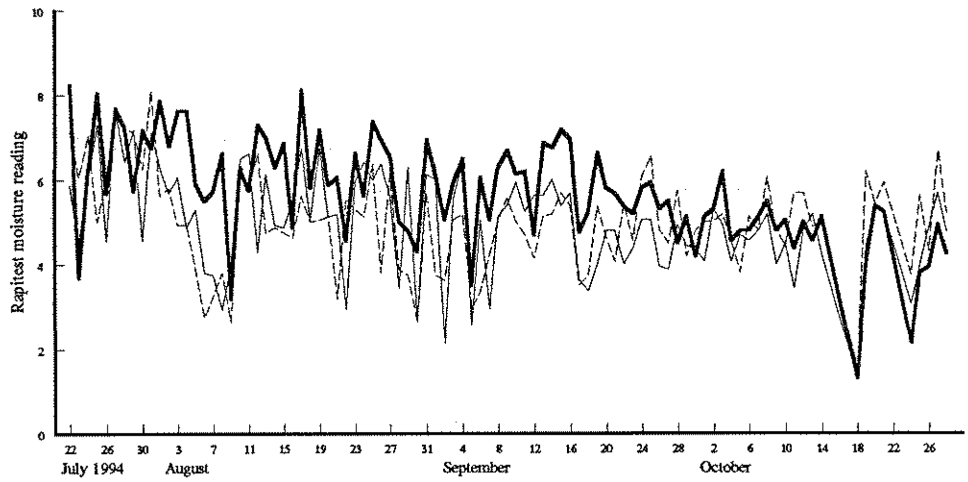
Figure 7a: Year 2 (1994-95): 25mm Gravel + Overhead Irrigation (Trt. A)

Mean daily Rapitest moisture measurements

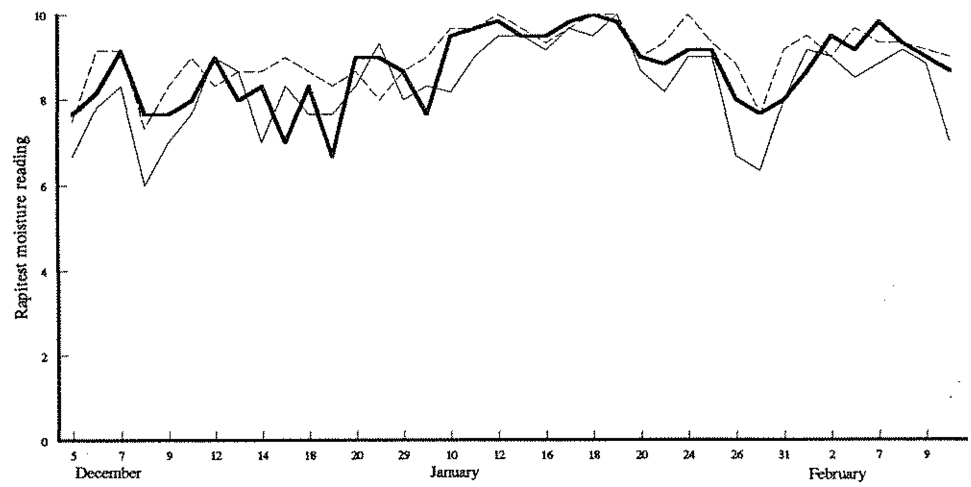
(average across 2 cultivars)

Hydrangea

Period 1
(average across 4 and 8 cm depths)



Period 2
(8cm depth only)



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Rep. 3 -----

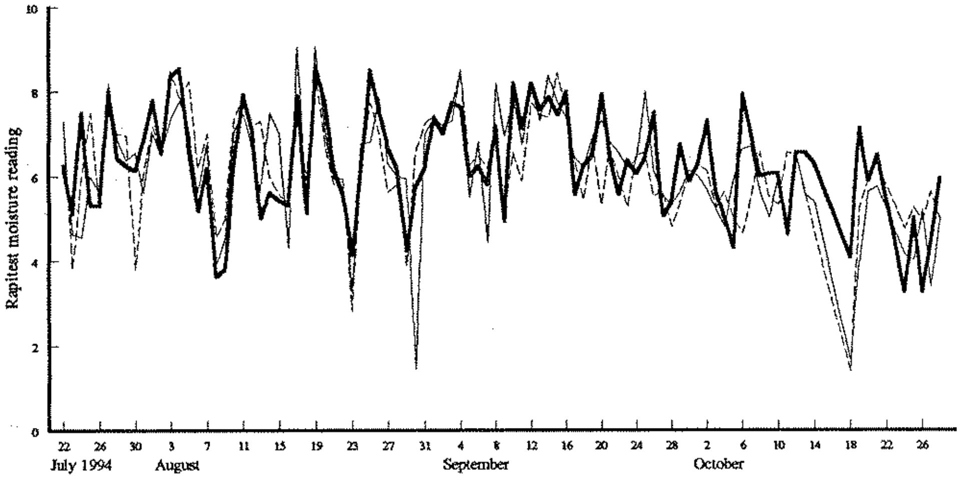
Figure 7b: Year 2 (1994-95): 75 mm Sand + Seephose (Trt. B)

Mean daily Rapitest moisture measurements

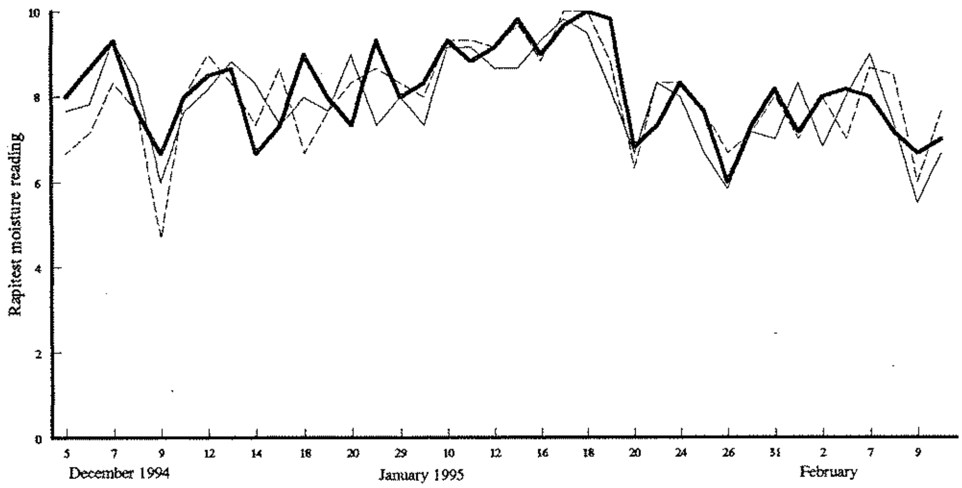
(average across 2 cultivars)

Hydrangea

Period 1
(average across 4 and 8 cm depths)



Period 2
(8cm depth only)



Key:

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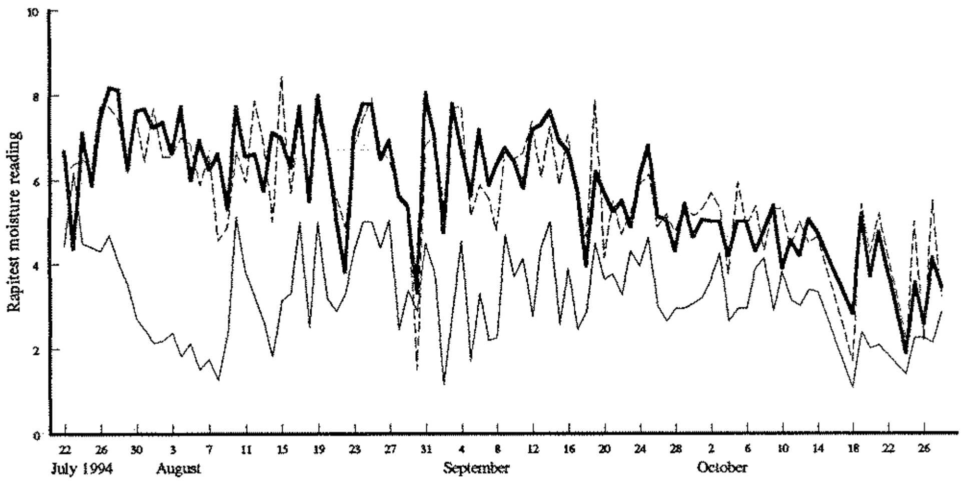
Figure 7c: Year 2 (1994-95): 75 mm Sand + Overhead Irrigation (Trt. C)

Mean daily Rapitest moisture measurements

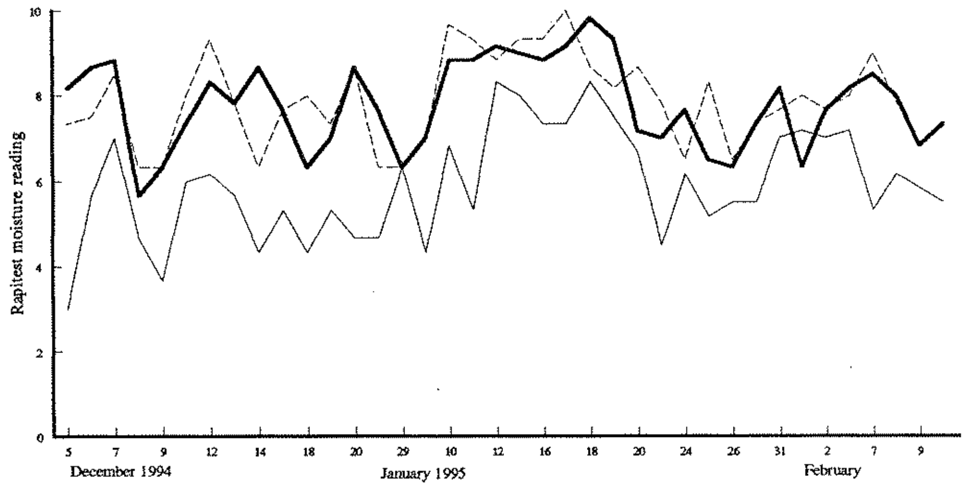
(average across 2 cultivars)

Hydrangea

Period 1
(average across 4 and 8 cm depths)



Period 2
(8cm depth only)



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Rep. 3 - - - -

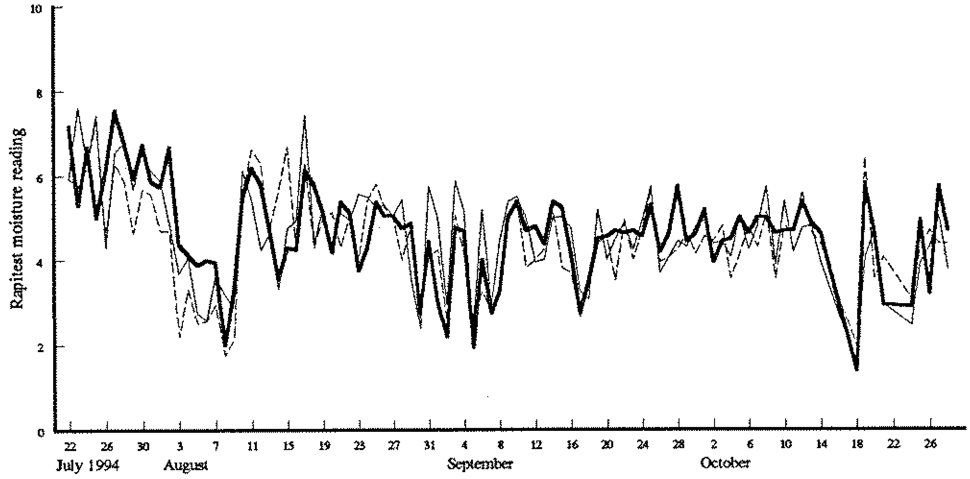
Figure 7d: Year 2 (1994-95): 25 mm Gravel + 25mm Sand (Trt. D)

Mean daily Rapitest moisture measurements

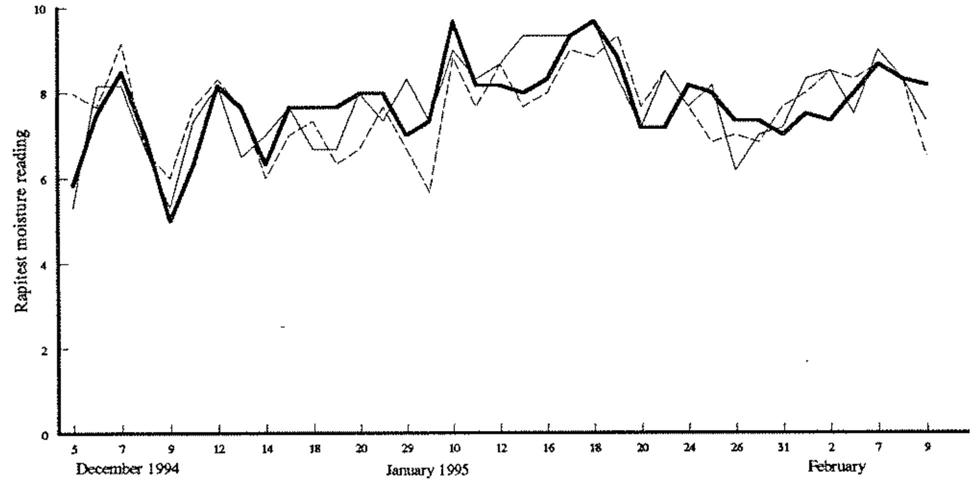
(average across 2 cultivars)

Hydrangea

Period 1
(average across 4 and 8 cm depths)



Period 2
(8cm depth only)



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Rep. 3 - - - -

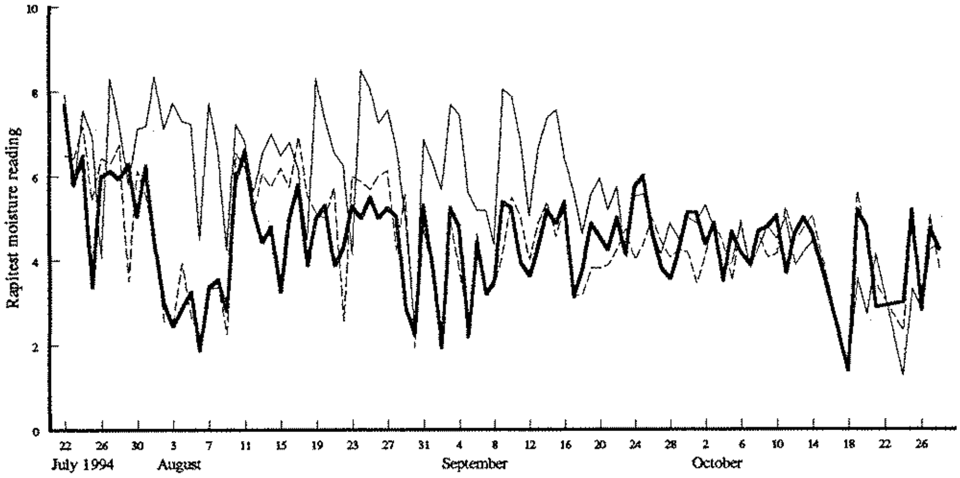
Figure 7e: Year 2 (1994-95): 25 mm Gravel + 50mm Sand (Trt. E)

Mean daily Rapitest moisture measurements

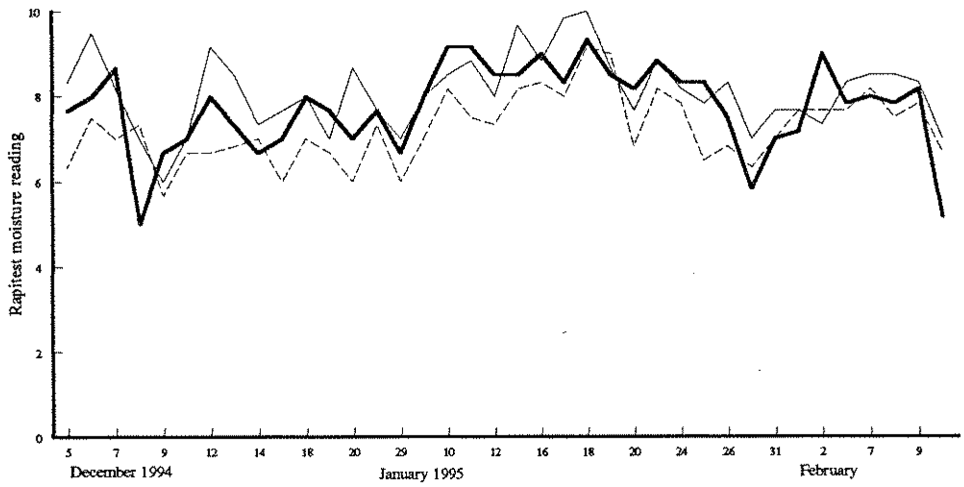
(average across 2 cultivars)

Hydrangea

Period 1
(average across 4 and 8 cm depths)



Period 2
(8cm depth only)



Key:

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Rep. 2 ━━━
Rep. 3 - - - -

Figure 7f: Year 2 (1994-95): 25 mm Sand + Overhead Irrigation (Trt. F)

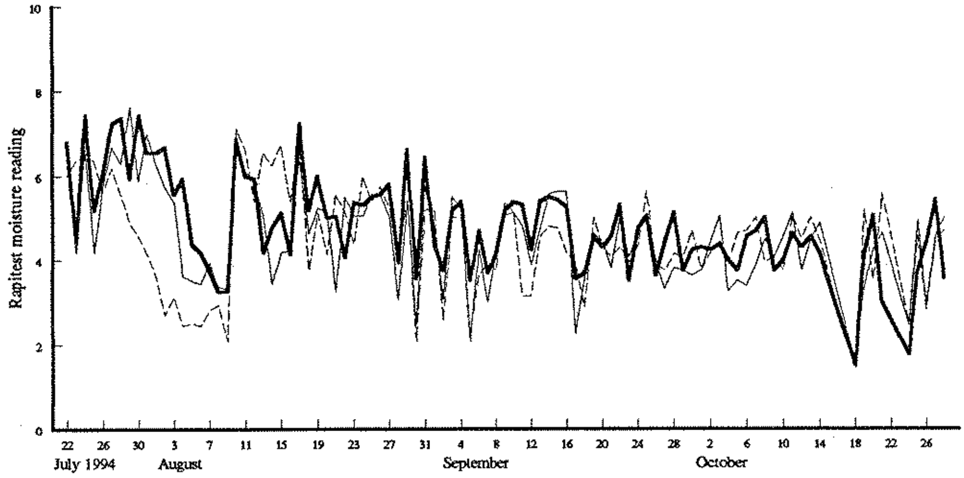
Mean daily Rapitest moisture measurements

(average across 2 cultivars)

Hydrangea

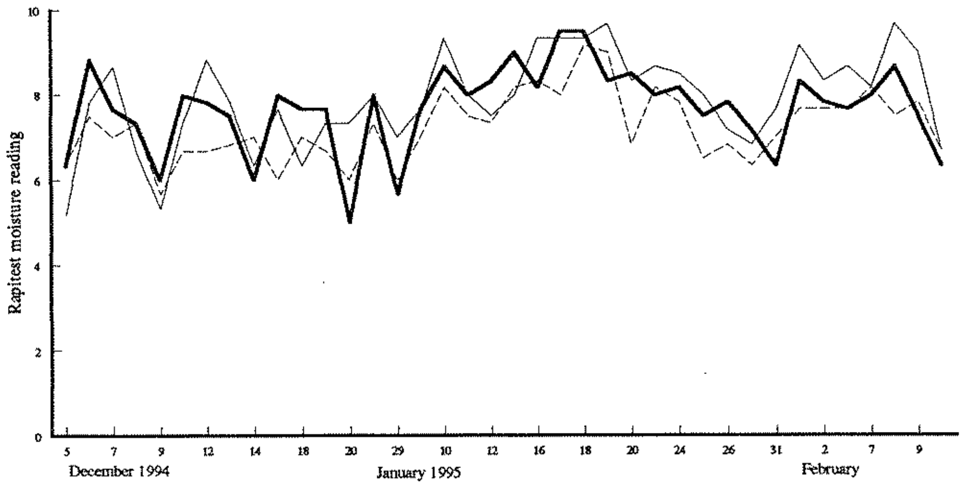
Period 1

(average across 4 and 8 cm depths)



Period 2

(8cm depth only)



Key:

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Rep. 2 ━━━

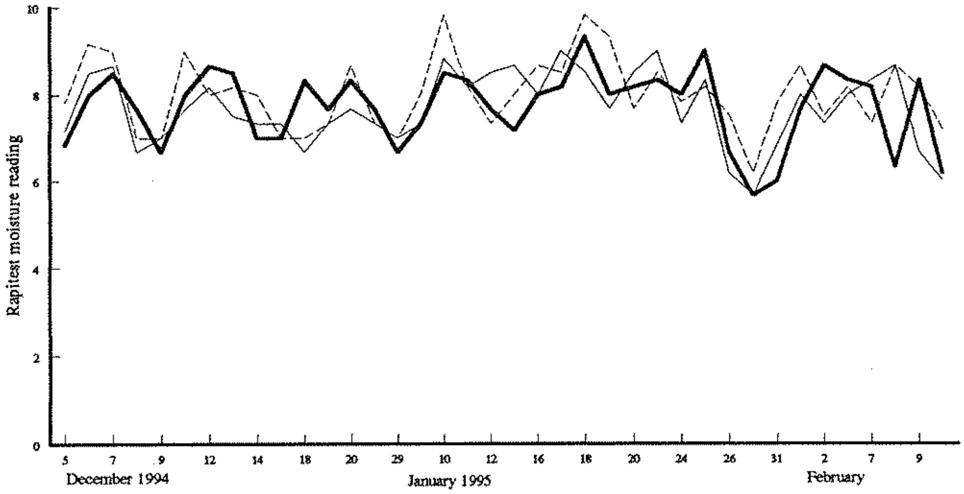
Rep. 3 - - - -

Figure 8a: Year 2 (1994-95): *Lavandula*

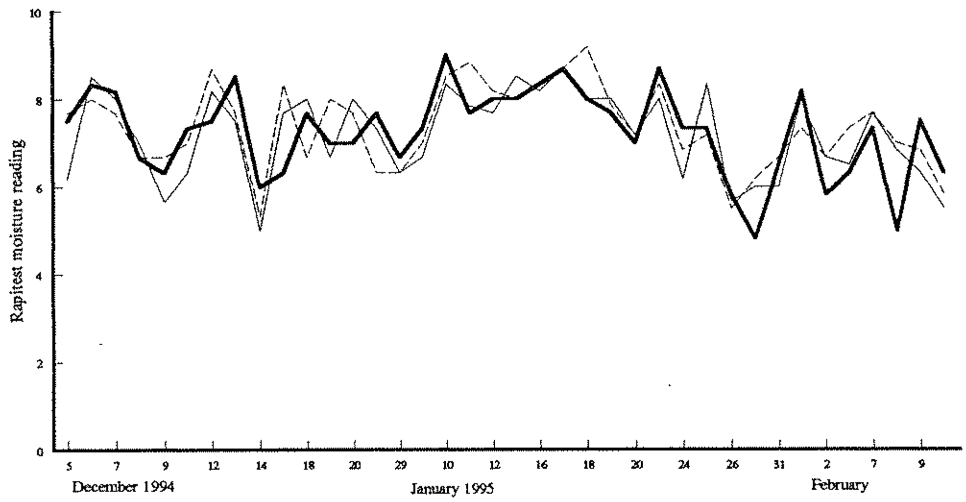
Mean daily Rapitest moisture measurements at 8 cm. depth

Period 2: 5 December 1994 - 13 February 1995

25mm Gravel + Overhead Irrigation (Trt. A)



75mm Sand + Seephose (Trt. B)



Key:

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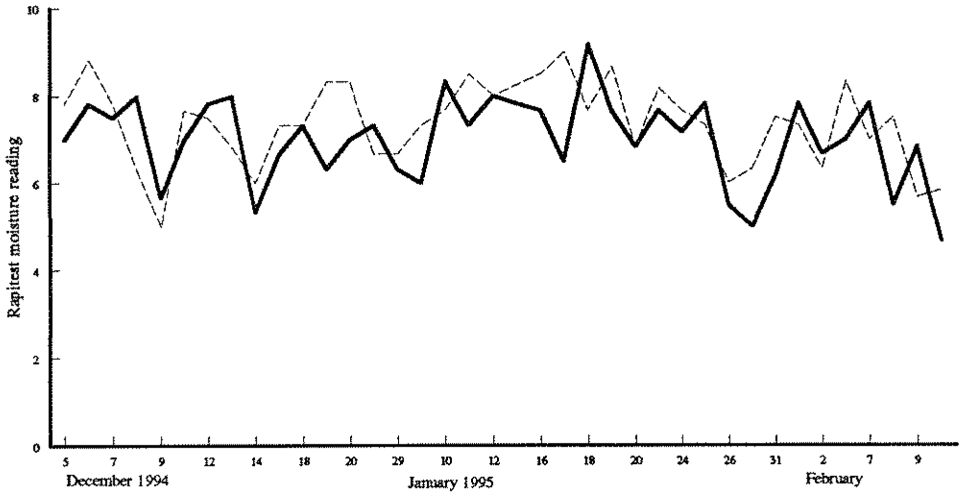
Rep. 3 - - -

Figure 8b Year 2 (1994-95): *Lavandula*

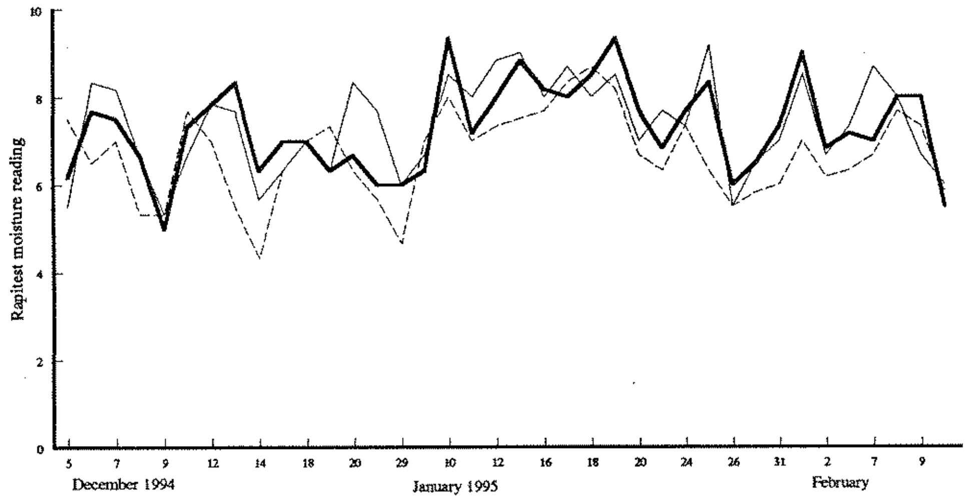
Mean daily Rapitest moisture measurements at 8 cm. depth

Period 2: 5 December 1994 - 13 February 1995

75mm Sand + Overhead Irrigation (Trt. C)



25mm Gravel + 25mm Sand (Trt. D)



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Rep. 2 ━━
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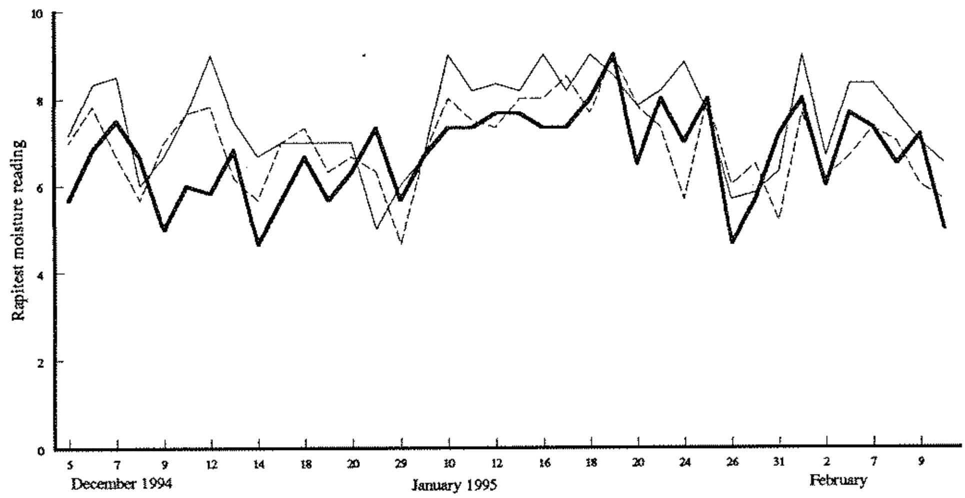
Figure 8c: Year 2 (1994-95): *Lavandula*

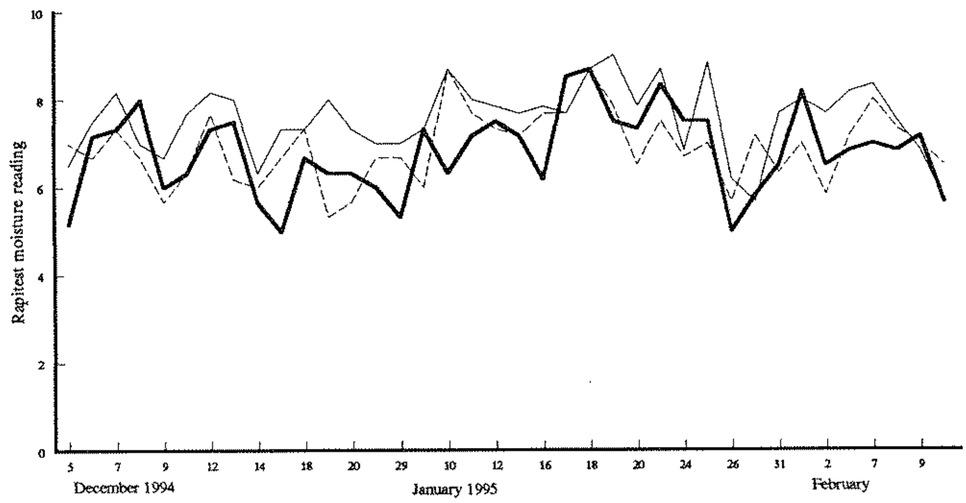
Mean daily Rapitest moisture measurements at 8 cm. depth

Period 2: 5 December 1994 - 13 February 1995

25mm Gravel + 50mm Sand (Trt. E)



25mm Sand + Overhead Irrigatiion (Trt. F)



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K. Effects of bed system on water status of the growing media

These results are presented in Figures 9a-d for *Hydrangea* and 10a-b for *Lavandula*. As in Year 1 the two control systems, 25 mm gravel and 75 mm sand + seephose, have been included in each graph for comparison with one of the other four bed systems.

Hydrangea

Figures 9a-b show the influence of bed system in moisture retention over the growing season and clearly show the benefits of the 75 mm sand + seephose system. However, the 75 mm sand + overhead system (C) appeared to dry out as quickly as the gravel system, though it needed less irrigation to maintain this status (see next section). The drier media on the 25 mm gravel and sand infill beds (D, E, F) reflected the higher irrigation requirement on these beds as already discussed, due in part at least to the downward capillary movement of water from the bed through the Mypex lining.

Over the winter period the potential for the 75 mm of sand to drain water from the pots was again demonstrated, compared with the 25 mm gravel bed (Figures 9c-d). The apparent increased drainage from the 25 mm sand and sand infill systems could still be related to the drier soil beneath the beds during the early part of the winter and continued downward capillary movement of water from the beds. As the water table rose the drainage from these beds became less, and by February 1995 the 75 mm sand beds were again showing the most positive drainage from the pots.

Lavandula

These results, (Figures 10a-b), relate to the winter period only and show close correlation to those obtained for *Hydrangea*.

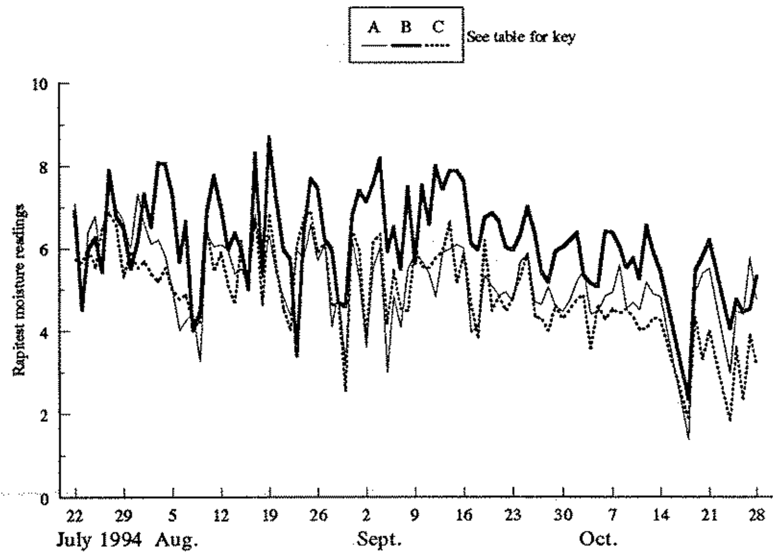
Figure 9a: Year 2 (1994-95): *Hydrangea*

Comparison of Bed Systems: July - October 1994

(figures are an average of 3 replicates)

Irrigation in litres applied/bed (9m²)

Date	A 25mm Gravel	B 75mm Sand +LL irrigation	C 75mm Sand with over-head irrigation	Rainfall (mm)
22-28 July'94	58.2	67.4	40.7	0.3
29-4 Aug. '94	87.9	37.8	26.8	2.2
5-11 Aug. '94	151.8	77.6	68.6	0.3
12-18 Aug. '94	123.6	54.5	21.1	1.9
19-25 Aug. '94	29.3	23.8	21.1	1.3
26-1 Sept. '94	90.7	24.0	21.1	2.0
2-8 Sept. '94	129.6	7.6	21.1	0.8
9-15 Sept. '94	36.8	8.8	0.0	5.8
16-22 Sept. '94	155.4	0.0	42.9	1.2
23-29 Sept. '94	145.0	7.6	40.4	2.3
30-6 Oct. '94	181.2	23.6	36.4	0.3
7-13 Oct. '94	174.3	15.5	70.4	0.0
14-20 Oct. '94	76.1	29.8	31.4	1.7
21-28 Oct. '94	68.8	31.5	50.9	7.2



Irrigation in litres applied/bed (9m²)

Date	A 25mm Gravel	B 75mm Sand +LL irrigation	F 25mm Sand	Rainfall (mm)
22-28 July'94	58.2	67.4	80.5	0.3
29-4 Aug. '94	87.9	37.8	118.8	2.2
5-11 Aug. '94	151.8	77.6	139.5	0.3
12-18 Aug. '94	123.6	54.5	131.2	1.9
19-25 Aug. '94	29.3	23.8	38.8	1.3
26-1 Sept. '94	90.7	24.0	80.0	2.0
2-8 Sept. '94	129.6	7.6	161.0	0.8
9-15 Sept. '94	36.8	8.8	104.0	5.8
16-22 Sept. '94	155.4	0.0	196.4	1.2
23-29 Sept. '94	145.0	7.6	223.1	2.3
30-6 Oct. '94	181.2	23.6	273.7	0.3
7-13 Oct. '94	174.3	15.5	216.4	0.0
14-20 Oct. '94	76.1	29.8	131.0	1.7
21-28 Oct. '94	68.8	31.5	130.4	7.2

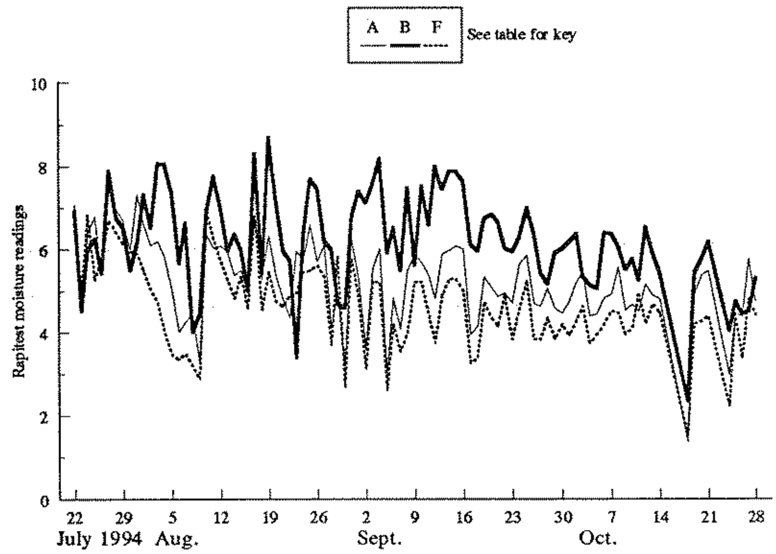


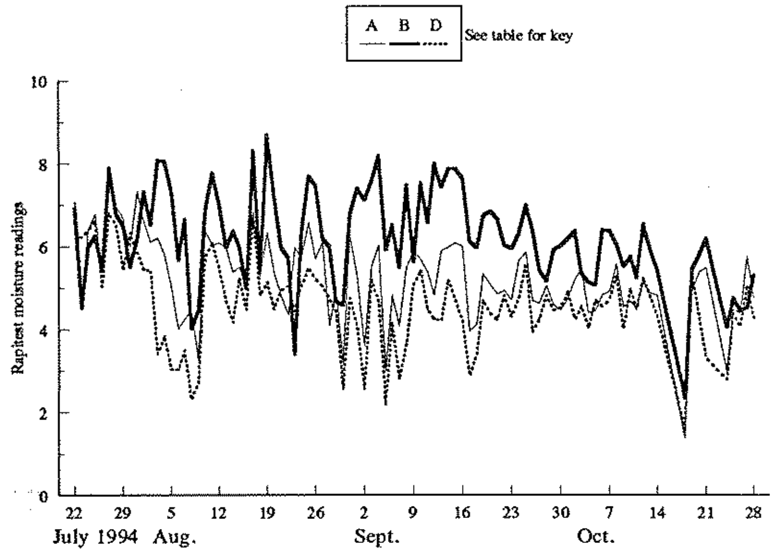
Figure 9b: Year 2 (1994-95): *Hydrangea*

Comparison of Bed Systems: July - October 1994

(figures are an average of 3 replicates)

Irrigation in litres applied/bed (9m²)

Date	A 25mm Gravel	B 75mm Sand +LL irrigation	D 25mm Gravel + 25mm sand	Rainfall (mm)
22-28 July'94	58.2	67.4	67.8	0.3
29-4 Aug. '94	87.9	37.8	125.1	2.2
5-11 Aug. '94	151.8	77.6	165.2	0.3
12-18 Aug. '94	123.6	54.5	155.2	1.9
19-25 Aug. '94	29.3	23.8	72.1	1.3
26-1 Sept. '94	90.7	24.0	134.8	2.0
2-8 Sept. '94	129.6	7.6	208.8	0.8
9-15 Sept. '94	36.8	8.8	135.2	5.8
16-22 Sept. '94	155.4	0.0	286.9	1.2
23-29 Sept. '94	145.0	7.6	263.8	2.3
30-6 Oct. '94	181.2	23.6	290.9	0.3
7-13 Oct. '94	174.3	15.5	186.4	0.0
14-20 Oct. '94	76.1	29.8	120.7	1.7
21-28 Oct. '94	68.8	31.5	195.8	7.2



Irrigation in litres applied/bed (9m²)

Date	A 25mm Gravel	B 75mm Sand +LL irrigation	E 25mm Gravel + 50mm sand	Rainfall (mm)
22-28 July'94	58.2	67.4	85.7	0.3
29-4 Aug. '94	87.9	37.8	150.0	2.2
5-11 Aug. '94	151.8	77.6	142.5	0.3
12-18 Aug. '94	123.6	54.5	132.9	1.9
19-25 Aug. '94	29.3	23.8	47.9	1.3
26-1 Sept. '94	90.7	24.0	114.6	2.0
2-8 Sept. '94	129.6	7.6	214.6	0.8
9-15 Sept. '94	36.8	8.8	157.1	5.8
16-22 Sept. '94	155.4	0.0	234.6	1.2
23-29 Sept. '94	145.0	7.6	256.4	2.3
30-6 Oct. '94	181.2	23.6	288.7	0.3
7-13 Oct. '94	174.3	15.5	266.4	0.0
14-20 Oct. '94	76.1	29.8	54.3	1.7
21-28 Oct. '94	68.8	31.5	189.4	7.2

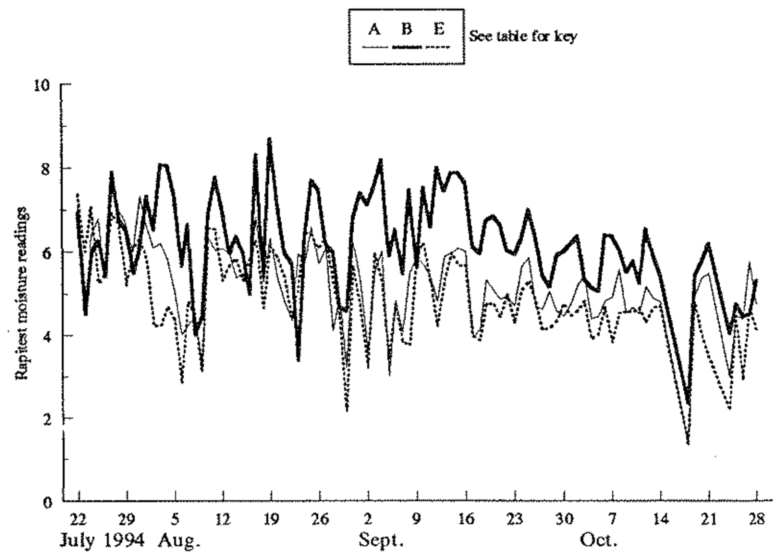


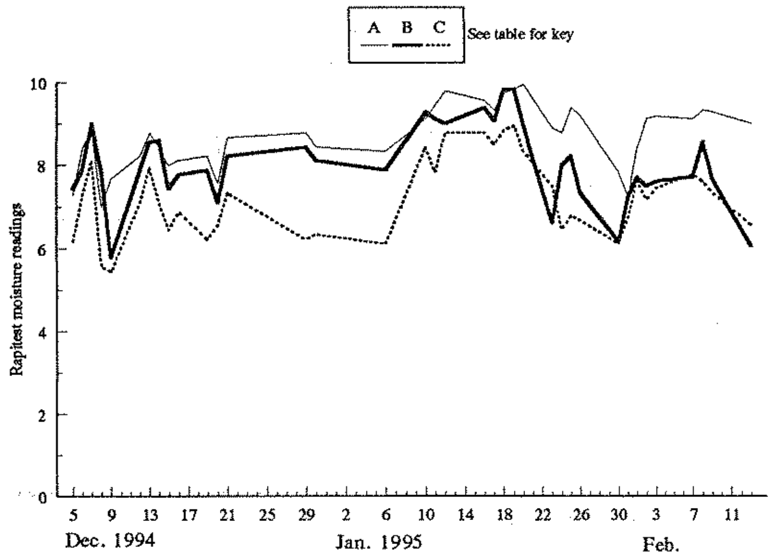
Figure 9c: Year 2 (1994-95): *Hydrangea*

Comparison of Bed Systems: December 1994 - February 1995

(figures are an average of 3 replicates)

Irrigation in litres applied/bed (9m²)

Date	A 25mm Gravel	B 75mm Sand +LL irrigation	C 75mm Sand with overhead irrigation	Rainfall (mm)
5-9 Dec. '94	0	0	0	9.0
10-14 Dec. '94	0	0	0	0.1
15-19 Dec. '94	0	0	0	1.8
20-24 Dec. '94	0	0	0	0.1
25-29 Dec. '94	0	0	0	8.7
30-3 Jan. '94	0	0	0	0.3
4-8 Jan. '95	0	0	0	3.3
9-13 Jan. '95	0	0	0	.02
14-18 Jan. '95	0	0	0	4.2
19-23Jan. '95	0	0	0	9.4
24-28 Jan. '95	0	0	0	9.8
29-2 Feb. '95	0	0	0	2.1
3-7 Feb. '95	0	0	0	2.8
8-13 Feb. '95	0	0	0	6.7



Irrigation in litres applied/bed (9m²)

Date	A 25mm Gravel	B 75mm Sand +LL irrigation	F 25mm Sand	Rainfall (mm)
5-9 Dec. '94	0	0	0	9.0
10-14 Dec. '94	0	0	0	0.1
15-19 Dec. '94	0	0	0	1.8
20-24 Dec. '94	0	0	0	0.1
25-29 Dec. '94	0	0	0	8.7
30-3 Jan. '94	0	0	0	0.3
4-8 Jan. '95	0	0	0	3.3
9-13 Jan. '95	0	0	0	.02
14-18 Jan. '95	0	0	0	4.2
19-23Jan. '95	0	0	0	9.4
24-28 Jan. '95	0	0	0	9.8
29-2 Feb. '95	0	0	0	2.1
3-7 Feb. '95	0	0	0	2.8
8-13 Feb. '95	0	0	0	6.7

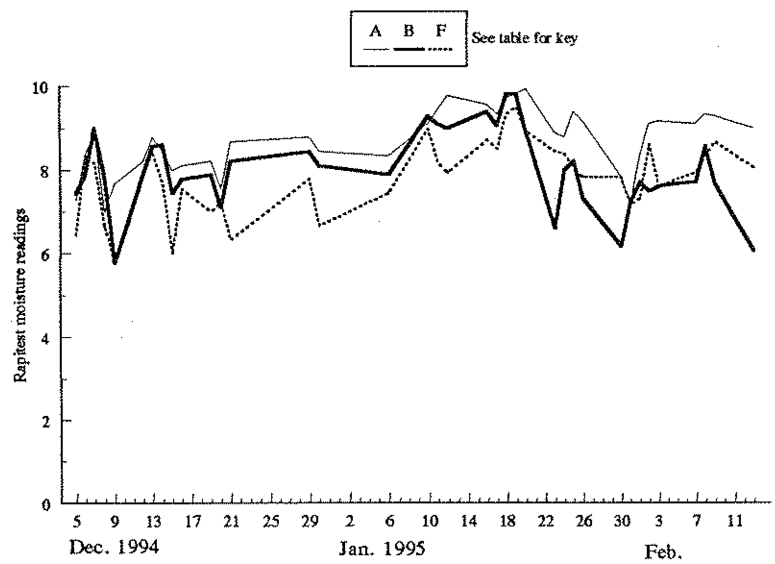


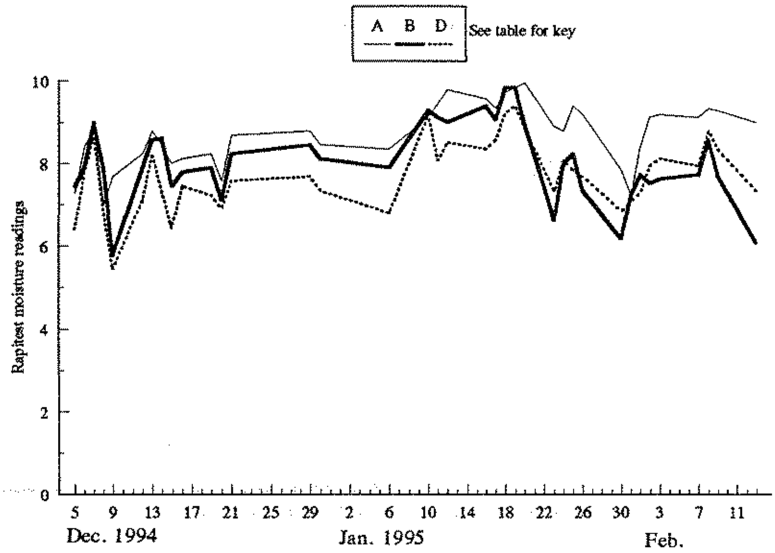
Figure 9d: Year 2 (1994-95): *Hydrangea*

Comparison of Bed Systems: December 1994 - February 1995

(figures are an average of 3 replicates)

Irrigation in litres applied/bed ($9m^2$)

Date	A 25mm Gravel	B 75mm Sand +LL irrigation	D 25mm Gravel + 50mm Sand	Rainfall (mm)
5-9 Dec. '94	0	0	0	9.0
10-14 Dec. '94	0	0	0	0.1
15-19 Dec. '94	0	0	0	1.8
20-24 Dec. '94	0	0	0	0.1
25-29 Dec. '94	0	0	0	8.7
30-3 Jan. '94	0	0	0	0.3
4-8 Jan. '95	0	0	0	3.3
9-13 Jan. '95	0	0	0	.02
14-18 Jan. '95	0	0	0	4.2
19-23Jan. '95	0	0	0	9.4
24-28 Jan. '95	0	0	0	9.8
29-2 Feb. '95	0	0	0	2.1
3-7 Feb. '95	0	0	0	2.8
8-13 Feb. '95	0	0	0	6.7



Irrigation in litres applied/bed ($9m^2$)

Date	A 25mm Gravel	B 75mm Sand +LL irrigation	E 25mm Gravel + 50mm Sand	Rainfall (mm)
5-9 Dec. '94	0	0	0	9.0
10-14 Dec. '94	0	0	0	0.1
15-19 Dec. '94	0	0	0	1.8
20-24 Dec. '94	0	0	0	0.1
25-29 Dec. '94	0	0	0	8.7
30-3 Jan. '94	0	0	0	0.3
4-8 Jan. '95	0	0	0	3.3
9-13 Jan. '95	0	0	0	.02
14-18 Jan. '95	0	0	0	4.2
19-23Jan. '95	0	0	0	9.4
24-28 Jan. '95	0	0	0	9.8
29-2 Feb. '95	0	0	0	2.1
3-7 Feb. '95	0	0	0	2.8
8-13 Feb. '95	0	0	0	6.7

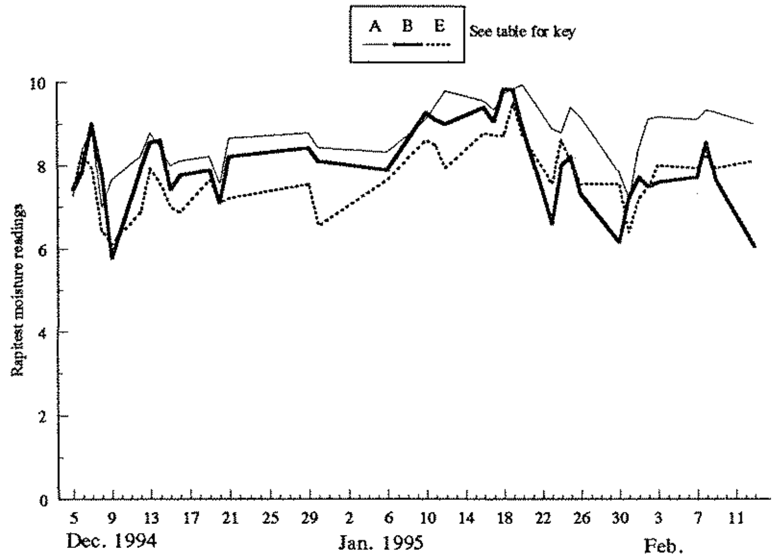


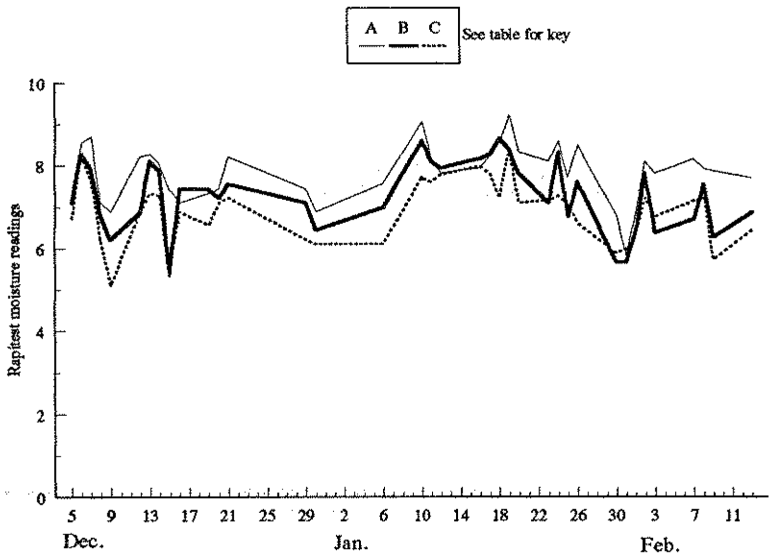
Figure 10a: Year 2 (1994-95): *Lavandula*

Comparison of Bed Systems: December 1994 - February 1995

(figures are an average of 3 replicates)

Irrigation in litres applied/bed (9m²)

Date	A 25mm Gravel	B 75mm Sand +LL irrigation	C 75mm Sand with overhead irrigation	Rainfall (mm)
5-9 Dec. '94	0	0	0	9.0
10-14 Dec. '94	0	0	0	0.1
15-19 Dec. '94	0	0	0	1.8
20-24 Dec. '94	0	0	0	0.1
25-29 Dec. '94	0	0	0	8.7
30-3 Jan. '94	0	0	0	0.3
4-8 Jan. '95	0	0	0	3.3
9-13 Jan. '95	0	0	0	.02
14-18 Jan. '95	0	0	0	4.2
19-23Jan. '95	0	0	0	9.4
24-28 Jan. '95	0	0	0	9.8
29-2 Feb. '95	0	0	0	2.1
3-7 Feb. '95	0	0	0	2.8
8-13 Feb. '95	0	0	0	6.7



Irrigation in litres applied/bed (9m²)

Date	A 25mm Gravel	B 75mm Sand +LL irrigation	F 25mm Sand	Rainfall (mm)
5-9 Dec. '94	0	0	0	9.0
10-14 Dec. '94	0	0	0	0.1
15-19 Dec. '94	0	0	0	1.8
20-24 Dec. '94	0	0	0	0.1
25-29 Dec. '94	0	0	0	8.7
30-3 Jan. '94	0	0	0	0.3
4-8 Jan. '95	0	0	0	3.3
9-13 Jan. '95	0	0	0	.02
14-18 Jan. '95	0	0	0	4.2
19-23Jan. '95	0	0	0	9.4
24-28 Jan. '95	0	0	0	9.8
29-2 Feb. '95	0	0	0	2.1
3-7 Feb. '95	0	0	0	2.8
8-13 Feb. '95	0	0	0	6.7

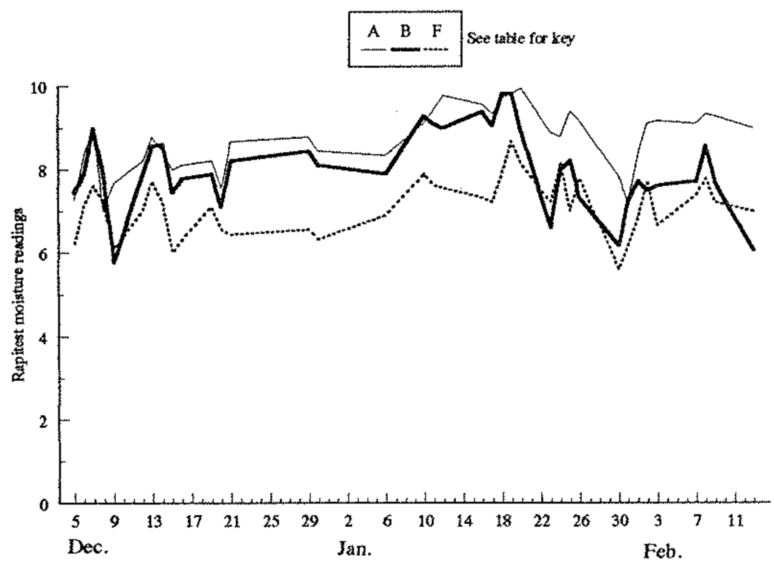


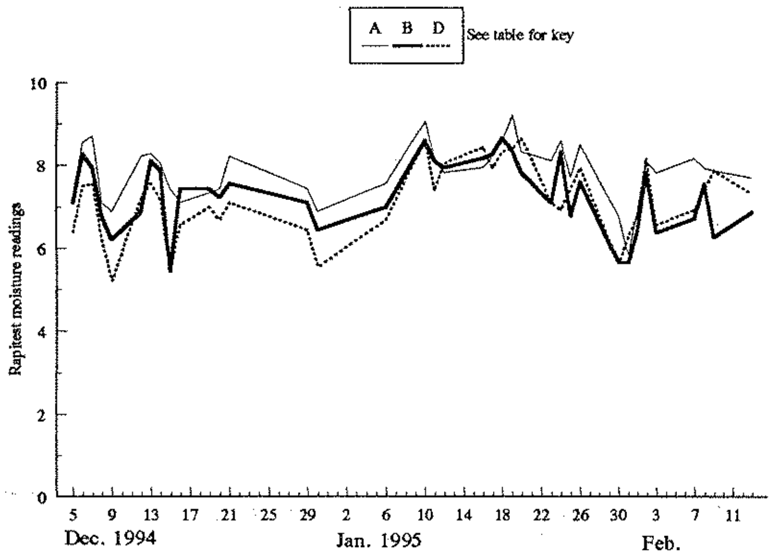
Figure 10b: Year 2 (1994-95): *Lavandula*

Comparison of Bed Systems: December 1994 - February 1995

(figures are an average of 3 replicates)

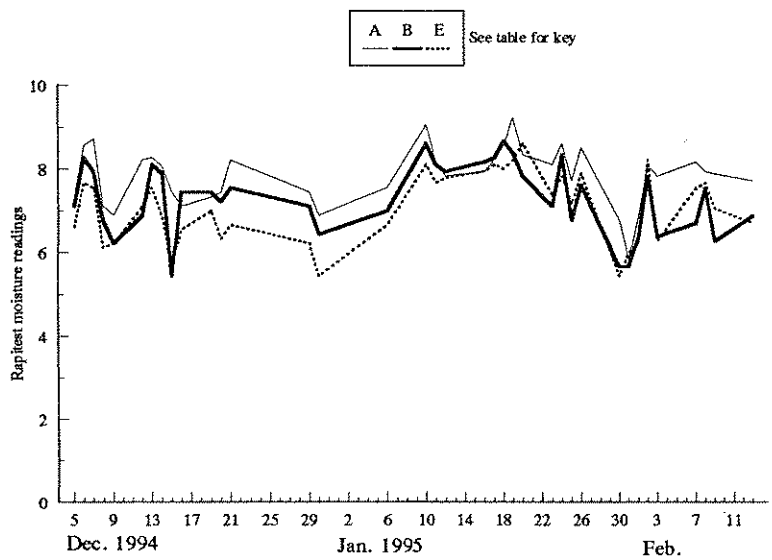
Irrigation in litres applied/bed (9m²)

Date	A 25mm Gravel	B 75mm Sand +LL irrigation	D 25mm Gravel + 50mm Sand	Rainfall (mm)
5-9 Dec. '94	0	0	0	9.0
10-14 Dec. '94	0	0	0	0.1
15-19 Dec. '94	0	0	0	1.8
20-24 Dec. '94	0	0	0	0.1
25-29 Dec. '94	0	0	0	8.7
30-3 Jan. '94	0	0	0	0.3
4-8 Jan. '95	0	0	0	3.3
9-13 Jan. '95	0	0	0	.02
14-18 Jan. '95	0	0	0	4.2
19-23Jan. '95	0	0	0	9.4
24-28 Jan. '95	0	0	0	9.8
29-2 Feb. '95	0	0	0	2.1
3-7 Feb. '95	0	0	0	2.8
8-13 Feb. '95	0	0	0	6.7



Irrigation in litres applied/bed (9m²)

Date	A 25mm Gravel	B 75mm Sand +LL irrigation	E 25mm Gravel + 50mm Sand	Rainfall (mm)
5-9 Dec. '94	0	0	0	9.0
10-14 Dec. '94	0	0	0	0.1
15-19 Dec. '94	0	0	0	1.8
20-24 Dec. '94	0	0	0	0.1
25-29 Dec. '94	0	0	0	8.7
30-3 Jan. '94	0	0	0	0.3
4-8 Jan. '95	0	0	0	3.3
9-13 Jan. '95	0	0	0	.02
14-18 Jan. '95	0	0	0	4.2
19-23Jan. '95	0	0	0	9.4
24-28 Jan. '95	0	0	0	9.8
29-2 Feb. '95	0	0	0	2.1
3-7 Feb. '95	0	0	0	2.8
8-13 Feb. '95	0	0	0	6.7



L. Total irrigation applied to different bed systems

The total amount of irrigation applied during 1994 is shown in Table 6. As already discussed, data for Replicate 2 of the 25 mm gravel, and Replicate 1 for the 75 mm sand + overhead and 25 mm + 50 mm sand systems have been taken out due to their being so different to the other two replicates in the same treatment.

In this very dry season the benefits of the 75 mm sand beds in efficiency of water use was marked, with the seephose irrigated system using less than 30% of that needed on the gravel bed. The overhead irrigated sand bed used slightly more water, but still used less than 35% of gravel.

As already discussed, the Mypex lined beds with sand or sand infills used considerably more water this season than the gravel, due to loss of water through the base into the dry soil conditions beneath.

Table 6 Total amount of irrigation applied/bed over 1994/95 season

	System	Replicate/ Bed No.	No. Occasions Irrigated	Total Applied (litres)	% of Gravel
A.	25 mm Gravel	1 (Bed 2)	52	10635	
		3 (Bed 13)	48	10622	
	Mean		*50.0*	*10629*	-
B.	75 mm Sand	1 (Bed 6)	21	3000	
	+ Seephose	2 (Bed 10)	23	3575	
		3 (Bed 17)	15	2120	
	Mean		*19.6*	*2898*	*27.3%*
C.	75 mm Sand	2 (Bed 8)	27	3295	
	+ Overhead	3 (Bed 18)	28	3705	
	Mean		*27.5*	*3500*	*32.9%*
D.	25 mm Gravel	1 (Bed 4)	62	14790	
	+ 25 mm Sand	2 (Bed 12)	62	15645	
		3 (Bed 14)	74	20700	
	Mean		*66.0*	*17045*	*160.4%*
E.	25 mm Gravel	2 (Bed 7)	63	16145	
	+ 50 mm Sand	3 (Bed 15)	65	16927	
	Mean		*64.0*	*16536*	*155.6%*
F.	25 mm Sand	1 (Bed 3)	61	12975	
	+ Overhead	2 (Bed 11)	59	14180	
		3 (Bed 16)	65	15758	
	Mean		*61.7*	*14304*	*134.6%*

M. Plant Growth

By Autumn 1994 (Table 7)

As in Year 1 there was a significant improvement in growth of *Hydrangea* on the 75 mm sand beds, especially where seephose irrigation was in operation, compared with the gravel system. While there was also a small improvement in growth on the 25 mm sand bed and 25 and 50 mm sand infills, these did not prove significant.

By Spring 1995 (Table 8)

Hydrangea: Assessments were made in mid May 1995 on the second flush of growth, the first flush having been severely damaged by frost. By this time differences in top or root growth between bed systems of Mme J de Schmedt were small and not significant. With Draps Pink top growth was delayed on the 75 mm sand + seephose bed giving a smaller size score at the point of assessment.

Lavandula: None of the bed systems had any obvious effect on the spring flush of growth, either top or visible root. However, the amount of new root occurring was significantly greater on the sand beds as compared to the gravel bed.

Table 7 **Year 2 (1994/95):** ***Hydrangea*: Plant Growth by 28 September 1994**

Mean Size Score (visual score of 1-5, 5 = largest)
(figures are a mean of 3 replicates, 16 plants/plot)

		Cultivar		
	System	**Mme J de Schmedt**	**Draps Pink**	***Mean***
A.	**25 mm Gravel**	2.56	2.60	*2.58*
B.	**75 mm Sand + Seephose**	3.00	3.18	*3.09*
C.	**75 mm Sand + Overhead**	2.91	2.97	*2.94*
D.	**25 mm Gravel + 25 mm Sand**	2.72	2.63	*2.68*
E.	**25 mm Gravel + 50mm Sand**	2.75	2.85	*2.80*
F.	**25 mm Sand + Overhead**	2.70	2.76	*2.73*
d.f. = 8	*SED ±*	*0.132*	*0.198*	
	LSD 5% ±	*0.30*	*0.46*	

Table 8 Year 2 (1994-95): Plant Growth by Spring 1995

(figures are a mean of 3 replicates, 18 plants/plot)

a. *Hydrangea* (Assessed 19 May 1995)

	System	Mme J de Schmedt: Size Score 1-5 (5 = largest)	Mme J de Schmedt: % Visible Root Cover over Pot Ball	Draps Pink: Size Score 1-5 (5 = largest)	Draps Pink: % Visible Root Cover over Pot Ball
A.	25 mm Gravel	3.02	40.9	2.89	37.8
B.	75 mm Sand + Seephose	2.90	31.6	1.89	35.0
C.	75 mm Sand + Overhead	3.04	35.2	2.57	33.8
D.	25 mm Gravel + 25 mm Sand	3.09	40.5	2.67	40.0
E.	25 mm Gravel + 50mm Sand	3.00	38.1	2.92	34.0
F.	25 mm Sand + Overhead	3.31	43.0	2.72	38.5
d.f. = 8	*SED ±*	*0.159*	*6.10*	*0.130*	*3.23*
	LSD 5% ±	*0.37*	*14.1*	*0.24*	*7.5*

b. *Lavandula* (Assessed early April 1995)

	System	Size Score 1-5 (5 = largest)	% Visible Root Cover over Pot Ball	Amount of new Root 1-5 (5 = most)
A.	25 mm Gravel	2.03	41.0	2.41
B.	75 mm Sand + Seephose	1.91	47.2	2.97
C.	75 mm Sand + Overhead	2.51	40.4	2.74
D.	25 mm Gravel + 25 mm Sand	1.86	44.8	2.72
E.	25 mm Gravel + 50mm Sand	2.19	43.9	2.89
F.	25 mm Sand + Overhead	2.13	43.9	2.92
d.f. = 8	*SED ±*	*0.389*	*2.84*	*0.150*
	LSD 5% ±	*0.90*	*6.6*	*0.35*

DISCUSSION

This Project looked at methods of improving water utilisation on gravel beds by infilling with 25 or 50 mm of sand and compared their performance against standard gravel and drained sand bed systems. The potential of a simple Rapitest Water Meter for monitoring water status of the growing media on the different bed systems was examined, linking into a watering regime aimed at plant requirements rather than watering to excess.

The two seasons over which the work was done had contrasting weather patterns, with 1993/94 being relatively wet, but 1994/95 very dry over the growing season. As a result differences in water regimes between bed systems were much smaller in the first season.

The 75 mm drained sand beds still proved the most efficient in terms of water use when compared against the 25 mm gravel bed, especially in the drier season where savings of around 70% were made. Savings were greatest where these sand beds were irrigated with low level seephose as compared to overhead irrigation systems. However, the use of a sand infill looked a promising method of improving efficiency of water utilisation on gravel systems, but measurement of the potential savings over the drier season were confounded by the permeable Mypex lining, which allowed water to be drawn out of the bed down into the drier soil profile beneath. Mypex linings under gravel are commonly used to improve drainage away from the beds, but non-permeable polythene linings would be required if sand infills were being considered as a means of improving water utilisation. More work is therefore required to determine the depth of sand infill required to achieve the most cost effective savings in water use, together with an assessment of winter drainage.

The Rapitest Meter provided a surprisingly accurate tool in monitoring differences in water status of growing media between species and the different bed systems as well as providing a means of identifying a set point for when to water, once calibrated to crop requirements. The small hand held meter proved simple to use with almost instantaneous readings once the probe was inserted into the media, enabling a number of readings to be taken very quickly. The results obtained showed just how responsive the meter was to rapid changes in moisture content of the growing media either from irrigation or rainfall events, far more so than the Watermark Meters which are normally used in the soil, and did not appear suited to container crops. (see p. 9) A single meter was used throughout the trial to ensure comparisons between bed systems were valid, since different meters could give varying readouts and each meter would need calibration to crop requirements. The readout scale of the Rapitest Meter would need further calibration against more accurate monitoring equipment if the actual moisture tension achieved under the different conditions was required. However, for the purpose of this work the relatively simple meter provided a cheap means of taking a large number of readings over a short period of time in different containers to obtain an average for a bed system to aid irrigation management. The depth of moisture measurement needed to be standardised, since this work showed the marked changes in water status from the drier zones towards the top of the container to the wetter lower horizons. In this work two depths were measured and an average taken for the purpose of monitoring irrigation requirements, though a single measurement at a set depth could probably do a similar job provided it was calibrated against crop requirements. The measurements also gave the opportunity to investigate a 'lean' water regime by only watering back up to a predetermined level, instead of to excess. Again this needed initial calibration to crop requirements but proved a useful tool in improving efficiency of water use. More work is required to determine the parameters of when and how much water needs to be applied, and the influence of these 'leaner' water regimes on plant growth and quality. Such information could gradually build up a database to provide guidelines on the amount of water to apply depending on the meter readings.

As to be expected, variation in species' requirements showed up clearly in this work, and highlighted the problem of mixed cropping on the same bed. Thus in Year 1, when one species with a high water requirement (*Hydrangea*), and three with a low water requirement (*Cytisus*, *Genista*, *Lavandula*) were on the same bed, irrigation applied was a compromise of an average of water measurements over the four species. Thus *Hydrangea* tended to be underwatered, the other three overwatered. This was overcome in the second year by only having one species on the bed (*Hydrangea*).

The different bed systems appeared to have little effect on the quality of plants over winter in this work, even though the 75 mm sand beds provided more positive drainage of water from the pots. However, it was noticeable with the *Lavandula* in the second year that new root development in the spring was improved on the sand compared to the gravel system.

In summary the use of a sand infill to existing gravel beds appears a promising method of improving their efficiency of water use, providing a non-permeable lining is used in the base, though the 75 mm drained sand bed still provides the greatest savings in water use, and winter drainage capability. The full potential of the 'infill beds' to conserve water needs further investigation over a dry season, since in this work results were confounded by the permeable lining which allowed water to be pulled from the bed in the drier season. The Rapitest Water Meter appears a useful tool for monitoring water status of growing media and identifying the point at which irrigation is required. However, each meter will need calibration to crop requirements, and further work is needed to develop the 'lean' watering regimes that become possible by such monitoring, since these requirements will vary with species and system of production.

CONCLUSIONS

This two-year Project over 1993/94 and 1994/95 investigated the potential of improving water efficiency of gravel systems by infilling with 25-50 mm of sand, and the use of a simple Rapitest Meter to monitor water status of growing media and provide a tool to aid crop water management. The two seasons provided extremes of weather conditions for the work with a wet first year and a dry second season, though both had wet winters. The main findings of the work were as follows.

- A 25 mm and in particular a 50 mm depth of sand infill to an existing 25 mm gravel bed improved efficiency of water use.

- When using a sand infill to gravel it will be important to have a non-permeable polythene lining over the base. In this work the use of permeable Mypex lining actually increased water use in the dry season as water was drawn out of the bed into the drier soil profile beneath. The 75 mm drained sand bed systems, particularly with seephose irrigation, still provided the most efficient system for improving water utilisation and winter drainage. In the dry season, savings of 70% were achieved compared to the gravel system. The savings which could be achieved with the 25-50 mm of sand infill to gravel systems needs further investigation on beds with a non-permeable lining.

- In this work bed system appeared to have little influence on quality of overwintered crops, though there was evidence of increased new root growth from drained sand as opposed to gravel bed systems for water sensitive species (*Lavandula*) in the spring.

- The Rapitest Meter provided a useful means of monitoring water status of the growing media between species and bed systems, and a tool for water management by determining the point at which irrigation needed to be applied, once calibrated to crop requirements.

- The measurement of water status of the growing media provided the means of managing irrigation to provide a 'leaner' regime by watering back up to a predetermined level instead of to excess, though again this needed calibration to crop requirements. Further work is required in the development of 'lean' water regimes, both in respect of irrigation management and effects on crop growth.

- Species with similar water requirements need to be grouped together to ensure differential watering regimes can be applied, thus avoiding over and under watering.

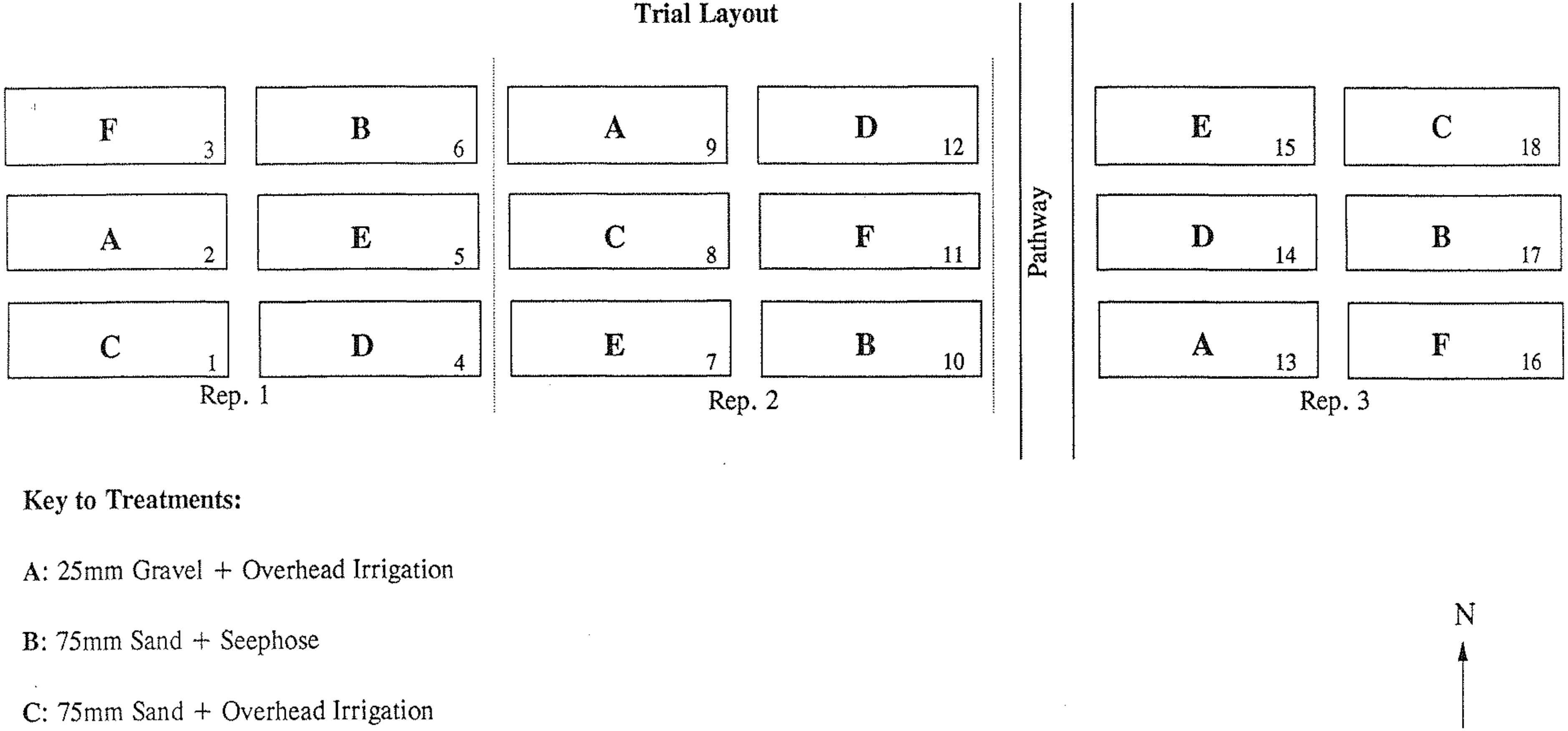
- More work is required to confirm these results and gain further information on the potential improvement in water utilisation from sand infills to gravel with non-permeable linings.

APPENDICES

APPENDIX I

HNS 38 Water Use under different HNS Container Systems (1993-95)

Trial Layout



Key to Treatments:

A: 25mm Gravel + Overhead Irrigation

B: 75mm Sand + Seephose

C: 75mm Sand + Overhead Irrigation

D: 25mm Gravel + 25mm Sand Infill

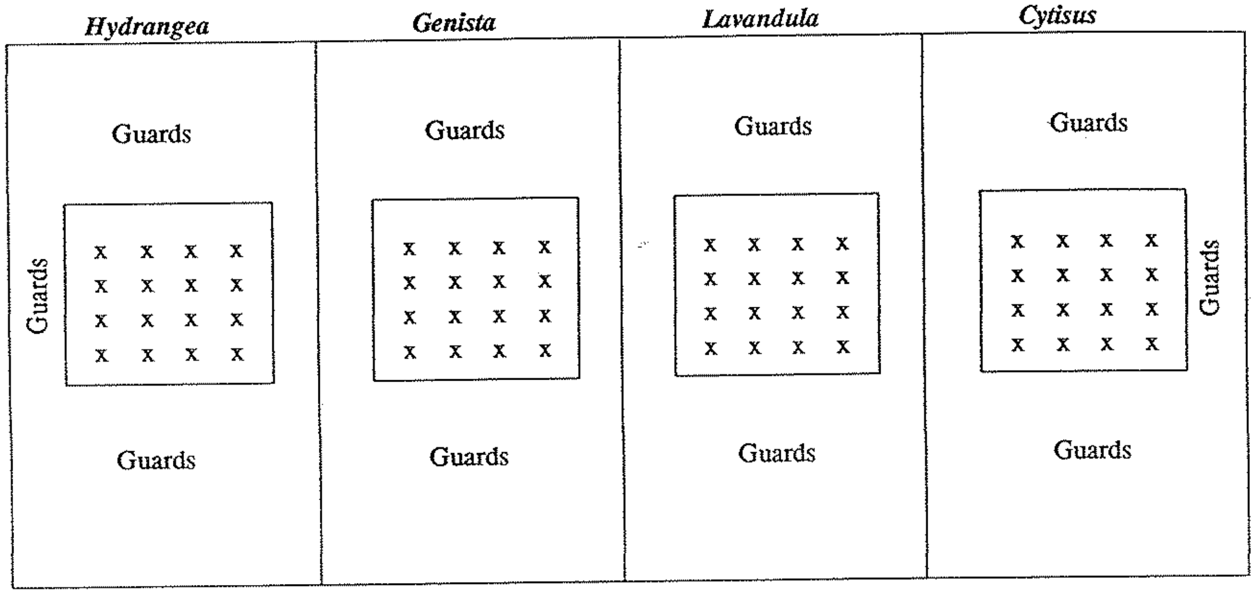
E: 25mm Gravel + 50mm Sand Infill

F: 25mm Sand + Overhead Irrigation

HNS 38 Water Use under different HNS Container Systems (1993-95)

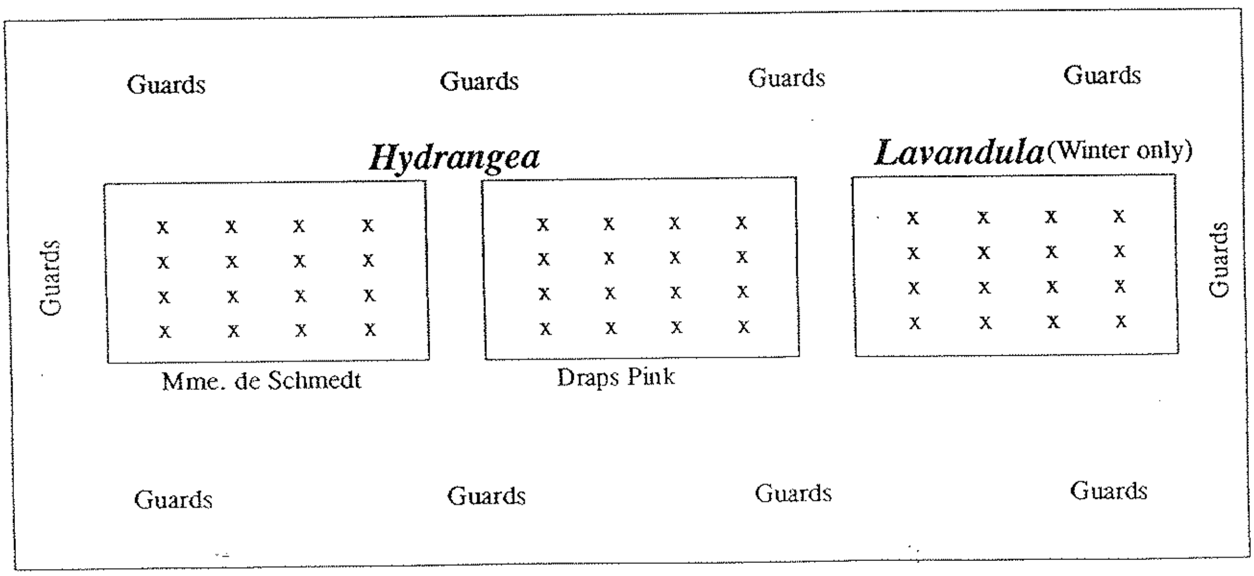
Bed Layout

1993-94



Recorded plot = 16 plants in centre of each species block

1994-95

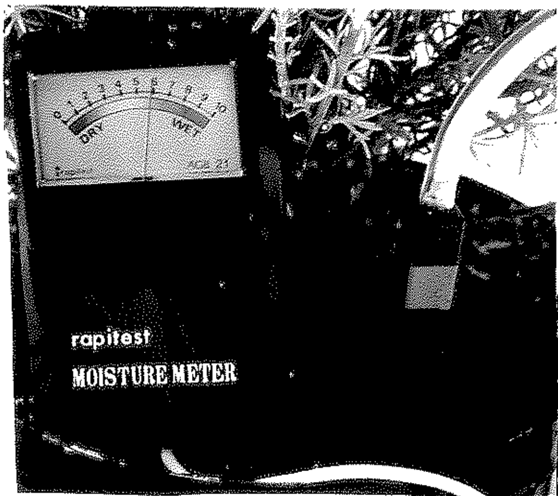


APPENDIX II

PLATE 1

Rapitest Moisture Meter

Probe marked for 4 and 8 cm depths



↑ Meter reading at which irrigation was applied

Rapitest Moisture Meter in use

APPENDIX III

HRI Efford Meteorological Data

Table 9 **Rainfall (mm)**

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1995	**143.8**	**116.8**	**40.2**	**27.1**	**22.2**							
1994	**132.2**	**89.4**	**57.8**	**61.3**	**81.7**	**23.4**	**19.6**	**47.6**	**70.9**	**125.8**	**91.4**	**116.9**
1993	98.0	6.2	45.2	74.7	45.7	61.6	**86.2**	**35.8**	**120.7**	**169.3**	**64.4**	**185.0**
1992	21.7	28.6	51.6	70.4	19.6	32.2	63.1	88.1	78.9	81.5	145.3	81.2
1991	88.5	29.3	77.9	42.3	4.0	113.0	63.3	12.3	48.6	63.0	49.2	33.4
1990	112.7	166.5	6.4	43.9	11.2	55.3	12.2	23.1	28.9	98.6	53.6	62.3
1989	30.6	69.8	74.8	71.7	13.7	34.6	22.5	23.6	37.3	91.0	56.6	242.4
1988	170.9	47.3	82.0	39.5	27.9	34.3	71.8	63.6	41.6	98.4	20.7	20.8
1987	15.8	60.4	89.4	69.1	19.3	54.4	61.4	16.4	37.7	195.6	78.3	43.2
1986	109.9	11.3	61.3	58.9	74.3	25.3	46.6	87.6	33.9	79.2	114.6	102.6
1985	69.5	47.0	51.6	43.8	44.6	61.1	37.8	88.2	24.3	32.4	53.4	88.0
1984	120.5	36.1	81.3	0.3	86.4	18.6	12.0	18.7	62.1	94.6	127.9	96.2
1983	68.1	25.9	36.9	86.0	77.3	47.8	7.1	32.7	66.3	57.2	40.9	82.0
12/13 yr mean	90.9	56.5	58.2	53.0	40.6	46.8	42.0	44.8	54.3	98.9	74.7	96.2
41/42 yr mean	83.9	55.2	59.0	45.3	47.8	54.1	46.9	57.7	70.0	83.8	83.2	88.3

N.B. **Bold** figures in body of table relate to the period of the trial.

APPENDIX III

HRI Efford Meteorological Data

Table 10 Mean Daily Sunshine Hours

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1995	**1.7**	**2.7**	**6.2**	**6.2**	**8.7**							
1994	**2.5**	**2.7**	**3.7**	**6.3**	**5.8**	**9.5**	**9.0**	**6.8**	**5.0**	**5.7**	**1.3**	**2.0**
1993	1.1	2.3	4.6	4.5	6.7	8.3	**6.0**	**8.2**	**4.6**	**4.3**	**2.8**	**1.9**
1992	2.4	2.1	2.02	5.5	9.25	8.25	5.4	5.2	4.7	4.2	2.0	1.7
1991	2.20	2.76	3.55	5.80	5.81	5.20	7.2	8.6	6.1	3.0	2.2	1.7
1990	1.52	3.24	5.15	8.13	9.63	4.60	10.18	8.64	6.34	3.52	3.02	1.95
1989	2.21	3.66	3.04	5.65	10.57	9.25	9.75	9.31	4.80	3.56	3.62	1.14
1988	1.97	4.58	3.39	6.49	8.02	6.10	6.65	5.91	3.84	3.46	3.46	1.48
1987	2.13	2.96	3.94	6.68	7.77	5.79	7.15	6.47	4.97	3.54	2.10	1.42
1986	2.03	2.74	3.57	5.57	5.85	7.22	6.16	5.65	5.64	3.37	2.75	2.05
1985	2.48	2.99	4.25	5.66	6.88	6.04	7.86	6.45	5.36	4.07	2.75	1.19
1984	2.80	2.92	2.92	8.22	4.93	9.86	8.92	6.84	4.03	2.89	2.21	1.87
1983	1.86	3.67	3.56	5.42	5.56	6.60	9.17	8.48	3.87	3.66	1.88	2.10
12/13 mean												
	2.1	3.0	3.8	6.2	7.3	7.2	7.8	7.2	4.9	3.8	2.5	1.6
41/42 yr mean												
	2.0	2.8	4.1	5.9	7.1	7.3	7.3	6.7	5.3	3.9	2.5	1.8

N.B. **Bold** figures in body of table relate to the period of the trial.

APPENDIX III

HRI Efford Meteorological Data

Table 11 **Mean Maximum Temperature (°C)**

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1995	**9.2**	**10.6**	**10.7**	**13.6**	**16.7**							
1994	**9.5**	**8.2**	**11.5**	**12.2**	**14.8**	**18.7**	**22.2**	**21.2**	**17.5**	**15.6**	**13.8**	**11.3**
1993	9.8	7.8	10.4	13.2	16.5	19.5	**19.1**	**19.6**	**17.1**	**13.0**	**9.4**	**9.7**
1992	7.2	9.0	10.9	12.7	18.7	20.6	20.1	19.5	17.6	12.9	12.3	8.2
1991	7.3	5.1	11.0	12.2	15.5	15.5	20.5	21.0	20.0	14.0	10.9	8.5
1990	10.4	11.2	11.8	13.6	18.4	16.9	21.9	22.7	19.1	16.1	10.8	7.9
1989	9.9	10.0	11.5	10.8	19.3	20.2	23.9	21.6	19.5	16.5	11.5	9.5
1988	9.1	8.9	10.2	12.7	16.7	18.8	17.5	19.1	17.7	15.1	10.6	10.7
1987	3.9	7.4	8.1	13.4	15.2	16.6	20.5	20.4	18.1	14.7	10.5	8.3
1986	7.8	2.2	8.3	9.9	13.7	20.0	19.4	17.9	15.9	15.4	12.3	10.0
1985	4.2	5.8	8.4	12.7	15.8	17.2	20.5	18.1	18.4	14.9	8.3	9.8
1984	8.5	7.7	8.6	13.7	14.4	19.5	22.0	22.0	18.0	15.0	12.1	9.8
1983	9.6	5.4	9.6	10.8	13.8	18.3	24.4	22.7	17.8	14.5	11.0	9.7
12/13 yr mean	8.2	7.6	10.1	12.4	16.1	18.5	21.0	20.5	18.1	14.8	11.1	9.5
41/42 yr mean	7.5	7.4	9.8	11.9	15.6	18.4	20.4	20.3	18.3	15.0	10.9	8.7

N.B. **Bold** figures in body of table relate to the period of the trial.

APPENDIX III **HRI Efford Meteorological Data**

Table 12 Mean Minimum Temperature (°C)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1995	**3.2**	**5.8**	**2.6**	**5.7**	**7.8**							
1994	**4.1**	**2.1**	**5.6**	**4.4**	**8.6**	**10.4**	**13.8**	**13.7**	**10.9**	**7.7**	**9.6**	**5.3**
1993	5.1	3.3	3.8	6.5	8.8	11.4	**12.4**	**11.3**	**10.0**	**7.0**	**2.8**	**4.1**
1992	1.7	2.8	5.3	5.6	9.2	10.8	13.5	13.4	12.0	5.4	6.2	2.7
1991	3.1	0.5	5.4	4.8	7.0	9.4	12.9	12.8	11.5	8.1	4.8	4.0
1990	5.5	6.3	5.6	4.3	8.6	10.8	12.6	13.5	9.7	10.3	5.8	3.3
1989	4.3	3.3	5.1	3.9	9.4	10.9	14.3	13.0	12.0	10.0	5.6	4.3
1988	4.0	2.5	4.5	4.8	8.8	10.7	12.4	11.9	10.3	7.6	3.0	5.3
1987	0.6	1.7	1.9	6.1	7.0	9.7	12.4	11.9	11.9	8.4	4.8	4.5
1986	1.8	2.2	2.2	2.9	7.8	10.5	12.4	11.5	7.6	8.8	5.9	4.2
1985	1.3	0.2	1.5	4.5	7.3	9.2	11.9	12.5	11.1	8.7	2.2	5.5
1984	2.7	2.1	2.3	3.7	6.7	10.3	11.6	13.3	11.2	9.3	6.6	3.2
1983	5.1	0.6	3.4	4.2	7.7	11.3	14.9	13.1	11.4	8.4	5.9	3.8
12/13 yr mean	3.3	2.6	3.8	4.7	8.1	10.5	12.9	12.7	10.8	8.3	5.3	4.2
41/42 yr mean	2.3	1.9	3.3	4.4	7.5	10.3	12.3	12.3	10.7	8.2	4.9	3.4

N.B. **Bold** figures in body of table relate to the period of the trial.

Contract between HRI (hereinafter called the "Contractor") and the Horticultural Development Council (hereinafter called the "Council") for a research/development project.

1. TITLE OF PROJECT

Contract No. HNS38
(Extension for a second year)

WATER USE UNDER DIFFERENT HARDY NURSERY STOCK CONTAINER SYSTEMS

2. BACKGROUND AND COMMERCIAL OBJECTIVE

As for HNS38.

3. POTENTIAL FINANCIAL BENEFIT TO THE INDUSTRY

As for HNS38.

4. SCIENTIFIC/TECHNICAL TARGET OF THE WORK

As for HNS38.

5. CLOSELY RELATED WORK

As for HNS38.

6. DESCRIPTION OF THE WORK IN YEAR 2

Bed Systems

The second year of work will look further at the potential of the six bed systems studied in the first year with the objective of improving water use on existing gravel based systems. These were:

1. 25mm gravel over Mypex with overhead irrigation.
2. 25mm sand over Mypex with overhead irrigation.
3. 25mm gravel over Mypex + 25mm sand infill with overhead irrigation.
4. 25mm gravel over Mypex + 50mm sand infill with overhead irrigation.
5. 75mm sand (+ drain) over polythene plus overhead irrigation.
6. 75mm sand (+ drain) over polythene plus seephose low level irrigation.

Species

Due to the different water requirements seen with the range of species used in the 1993/94 period of work this year's trial will be limited to *Hydrangea* during the summer period. This species has a high water requirement and will, therefore, give more opportunity for irrigation measurements. *Lavendula* 'Hidcote', which is susceptible to over-wet conditions, will be grown over the season on a gravel bed with overhead irrigation and transferred to the treatment beds over winter to monitor their influence on water drainage and subsequent plant quality.

Design

6 systems
x
3 replicates

18
x
4 blocks of *Hydrangea*

72 sub-plots

16 plants/sub-plot to be recorded

Assessments

1. Daily moisture measurements of 2 plants per sub-plot at 4cm and 8cm depth using a Rapitest moisture meter to determine when to irrigate and show the fluctuations in moisture content throughout the trial.

2. Record of irrigation requirements and adjustment of amount of irrigation applied to aim at a fixed moisture content.

3. Plant top growth record autumn 1994 and top and root growth record spring 1995.

7. COMMENCEMENT DATE, DURATION AND REPORTING

Start date 01.06.93; duration 2½ years.

The HDC water use leaflet will be produced by 01.10.94.

/.e.g.

~~The report for the first year's work will be produced by October 1994~~. The experimental work will be completed by May/June 1995 and the final report will be produced by October 1995. (This report will include the results from 1994/95 together with the results from the earlier work).

8. STAFF RESPONSIBILITIES

As for HNS38.

9. LOCATION

As for HNS38.

Contract No: HNS38-Ext

TERMS AND CONDITIONS

The Council's standard terms and conditions of contract shall apply.

Signed for the Contractor(s)	Signature..
	Position.. Commercial and Marketing Manager HCl
	Date.............27.2.95....................
Signed for the Contractor(s)	Signature..
	Position..
	Date..
Signed for the Council	Signature..
	Position.......CHIEF EXECUTIVE.......
	Date.............27.10.94....................