CONTRACT REPORT
INFLUENCE OF HUMIDITY AND OTHER STRESS FACTORS ON PLANT GROWTH

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Influence of humidity and other stress factors on plant growth

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Hewton Trees & Shrubs

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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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SUMMARY

Concern has been expressed by many Hardy Nursery Stock (HNS) growers at the incidence of leaf tipping/distortion on 'late' potted liners of a number of evergreen HNS species grown 'cold' overwinter in polythene tunnels.

In the first year of this work, jointly funded by Electricity Association Technology Ltd (who supplied the DH150 dehumidification unit) and through HDC, a number of potential stress factors were investigated with a view to finding the cause of these leaf disorders.

Three target humidity regimes were used, low (<80% RH, using a Calorex DH150 dehumidifier), ambient, and high (>95% RH, achieved using a fogging system). A single tunnel was used to house each of these humidity treatments.

Two bed types were included, with each tunnel containing an overhead irrigated gravel bed and a low level irrigated sand bed.

Two different Air Filled Porosities (AFP's) were achieved by using different preparation methods of the same growing media (medium grade Irish Shamrock moss peat). In addition, two sources of lime were evaluated, ground limestone and magnesian limestone, together with a 'standard' and 'high' rate (30% above the standard rate) of Controlled Release Fertilizer (CRF), (Osmocote Plus 12-14 month 'Autumn' (15+8+11+2 MgO + traces).

Treatments were applied to five test species/cultivars, *Choisya ternata*, *Pieris* 'Forest Flame', *Prunus laurocerasus* 'Otto Luyken', *Rhododendron* 'Fairylight' and *R.* 'Surrey Heath'.

None of the stress factors investigated produced the leaf scorching/distortion that had been reported previously elsewhere. However, trends in growth were recorded as a result of the treatments applied.

The high target humidity was readily achieved using fogging equipment, but it proved difficult to consistently maintain an RH of less than 80% in the low humidity regime, particularly when air temperatures were less than 8-10°C. However, the humidities achieved in this tunnel were still significantly lower than in the ambient humidity regime.

The minimum air temperature in the low humidity tunnel was several degrees higher than in the other two tunnels and this inevitably advanced the growth of some of the species, particularly *Pieris*. The equipment has since been recalibrated to allow a standard temperature regime to be maintained between tunnels for future work.

However, the potential of the dehumidification equipment to supply a 3-4°C temperature lift could be a significant advantage commercially for 'frost protection'. Apart from this there was no consistent effect of humidity regime on plant growth. However, the incidence of liverwort was generally greater in the high humidity regime, particularly where overhead irrigation was used.

Bed system, coupled with irrigation regime, also affected growth, with plants of *Choisya ternata* and *Prunus laurocerasus* 'Otto Luyken' growing better on the low level irrigated sand beds than on the overhead irrigated gravel beds. Little difference in growth was seen between the two systems with *Pieris* and *Rhododendron*.

Despite obvious differences in media structure, no consistent effect on growth of any species was observed. Similarly, the 'high' rate of CRF appeared to cause few problems, even with the 'salt sensitive' species *Pieris* and *Rhododendron*.

By the end of the trial, nutrient levels and conductivity were higher in growing media on the low level irrigated sand beds than in those used on overhead irrigated gravel beds, reflecting the reduced leaching with this system.

Results are discussed in relation to the equipment and systems used, and their commercial relevance, and suggestions for future work are presented.

INTRODUCTION

Problems of leaf disorders (distortion, tip cupping/burning, chlorosis), have been recorded on young evergreen plants grown overwinter under protection. Various theories as to the cause have been investigated, including exposure to herbicides, but no definite conclusions have been reached. Another theory is that the problem might be linked to trace element deficiency, particularly calcium, brought on as a result of low transpiration rates linked to slow growth/high humidities at this time of year under protection which will limit transport of calcium via the xylem system. Unlike protected crops, most tunnels for hardy nursery stock are unheated and relative humidity (RH) builds up, such that in the early mornings dew point can be reached on occasion. Plant stress, particularly root stress, also appears to be involved, symptoms having occurred where poor root development was related to potting too firm in mixes with low Air Filled Porosity (AFP), or where nutrient levels were relatively high. Current lime recommendations are based on work in the 1970's and in the main are for the use of magnesian limestone. However, new Controlled Release Fertilizer (CRF) formulations include magnesium in the granule and the whole topic of type and rate of lime to use needs reappraising, especially as too high a magnesium level can affect uptake of calcium.

Dehumidification offers an opportunity to investigate these theories further, as well as exploring effects of RH on overall plant quality.

The work carried out in 1992/93 was jointly funded through the Horticultural Development Council and Electricity Association Technology Ltd.

OBJECTIVE

To evaluate the effects of humidity and other stress factors such as poor growing media structure, high levels of nutrition, lime source and irrigation regime on quality of growth of a range of evergreen hardy nursery stock species.

MATERIALS AND METHODS

Treatments

1. Target humidities

a) ambient.

b) minimum of 95%, achieved by using a CF-2 fogging system (Duntech Irrigation Services Ltd).

c) maximum of 80%, achieved by using a Calorex DH 150 dehumidifier (supplied by Electricity Association Technology Ltd).

Three single span tunnels (11 m long x 4.25 m wide) were used with one humidity treatment in each tunnel.

2. Irrigation regime

a) seephose irrigation on a sand bed.

b) overhead irrigation on a gravel bed.

Each tunnel contained one sand bed and one gravel bed. Overhead irrigation nozzles giving 180° throw pattern were used on the gravel bed to prevent overspill onto the sand bed.

3. Growing media structure

a) 'open' (target AFP = 18-20%).

b) 'poor' (target AFP = 9-10%).

Medium grade Irish Shamrock moss peat was used for both mixes. Peat for the 'open' mix was used 'ex bale', whilst that for the 'poor' mix was sieved twice and mixed for longer to reduce the AFP. Details are given in Appendix I (page 44).

4. Nutrition

a) Osmocote Plus 12-14 month 'Autumn' (15+8+11+2MgO+traces) at standard rate*.

b) Osmocote Plus 12-14 month 'Autumn' (15+8+11+2MgO+traces) at 30% above standard rate*.

*Standard rate varied with species. Details are given in Table 1 below.

Table 1: Rate of Controlled Release Fertilizer used according to species

Irrigation regime	Overhead		Seephose	
Rate of Osmocote (kg/m^3)**	Standard	High	Standard	High
Species				
Pieris 'Forest Flame' (very sensitive)	2.5	3.3	2.0	2.7
Rhododendron cvs (sensitive)	3.0	4.0	2.5	3.3
Choisya ternata } *Prunus laurocerasus* 'Otto Luyken' } (general)	4.0	5.3	3.5	4.6

**Osmocote Plus 12-14 month 'Autumn' (15+8+11+2MgO+traces)

5. Lime source

a) calcium carbonate (as ground limestone).

b) magnesian limestone.

(both used at 1.5 kg/m^3 for all species as neutralising values very similar).

6. Species

Choisya ternata
Pieris 'Forest Flame'
Prunus laurocerasus 'Otto Luyken'
Rhododendron 'Fairylight'
Rhododendron 'Surrey Heath'

Experimental design

The humidity and irrigation treatments were not replicated. However, there were four replicates of each of the remaining treatments (i.e. growing media structure, nutrition and lime source), with seven recorded plants/plot (unless otherwise specified under individual species). The same plot layout was used in each tunnel, to avoid any interaction of positional effects within the tunnel. The plot layout within the tunnels is given in Appendix II (page 45).

Trial site

The three small tunnels (orientated east-west) were fully clad in polythene, with a single door at the eastern end. In each tunnel the gravel bed with overhead irrigation was situated on the northern side, and the sand bed with seephose irrigation on the southern side.

The northernmost tunnel contained the CF-2 fogging system, and the southernmost the Calorex DH 150 dehumidifier. The centre tunnel was the ambient humidity 'control'.

Husbandry

Plants were potted into 9 cm pots according to treatment on the dates shown in Table 2 below.

Table 2: Source of plant material, potting and treatment introduction dates

Species	Source	Date potted	Date moved into treatment tunnels*
Rhododendron 'Fairylight'	Ex micropropagation	Early Nov. '92	Early Dec. '92
R. 'Surrey Heath'	Ex micropropagation	Early Nov. '92	Early Dec. '92
Choisya ternata	Rooted cuttings	Early Dec. '92	Mid Dec. '92
Pieris 'Forest Flame'	Rooted cuttings	Late Dec. '92	Mid Jan. '93
Prunus laurocerasus 'Otto Luyken'	Rooted cuttings	Late Jan. '93	Early Feb. '93

*After potting plants were held under cold glass until transfer to the trial tunnels.

During the winter period whilst there was a risk of frost, plants were protected using Agrifleece laid over hoops erected over the beds.

Throughout the winter/early spring, and on dull days thereafter, the doors of the tunnels were kept closed and the treatment humidities maintained. However, as the weather improved in March the doors were opened during the day to provide ventilation and reduce the air temperature within. The fogging equipment and dehumidification unit were switched off whilst the doors were open, but were switched on again when the doors were closed at night.

Assessments

Environmental records

The minimum and maximum air temperatures (°C) within each tunnel were recorded daily. The Relative Humidity (%) was measured at 30 minute intervals in each humidity regime throughout the trial period using a Delta T data logger.

Irrigation water applied

The quantity of water (in litres) applied through the two types of irrigation system in each of the three tunnels was recorded (using a Kent water meter) throughout the trial period.

Air Filled Porosity (AFP)

The AFP of the two different 'structures' of growing media was recorded at the beginning of the trial, before potting, using the 'Rapid Drainage Test' developed by Neil Bragg. Five samples of each of the 'open' and 'poor' structured mixes were recorded.

Growing media analyses

The pH, conductivity and levels of phosphorus, potassium, magnesium, nitrate and ammonium nitrogen in the various growing media used for *Prunus laurocerasus* 'Otto' Luyken' and *Rhododendron* 'Surrey Heath' were determined at the beginning and end of the trial in each humidity regime (ADAS analytical services).

Plant growth records

Choisya ternata

The number of shoots/plant and the length (cm) of the longest shoot/plant were recorded on 11 June 1993.

Pieris **'Forest Flame'**

Plants were graded according to stage of growth on 17 May 1993 using a 1-7 scale, where 1 = no new shoot growth and 7 = full flush of growth complete (see Plate 1, page 41).

Rhododendron **'Fairylight'**

Plants were graded according to stage of growth on 24 May 1993 using a 1-4 scale, where 1 = smallest and 4 = largest (see Plate 2, page 41).

Rhododendron **'Surrey Heath'**

Plants were graded according to stage of growth on 1 June 1993 using a 1-5 scale, where 1 = smallest and 5 = largest (see Plate 3, page 41).

Prunus laurocerasus **'Otto Luyken'**

Plants were graded according to stage of growth/size on 19 June 1993 using a 1-9 scale where 1 = smallest and 9 = largest (see Plate 4, page 42).

Liverwort growth

Liverwort cover on the surface of each pot was scored at the end of the trial period using a 0-5 scale, where 0 = no liverwort and 5 = liverwort growth over whole surface of growing media, and overhanging pot rim (see Plate 5, page 42).

RESULTS

Environmental records

a) Air temperature

The minimum and maximum air temperature (°C) was recorded daily throughout the trial period using max/min thermometers situated in each tunnel. The data for February (as a representative month) is presented in Table 3 on page 10.

The minimum air temperature recorded in the 'dehumidified' tunnel was consistently several degrees higher than in the ambient and 'fogged' tunnels. A similar trend was evident in the maximum temperatures, although this was generally more obvious on 'cooler' days, and the differential was much smaller.

The lowest average minimum and maximum air temperatures were recorded in the 'fogged' tunnel.

b) Relative Humidity (RH)

The % RH for a typical 24-hour period during the latter part of the trial is shown in Table 4, on page 11.

The difference in RH due to treatment is obvious from 00.00 - 08.00 hours, and from 19.00 - 23.00 hours when the dehumidification unit and fogging equipment was switched on. In the intervening period during the day, from 08.00 - 19.00, when the tunnel doors were open and the equipment switched off, the RH was similar in all 3 tunnels.

Table 3: Minimum and maximum air temperature (°C) throughout February 1993

Date		Air temperature °C				
	Minimum			Maximum		
	Humidity regime			Humidity regime		
	Low	Ambient	High	Low	Ambient	High
February 1	8	4	3	16	12	10
2	9	3	2	14	10	9
3	10	9	3	20	21	19
4	9	4	3	18	13	18
5	8	2	1	12	7	6
6	6	1	1	13	9	7
7	9	4	3	22	22	19
8	14	8	7	19	17	16
9	10	5	5	16	11	10
10	10	5	4	13	9	8
11	6	5	4	13	9	7
12	10	5	4	15	11	10
13	11	6	5	14	10	9
14	9	4	4	21	23	20
15	10	5	4	20	18	17
16	9	2	1	23	23	21
17	11	1	1	28	30	26
18	14	3	2	20	18	16
19	9	3	3	19	15	12
20	8	1	1	20	21	18
21	12	4	3	25	26	21
22	4	0	0	29	25	21
23	6	0	1	25	26	23
24	6	3	2	27	30	25
25	10	4	3	24	25	20
26	8	2	1	24	25	20
27	6	1	0	21	21	18
28	2	0	0	23	24	19
Mean	8.7	3.4	2.5	19.8	18.3	15.9

Table 4: Percentage Relative Humidity measured at hourly intervals from 00.00 - 23.00 hours on 21 April 1993

Time	% Relative Humidity		
	Humidity regime		
	Low	Ambient	High
00.00	84	95	100
01.00	84	96	100
02.00	84	96	100
03.00	83	96	100
04.00	83	96	100
05.00	83	96	100
06.00	83	97	100
07.00	83	96	100
08.00	87	89	99
→	Dehumidifier and fog system switched off, as tunnel doors open.		
09.00	62	53	77
10.00	50	41	45
11.00	38	33	35
12.00	49	55	54
13.00	48	49	47
14.00	46	50	49
15.00	26	26	30
16.00	31	32	32
17.00	37	39	43
18.00	50	50	51
→	Dehumidifier and fog system switched on, tunnel doors closed.		
19.00	74	77	89
20.00	78	87	96
21.00	80	92	99
22.00	81	93	100
23.00	81	93	100

Irrigation water applied

The quantity of water applied using low level and overhead irrigation in each of the tunnels is given in Tables 5a and 5b. More water was used in low level watering in all humidity regimes, than where an overhead sprinkler system was used. However, a similar trend in the quantity of water used in the three tunnels was evident with both irrigation systems, with the most water being applied in the low humidity tunnel, and the least in the high humidity regime.

Table 5a: Quantity of water applied (litres)/month using low level irrigation on sand beds

Month '93	Humidity regime		
	Low	Ambient	High
January	600	0	0
February	0	0	0
March	612	612	700
April	817	1432	0
May	2641	1739	2306
June	1233	811	1606
Total	5903	4594	4612

Table 5b: Quantity of water applied (litres)/month using overhead irrigation on gravel beds

Month '93	Humidity regime		
	Low	Ambient	High
January	134	105	0
February	113	90	0
March	769	580	179
April	868	808	500
May	2095	1521	1527
June	1005	1301	1220
Total	4984	4405	3426

Air Filled Porosity (AFP)

The recorded AFP's of the 'open' and 'poor' structured growing media were 12% and 7% respectively. Although these were slightly lower than the target values of 18-20% and 9-10%, a differential was established.

Growing media analyses

The results of the growing media analyses taken at the beginning and end of the trial are summarised in Tables 6a and 6b on page 15 for *Prunus laurocerasus* 'Otto Luyken' and Tables 9a and 9b on page 18 for *Rhododendron* 'Surrey Heath'. The full analyses are given in Tables 7 and 8 (pages 16 and 17) and 10 and 11 (pages 19 and 20).

a) *Prunus laurocerasus* **'Otto Luyken'**

The **pH** of the growing media remained similar throughout the trial where plants were grown on gravel beds, but fell slightly in those on the low level irrigated sand beds.

The level of **phosphorus** did not alter substantially during the trial in the growing media used on gravel beds, but almost trebled in the growing media on sand beds.

Levels of **potassium** had increased markedly in growing media used on both sand and gravel beds by the end of the trial.

A similar trend was recorded for **magnesium**, although levels were generally lower in media on the overhead irrigated gravel beds at the end of the trial, compared to those on the low level irrigated sand beds.

Conductivity was generally lower in the final analyses of media on the gravel beds, irrespective of the rate of CRF used.

b) *Rhododendron* **'Surrey Heath'**

The **pH** of growing media on the gravel beds was slightly lower than that on the sand beds by the end of the trial.

Levels of **phosphorus** and **potassium** decreased during the trial in media on the gravel beds but increased in media on the sand beds.

Levels of **magnesium** increased in all growing media during the trial period, but more markedly in those on the low level irrigated sand beds.

Conductivity was higher in growing media on the sand beds at the end of the trial, particularly where a 'high' rate of CRF was used. In contrast, the conductivity decreased slightly in media on the overhead irrigated gravel beds.

Table 6a: Growing media analyses for *Prunus laurocerasus* 'Otto Luyken' meaned according to irrigation and humidity regime

	Irrigation regime	Initial	At end of trial Humidity regime Low	Ambient	High
pH	overhead	5.1*	4.9	5.0	4.9
	low level	5.0	4.5	4.6	4.8
Phosphorus (mg/l)	overhead	13*	17	14	20
	low level	10	29	27	28
Potassium (mg/l)	overhead	29*	83	45	73
	low level	27	90	78	76
Magnesium (mg/l)	overhead	14*	53	18	36
	low level	12	71	68	78
Conductivity (μS)	overhead	152*	302	165	238
	low level	140	332	340	355

* Data not available for initial analyses of ground limestone/'high' CRF combination.

Table 6b: Conductivity (μS) of growing media for *Prunus laurocerasus* 'Otto Luyken' meaned according to rate of CRF, irrigation and humidity regime

Irrigation regime	Rate of CRF	Initial	At end of trial Humidity regime Low	Ambient	High
Overhead	'standard'	157	310	169	215
	'high'	145*	294	161	261
Low level	'standard'	132	254	319	256
	'high'	148	410	361	455

* Data not available for initial analyses of ground limestone/'high' CRF combination

Table 8: **Growing media analyses for *Prunus laurocerasus* 'Otto Luyken' at beginning and end of trial period: overhead irrigated gravel beds**

Source of lime	Rate of CRF	pH, nutrient levels and conductivity	Initial	At end of trial Humidity regime Low	Ambient	High
'Low' AFP						
Ground limestone	'standard'	pH	4.8	4.7	4.9	4.5
		Phosphorus mg/l	22	22	11	21
		Potassium mg/l	28	92	36	76
		Magnesium mg/l	10	61	9	30
		Nitrate mg/l N	50	82	7	26
		Ammonium mg/l N	59	13	27	1
		Conductivity μS	156	356	135	232
Ground limestone	'high'	pH		5.6	5.5	5.4
		Phosphorus mg/l		10	15	12
		Potassium mg/l	Data	57	55	43
		Magnesium mg/l	not	42	20	23
		Nitrate mg/l N	available	5	11	1
		Ammonium mg/l N		3	52	22
		Conductivity μS		288	196	180
Magnesian limestone	'standard'	pH	4.8	4.5	4.6	4.7
		Phosphorus mg/l	13	21	14	12
		Potassium mg/l	31	105	50	61
		Magnesium mg/l	16	76	23	24
		Nitrate mg/l N	63	10	10	41
		Ammonium mg/l N	57	7	39	20
		Conductivity μS	179	368	161	187
Magnesian limestone	'high'	pH	5.0	4.5	4.9	4.6
		Phosphorus mg/l	13	26	17	37
		Potassium mg/l	35	110	59	122
		Magnesium mg/l	17	82	23	65
		Nitrate mg/l N	51	106	17	12
		Ammonium mg/l N	51	64	16	44
		Conductivity μS	161	368	181	352

Source of lime	Rate of CRF	pH, nutrient levels and conductivity	Initial	At end of trial Humidity regime Low	Ambient	High
'High' AFP						
Ground limestone	'standard'	pH	4.9	4.6	4.8	4.4
		Phosphorus mg/l	12	16	7	14
		Potassium mg/l	31	74	43	61
		Magnesium mg/l	11	34	17	24
		Nitrate mg/l N	53	54	9	14
		Ammonium mg/l N	47	5	34	22
		Conductivity μS	163	240	173	214
Ground limestone	'high'	pH	5.8	5.8	6.0	5.7
		Phosphorus mg/l	9	7	4	17
		Potassium mg/l	25	39	15	65
		Magnesium mg/l	15	25	12	35
		Nitrate mg/l N	56	28	1	18
		Ammonium mg/l N	23	8	13	16
		Conductivity μS	122	207	128	258
Magnesian limestone	'standard'	pH	5.0	4.7	4.7	4.7
		Phosphorus mg/l	10	16	22	20
		Potassium mg/l	24	84	55	72
		Magnesium mg/l	13	52	27	42
		Nitrate mg/l N	44	64	12	9
		Ammonium mg/l N	41	11	40	21
		Conductivity μS	131	278	206	225
Magnesian limestone	'high'	pH	5.1	4.5	4.9	4.8
		Phosphorus mg/l	11	20	20	27
		Potassium mg/l	31	104	44	82
		Magnesium mg/l	16	54	13	41
		Nitrate mg/l N	51	29	8	57
		Ammonium mg/l N	49	70	21	70
		Conductivity μS	151	314	142	255

Table 9a: **Growing media analyses for *Rhododendron* 'Surrey Heath' meaned according to irrigation and humidity regime**

	Irrigation regime	Initial	At end of trial Humidity regime Low	Ambient	High
pH	overhead	4.9*	4.4	4.6	4.6
	low level	4.9	4.7	4.8	4.8
Phosphorus (mg/l)	overhead	14*	7	6	9
	low level	8	19	24	9
Potassium (mg/l)	overhead	29*	14	14	15
	low level	19	52	58	25
Magnesium (mg/l)	overhead	13*	19	22	28
	low level	8	35	34	19
Conductivity (μS)	overhead	157*	131	128	121
	low level	115	272	250	173

* Data not available for initial analyses of media containing 'standard' rate CRF.

Table 9b: **Conductivity (μS) of growing media for *Rhododendron* 'Surrey Heath' meaned according to rate of CRF, irrigation and humidity regime**

Irrigation regime	Rate of CRF	Initial	At end of trial Humidity regime Low	Ambient	High
Overhead	'standard'	Data not available	127	132	105
	'high'	157	136	124	136
Low level	'standard'	97	213	209	146
	'high'	133	332	290	201

Table 11: Growing media analyses for *Rhododendron* 'Surrey Heath' at beginning and end of trial period: overhead irrigation on gravel beds

Source of lime	Rate of CRF	pH, nutrient levels and conductivity	Initial	At end of trial Humidity regime Low	Ambient	High
'Low' AFP						
Ground limestone	'standard'	pH		4.4	4.7	4.6
		Phosphorus mg/l		5	5	5
		Potassium mg/l	Data	13	10	2
		Magnesium mg/l	not	21	35	5
		Nitrate mg/l N	available	44	33	7
		Ammonium mg/l N		9	6	3
		Conductivity µS		163	157	80
Ground limestone	'high'	pH	4.8	4.3	4.5	4.4
		Phosphorus mg/l	22	6	7	8
		Potassium mg/l	28	17	20	14
		Magnesium mg/l	10	19	23	10
		Nitrate mg/l N	50	32	32	23
		Ammonium mg/l N	59	3	4	4
		Conductivity µS	156	138	118	113
Magnesian limestone	'standard'	pH		4.3	4.6	4.4
		Phosphorus mg/l		4	8	12
		Potassium mg/l	Data	7	19	9
		Magnesium mg/l	not	29	28	18
		Nitrate mg/l N	available	24	33	16
		Ammonium mg/l N		3	6	5
		Conductivity µS		159	134	120
Magnesian limestone	'high'	pH	4.8	4.3	4.5	4.7
		Phosphorus mg/l	13	13	8	22
		Potassium mg/l	31	21	21	46
		Magnesium mg/l	16	26	25	31
		Nitrate mg/l N	63	36	34	35
		Ammonium mg/l N	57	8	6	21
		Conductivity µS	179	152	137	191

Source of lime	Rate of CRF	pH, nutrient levels and conductivity	Initial	At end of trial Humidity regime Low	Ambient	High
'High' AFP						
Ground limestone	'standard'	pH		4.6	4.6	4.8
		Phosphorus mg/l		4	6	6
		Potassium mg/l	Data	12	21	10
		Magnesium mg/l	not	4	14	7
		Nitrate mg/l N	available	17	21	10
		Ammonium mg/l N		3	7	10
		Conductivity µS		76	123	102
Ground limestone	'high'	pH	4.9	4.4	4.7	4.6
		Phosphorus mg/l	12	3	3	5
		Potassium mg/l	31	6	1	15
		Magnesium mg/l	11	14	7	8
		Nitrate mg/l N	53	18	18	10
		Ammonium mg/l N	47	4	3	6
		Conductivity µS	163	112	104	113
Magnesian limestone	'standard'	pH		4.4	4.5	4.7
		Phosphorus mg/l		4	3	6
		Potassium mg/l	Data	11	6	12
		Magnesium mg/l	not	5	16	16
		Nitrate mg/l N	available	11	33	1
		Ammonium mg/l N		5	5	7
		Conductivity µS		108	113	119
Magnesian limestone	'high'	pH	5.0	4.4	4.6	4.6
		Phosphorus mg/l	10	14	9	4
		Potassium mg/l	24	24	16	8
		Magnesium mg/l	13	32	25	18
		Nitrate mg/l N	44	34	40	5
		Ammonium mg/l N	41	7	7	18
		Conductivity µS	131	142	135	128

Growth records and liverwort score

Choisya ternata (Tables 12-14)

No leaf tipping/distortion was seen on any of the plants.

There was a small improvement in plant size in the low and ambient humidity regimes, on the low level irrigated sand beds, and where magnesian limestone was used as the source of lime. However, rate of CRF and AFP of the growing media had little consistent effect on either shoot number or length.

Liverwort was more prevalent on pots grown on gravel beds with overhead irrigation, particularly in the high humidity environment.

Table 12: Data averaged according to treatments listed - *Choisya ternata*

Treatment	Mean shoot length (cm)	% dead	% pots with no liverwort
Humidity regime			
Low	23.8	2	60
Ambient	22.2	3	79
High	21.7	4	35
Irrigation regime			
Overhead	21.8	2	47
Low level	23.4	4	69
Source of lime			
Ground limestone	21.8	3	58
Magnesian limestone	23.3	4	58
Rate of CRF			
'Standard'	22.3	4	58
'High'	22.9	2	58
AFP of growing media			
'Low'	22.7	2	55
'High'	22.5	4	61

Table 14: *Choisya ternata*, overhead irrigation on gravel beds; mean shoot number and length, % dead and liverwort score

Humidity regime	AFP	Source of lime	Rate of CRF	Mean no. of shoots/plant	Mean shoot length (cm)	% dead plants	Liverwort score (% plants in each category) 0 (nil)	1	2	3	4	5 (most)
Low	'low'	ground limestone	'standard'	3.2	22.3	0	26	31	17	13	13	0
Ambient				3.4	19.2	0	54	42	4	0	0	0
High				2.9	22.3	8	33	63	0	0	4	0
Low	'low'	ground limestone	'high'	3.2	21.4	0	35	52	13	0	0	0
Ambient				2.7	22.2	4	62	30	4	4	0	0
High				3.5	20.7	4	35	44	13	4	4	0
Low	'low'	magnesian limestone	'standard'	2.5	27.2	0	29	33	4	8	22	4
Ambient				3.1	21.3	4	71	25	0	0	4	0
High				2.6	22.8	4	41	29	13	13	4	0
Low	'low'	magnesian limestone	'high'	3.2	22.9	0	21	50	4	13	8	4
Ambient				3.2	20.9	4	79	17	0	0	0	4
High				3.0	22.1	0	33	33	18	8	8	0
Low	'high'	ground limestone	'standard'	3.5	21.8	0	34	50	4	8	4	0
Ambient				3.3	21.8	4	58	38	0	4	0	0
High				3.3	21.8	4	58	38	0	4	0	0
Low	'high'	ground limestone	'high'	3.6	21.0	4	46	42	4	4	4	0
Ambient				3.3	17.9	0	70	26	0	4	0	0
High				3.8	18.0	8	54	42	4	0	0	0
Low	'high'	magnesian limestone	'standard'	3.2	22.1	0	26	35	22	13	4	0
Ambient				3.4	18.4	0	78	22	0	0	0	0
High				3.0	21.5	0	54	42	4	0	0	0
Low	'high'	magnesian limestone	'high'	2.8	28.9	0	50	13	13	0	20	4
Ambient				2.9	21.0	4	61	35	0	4	0	0
High				3.1	22.9	4	20	46	17	0	17	0

Pieris **'Forest Flame'** (Tables 15-17)

No leaf tipping/scorching was seen on plants in any of the treatments.

As with *Choisya* humidity regime had the greatest effect on growth, with plants being more advanced in the low humidity tunnel. Irrigation regime, source of lime and rate of CRF had little effect on growth.

Fewer plants died on the sand beds compared to the gravel beds (4% cf 11%), where ground limestone was used as the source of lime instead of magnesian limestone (4% cf 10%), when a 'standard' rate of CRF was used instead of a 'high' rate (5% cf 10%), and when potted in a growing media with a 'low' AFP.

The incidence of liverwort was generally low throughout all irrigation and humidity treatments.

Table 15: Data averaged according to treatments listed - *Pieris* 'Forest Flame'

Treatment	% plants with new flush of growth (grades 2-7)	% dead	% pots with no liverwort
Humidity regime			
Low	78	7	88
Ambient	43	8	98
High	59	7	87
Irrigation regime			
Overhead	54	11	89
Low level	66	4	92
Source of lime			
Ground limestone	64	4	90
Magnesian limestone	57	10	92
Rate of CRF			
'Standard'	62	5	90
'High'	58	10	91
AFP of growing media			
'Low'	59	5	92
'High'	62	10	90

Table 17: *Pieris* 'Forest Flame', overhead irrigation on gravel beds; grade of plant, % dead and liverwort score

Humidity regime	AFP	Source of lime	Rate of CRF	Grade of plant (% in each grade)* 1 (no new growth)	2	3	4	5	6	7 (growth most advanced)	% dead plants	Liverwort score (% plants in each category) 0 (nil)	1	2	3	4	5 (most)
Low	'low'	ground limestone	'standard'	7	11	11	4	14	25	21	7	64	18	14	4	0	0
Ambient				60	7	0	7	0	4	11	11	82	11	7	0	0	0
High				35	11	4	0	11	0	35	4	82	7	11	0	0	0
Low	'low'	ground limestone	'high'	17	4	4	3	11	25	25	11	82	18	0	0	0	0
Ambient				68	7	7	0	0	0	14	4	96	4	0	0	0	0
High				36	3	7	3	0	4	43	4	93	7	0	0	0	0
Low	'low'	magnesian limestone	'standard'	18	11	4	7	0	39	17	4	93	7	0	0	0	0
Ambient				68	7	3	4	0	4	14	0	100	0	0	0	0	0
High				53	11	0	0	0	0	29	7	93	7	0	0	0	0
Low	'low'	magnesian limestone	'high'	28	11	11	11	7	11	17	4	82	14	4	0	0	0
Ambient				57	21	4	4	4	0	0	10	100	0	0	0	0	0
High				46	11	0	0	0	4	32	7	96	4	0	0	0	0
Low	'high'	ground limestone	'standard'	7	25	4	18	11	14	17	4	89	11	0	0	0	0
Ambient				61	4	7	0	0	7	14	7	96	4	0	0	0	0
High				32	7	0	4	0	4	42	11	96	4	0	0	0	0
Low	'high'	ground limestone	'high'	7	11	11	4	21	25	17	4	82	11	7	0	0	0
Ambient				50	25	4	0	7	0	7	7	96	4	0	0	0	0
High				21	7	0	4	4	4	53	7	96	4	0	0	0	0
Low	'high'	magnesian limestone	'standard'	4	21	14	4	21	21	11	4	64	32	4	0	0	0
Ambient				68	14	0	0	0	4	4	10	96	4	0	0	0	0
High				21	14	0	0	4	0	61	0	100	0	0	0	0	0
Low	'high'	magnesian limestone	'high'	18	0	7	11	7	11	11	35	78	11	4	7	0	0
Ambient				39	11	0	4	0	0	0	46	92	4	4	0	0	0
High				11	0	7	0	4	11	17	50	92	4	4	0	0	0

* See Plate 1, page 41

Rhododendron **'Fairylight'** (Tables 18-20)

No leaf tipping/distortion was seen on any of the plants. In contrast to *Pieris*, growth on plants in the lower humidity regime was slightly less advanced than that on plants in the other two tunnels.

Irrigation regime, source of lime and rate of CRF had little apparent effect on growth. However, more plants died in the growing media with a 'low' AFP, particularly in combination with overhead irrigation on gravel beds, (Table 20).

The incidence of liverwort varied, but was generally slightly higher on plants grown on the overhead irrigated gravel beds, and in the higher humidity regime.

Table 18: Data averaged according to treatments listed - *Rhododendron* 'Fairylight'

Treatment	% plants actively growing (grades 2-4)	% dead	% pots with no liverwort
Humidity regime			
Low	65	7	58
Ambient	81	9	76
High	84	8	40
Irrigation regime			
Overhead	75	7	48
Low level	79	9	65
Source of lime			
Ground limestone	75	8	62
Magnesian limestone	80	6	54
Rate of CRF			
'Standard'	75	8	58
'High'	77	9	58
AFP of growing media			
'Low'	71	12	58
'High'	81	6	58

'able 20: *Rhododendron* 'Fairylight', overhead irrigation on gravel beds; grade of plant, % dead and liverwort score

Humidity regime	AFP	Source of lime	Rate of CRF	Grade of plant (% in each grade)*				% dead plants	Liverwort score (% plants in each category)					
				1 (little new growth)	2	3	4 (most advanced growth)		0 (nil)	1	2	3	4	5 (most)
Low	'low'	ground limestone	'standard'	41	21	21	13	4	67	21	8	4	0	0
Ambient				8	46	38	0	8	92	4	4	0	0	0
High				13	33	25	8	21	42	25	21	8	4	0
Low	'low'	ground limestone	'high'	50	13	21	8	8	41	8	17	17	17	0
Ambient				8	21	54	4	13	83	17	0	0	0	0
High				8	38	33	4	17	25	25	12	25	13	0
Low	'low'	magnesian limestone	'standard'	21	17	29	4	29	25	21	17	29	8	0
Ambient				13	50	33	0	4	58	21	13	8	0	0
High				4	46	38	0	12	25	33	21	17	4	0
Low	'low'	magnesian limestone	'high'	} Data not available										
Ambient				}										
High				}										
Low	'high'	ground limestone	'standard'	21	29	38	8	4	50	38	12	0	0	0
Ambient				17	29	46	4	4	75	8	13	4	0	0
High				8	42	33	13	4	42	25	16	17	0	0
Low	'high'	ground limestone	'high'	25	29	21	25	0	50	8	21	21	0	0
Ambient				8	63	29	0	0	58	33	9	0	0	0
High				8	46	33	9	4	33	17	38	12	0	0
Low	'high'	magnesian limestone	'standard'	46	21	29	4	0	58	21	13	8	0	0
Ambient				17	38	38	0	7	63	13	17	7	0	0
High				4	44	48	4	0	35	30	30	5	0	0
Low	'high'	magnesian limestone	'high'	42	29	17	12	0	50	29	17	4	0	0
Ambient				8	42	38	4	8	63	25	12	0	0	0
High				4	25	50	17	4	25	41	13	17	4	0

* See Plate 2, page 41

Rhododendron **'Surrey Heath'** (Tables 21-23)

No leaf tipping/distortion was seen on any of the plants. Plant growth in all three humidity regimes was very similar; but 20% of the plants in the ambient regime died, compared to only 5% in each of the other regimes.

Irrigation regime, source of lime, rate of CRF and AFP of the growing media had little effect on plant growth.

More liverwort was found on plants grown in the high humidity tunnel, and where overhead irrigation was used.

Table 21: Data averaged according to treatments listed - *Rhododendron* 'Surrey Heath'

Treatment	% plants actively growing (grades 2-5)	% dead	% pots with no liverwort
Humidity regime			
Low	89	5	29
Ambient	79	20	94
High	94	5	4
Irrigation regime			
Overhead	88	8	39
Low level	88	11	47
Source of lime			
Ground limestone	87	10	41
Magnesian limestone	87	10	43
Rate of CRF			
'Standard'	89	9	40
'High'	86	11	45
AFP of growing media			
'Low'	86	12	45
'High'	89	8	40

Table 23: *Rhododendron* 'Surrey Heath', overhead irrigation on gravel beds; grade of plant, % dead and liverwort score

Humidity regime	AFP	Source of lime	Rate of CRF	Grade of plant (% in each grade)*					% dead plants	Liverwort score (% plants in each category)					
				1 (little new growth)	2	3	4	5 (most advanced growth)		0 (nil)	1	2	3	4	5 (most)
Low	'low'	ground limestone	'standard'	7	11	25	21	32	4	25	28	11	18	18	0
Ambient				0	0	14	43	22	21	82	14	4	0	0	0
High				0	7	25	43	25	0	0	32	7	43	18	0
Low	'low'	ground limestone	'high'	11	11	18	29	14	17	4	14	28	25	29	0
Ambient				0	7	18	39	21	15	96	4	0	0	0	0
High				0	0	29	43	25	3	0	7	14	61	18	0
Low	'low'	magnesian limestone	'standard'	4	0	14	61	21	0	21	40	21	18	0	0
Ambient				0	4	14	50	11	21	100	0	0	0	0	0
High				0	0	29	43	25	3	0	15	39	25	21	0
Low	'low'	magnesian limestone	'high'	7	11	11	41	22	8	26	19	29	19	7	0
Ambient				4	4	19	27	15	31	81	11	8	0	0	0
High				8	23	27	19	23	0	15	19	19	23	15	9
Low	'high'	ground limestone	'standard'	4	18	21	32	25	0	4	18	21	39	18	0
Ambient				0	4	11	38	36	11	92	4	4	0	0	0
High				0	0	25	57	18	0	0	11	29	43	17	0
Low	'high'	ground limestone	'high'	18	14	14	32	22	0	18	46	21	15	0	0
Ambient				0	4	4	39	36	17	100	0	0	0	0	0
High				7	4	11	39	35	4	18	7	21	33	21	0
Low	'high'	magnesian limestone	'standard'	18	32	11	28	7	4	28	14	36	11	11	0
Ambient				4	4	10	36	32	14	89	11	0	0	0	0
High				0	0	11	36	46	7	7	25	25	32	11	0
Low	'high'	magnesian limestone	'high'	0	0	14	39	43	4	21	15	43	21	0	0
Ambient				0	4	21	46	11	18	92	8	0	0	0	0
High				0	0	22	46	32	0	7	36	25	18	14	0

* See Plate 3, page 41

Prunus laurocerasus **'Otto Luyken'** (Tables 24-26)

Growth in all three humidity regimes was very similar.

Growth was slightly more advanced on plants grown on sand beds, where magnesian limestone was used as the lime source, and where the 'standard' rate of CRF was used.

Humidity regime had the greatest effect on liverwort growth, with few pots having any liverwort in the low humidity tunnel, and almost half having liverwort present in the high humidity tunnel.

Table 24: Data averaged according to treatments listed - *Prunus laurocerasus* 'Otto Luyken'

Treatment	% plants not actively growing (grade 1)	% dead	% pots with no liverwort
Humidity regime			
Low	12	6	93
Ambient	9	4	88
High	11	7	52
Irrigation regime			
Overhead	17	7	76
Low level	6	4	79
Source of lime			
Ground limestone	13	5	78
Magnesian limestone	8	6	77
Rate of CRF			
'Standard'	7	6	75
'High'	14	5	80
AFP of growing media			
'Low'	9	4	77
'High'	12	7	78

Table 26: *Prunus laurocerasus* 'Otto Luyken', overhead irrigation on gravel beds; grade of plant, % dead and liverwort score

Humidity regime	AFP	Source of lime	Rate of CRF	Grade of plant (% in each grade)* 1 (no active growth)	2	3	4	5	6	7	8	9 (most advanced growth)	% dead plants	Liverwort score (% plants in each category) 0 (nil)	1	2	3	4	5 (most)
Low	'low'	ground limestone	'standard'	21	14	7	0	0	0	22	36	0	0	93	7	0	0	0	0
Ambient				7	7	14	7	7	11	11	28	4	4	78	14	0	4	4	0
High				4	14	0	0	4	11	25	39	0	3	75	21	0	0	4	0
Low	'low'	ground limestone	'high'	21	14	7	0	0	4	18	32	0	4	96	4	0	0	0	0
Ambient				25	31	11	4	14	4	4	4	0	3	89	7	0	0	4	0
High				43	14	11	0	10	4	10	4	0	4	50	32	14	4	0	0
Low	'low'	magnesian limestone	'standard'	11	14	4	7	14	4	18	21	0	7	79	18	3	0	0	0
Ambient				0	4	14	7	14	21	0	36	0	4	75	19	3	0	3	0
High				11	0	7	4	11	4	11	46	4	4	68	11	7	4	10	0
Low	'low'	magnesian limestone	'high'	21	7	4	11	4	0	11	35	7	0	89	11	0	0	0	0
Ambient				4	7	11	4	4	4	7	38	14	7	54	42	0	4	0	0
High				14	7	0	4	4	7	14	32	14	4	46	36	4	14	0	0
Low	'high'	ground limestone	'standard'	4	11	7	4	7	7	25	28	0	7	89	11	0	0	0	0
Ambient				21	11	4	11	14	7	11	18	0	3	64	32	4	0	0	0
High				25	7	4	7	7	0	18	21	4	7	46	32	4	7	11	0
Low	'high'	ground limestone	'high'	21	11	11	4	4	7	14	14	0	14	89	11	0	0	0	0
Ambient				46	22	7	14	4	7	0	0	0	0	93	7	0	0	0	0
High				39	22	14	0	0	4	7	0	0	14	71	29	0	0	0	0
Low	'high'	magnesian limestone	'standard'	0	4	14	4	7	0	25	36	0	10	86	14	0	0	0	0
Ambient				7	14	4	7	18	11	0	28	0	11	75	25	0	0	0	0
High				14	11	4	14	11	4	0	25	0	17	78	22	0	0	0	0
Low	'high'	magnesian limestone	'high'	4	4	14	4	0	0	21	42	0	11	93	7	0	0	0	0
Ambient				29	7	0	14	0	4	14	25	0	7	82	18	0	0	0	0
High				11	14	11	7	4	4	11	11	0	27	68	32	0	0	0	0

* See Plate 4, page 42

DISCUSSION

Work on this Project was started as a result of the concern over problems of leaf distortion/tipping (and the resulting loss of quality) on liners of a wide range of evergreen nursery stock species overwintered under protection (without heat).

The objective of this first year's work was to evaluate the effect of a number of stress factors on the growth of newly potted liners of several species of evergreen HNS, held under polythene tunnel protection overwinter, to see if any of these disorders could be linked to a specific treatment.

In this particular season, none of the stress factors investigated produced the detrimental leaf symptoms noted previously elsewhere. However, a number of other trends in growth as a result of the treatments were recorded.

Influence of humidity: The target RH (a minimum of 95%) was readily achieved by the use of fogging equipment which worked efficiently apart from some initial problems with nozzle blockage. However, it proved more difficult to achieve the target maximum RH of 80% in the low humidity tunnel, particularly when air temperatures were low (<8-10°C). For much of the early part of the trial period, the recorded humidity levels were in the mid-high 80% - still significantly lower than in the ambient humidity tunnel. Problems of poor air distribution throughout the tunnel were overcome by attaching a perforated polythene tube to the air outlet on the top of the dehumidification unit and running it along the length of the tunnel at just above head height.

The higher minimum air temperature recorded in the low humidity tunnel compared to the other two humidity regimes inevitably had an effect on growth. The magnitude of this effect varied with species. *Pieris* showed a much earlier flush of growth in the low humidity tunnel, whilst conversely, *Rhododendron* 'Fairylight' was less advanced in this environment. The reason for this is difficult to explain since in other trials plants of *Rhododendron* have always grown better in 'warmer' temperatures.

This differential temperature problem has now been overcome by recalibration of the machine for the purpose of achieving comparable temperatures between treatments. However, a temperature lift could be of advantage in the commercial situation for both frost protection and advancing growth. In this trial the heat exchange unit of the dehumidifier was located outside, but, again, in a commercial situation it would be beneficial to site it inside the tunnel, and make use of the heat generated by the dehumidification process.

The slightly lower minimum and maximum air temperatures recorded in the high humidity regime were probably due to the cooling effect of the moisture in the air. This high humidity content also favoured the growth and spread of liverwort, especially in combination with overhead irrigation. With the scarcity of chemicals currently available for the control of liverwort, particularly for use under protection, and on young plants, low level irrigated sand beds provide a useful cultural method of minimising the incidence of this troublesome weed.

Influence of bed type/irrigation: The quantity of water applied through low level irrigation on the sand beds was, surprisingly, greater than that applied through the overhead sprinkler system on the gravel beds, particularly in the low humidity regime. When irrigated the sand beds were watered until free water was present on the surface, before being drained back and more water would have been required to 're-wet' the sand in the drier environment of the low humidity tunnel than in the other humidity regimes.

The overhead irrigation system was very efficient, utilising nozzles with a 180° throw pattern. This, combined with a 'protected' growing system where little water was wasted due to wind blow and evaporation, may have contributed to the relatively 'low' water usage with this system. In addition, the crop would not have been taking up a lot of water at this time of the year.

Plants of *Choisya ternata* and *Prunus laurocerasus* 'Otto Luyken' grew better on the low level irrigated sand beds than on the gravel beds, and by the end of the trial, plants had started to root through into the sand, whilst few roots were visible at the base of the pots grown on gravel. In contrast, with the flushing habit of growth of *Pieris* and *Rhododendron* there was little difference in shoot or root growth between the two irrigation systems at the end of the trial.

Influence of AFP: Media with two AFP values were obtained by differential mixing techniques using medium baled peat. The standard mixing procedure produced a mix with an AFP of approximately 12% (according to measurements), somewhat lower than was hoped for. It proved very difficult to produce a mix with a very low AFP, in spite of prolonged mixing, indicating, perhaps, the reduced 'fines' now present in such baled peat. Although the measured AFP of this mix was 7%, there were obvious visual differences between the two mixes. However, the results showed little consistent effect of AFP on plant growth.

AFP's of 7-12% are considered suitable for drained sand beds and it is perhaps not surprising that no differences in growth occurred. However, a mix with an AFP of only 7% is somewhat low for use on overhead irrigated gravel beds, with the danger of waterlogging if irrigation is excessive.

The experimental design did not permit differential watering of growing media and this may have masked any effect of AFP on plant growth. In practice, growing media with a high AFP would require watering more often than those with a low AFP, particularly in a low humidity regime.

Influence of lime source and rate of CRF: Analyses of the growing media at the beginning and end of the trial revealed obvious trends in the levels of nutrients present for both of the selected species, *Prunus laurocerasus* 'Otto Luyken' (a 'general' subject) and *Rhododendron* 'Surrey Heath' (a 'sensitive' subject). Predictably, the nutrient levels within the growing media were higher on the low level irrigated sand beds than on the overhead irrigated gravel beds, since fewer nutrients would have been lost by leaching. Similarly, on the gravel beds there was little difference between the 'standard' and 'high' rates of CRF, whilst on the sand beds the 'high' rate of CRF resulted in higher nutrient levels, again reflecting the greater leaching on the overhead irrigated gravel beds.

The pH of growing media used for *Prunus*, where ground limestone was used in association with a 'high' rate (5.3 kg/m^3) of CRF on the overhead irrigated gravel beds was markedly higher throughout the trial period than that of growing media containing other combinations of lime and CRF. The converse would have been expected with 'high' rates of CRF tending to reduce the pH.

None of the physiological disorders reported previously elsewhere were observed in this trial, in spite of the range of stress factors investigated, suggesting that there must be different factors involved.

Of greater importance are the implications of improving plant quality/advancing growth by the use of lower humidities, and the possibility of reducing the incidence of disease in the absence of chemicals. This needs to be investigated further. However, consideration must be given to the type of equipment required for use at the 'low' temperatures experienced throughout the winter months for protected HNS. This will be discussed with Electricity Association Technology Ltd.

CONCLUSIONS

- None of the treatments investigated produced any of the leaf disorders that had been recorded previously elsewhere on overwintered liners of evergreen nursery stock.

- Relative Humidities between 80-95% had little consistent effect on plant growth or quality in this trial, though the minimum air temperature maintained in the low humidity tunnel was several degrees higher than that in the other humidity regimes, as a result of running the dehumidification equipment. This resulted in slightly more advanced growth on *Choisya*, *Pieris* and *Prunus*. A minimum Relative Humidity of 95% was readily maintained using a fogging system in the high humidity tunnel. It proved difficult to maintain a maximum Relative Humidity of 80% using the DH150 dehumidifier, particularly when air temperatures fell below 8-10°C.

- The incidence of liverwort was greater in the high humidity regime, particularly where overhead irrigation was used.

- Plants of *Choisya* and *Prunus* grew better on the low level irrigated sand beds than on the overhead irrigated gravel beds. No such difference was seen with *Pieris* and *Rhododendron*.

- Within the band of 7-12% AFP, growing media structure had no consistent effect on plant growth, although it was not possible to water differentially in this trial.

- Lime source and rate of CRF also had little consistent effect on plant growth.

- At the end of the trial, nutrient levels were higher in growing media on the low level irrigated sand beds than in those used on the overhead irrigated gravel beds, reflecting the reduced leaching in this system.

RECOMMENDATIONS FOR FURTHER WORK

- The influence of Relative Humidity on the incidence of disease warrants investigation on species where this can result in plant loss/loss of quality over the winter and early spring period, e.g. *Hebe*, *Rosa*.

- The use of chemicals for the control of liverwort on young plants grown under protection also requires evaluation.

- Further discussions should be held with Electricity Association Technology Ltd regarding the types of dehumidification equipment suitable for use in 'cold' polythene tunnels overwinter.

Plate 1: *Pieris* **'Forest Flame'**, grades of plant at final assessment
From left to right: grade 1, 2, 3, 4, 5, 6 and 7

Plate 2: *Rhododendron* **'Fairylight'**, grades of plant at final assessment
From left to right: grade 1, 2, 3 and 4

Plate 3: *Rhododendron* **'Surrey Heath'**, grades of plant at final assessment
From left to right: grade 1, 2, 3, 4 and 5

Plate 4: *Prunus laurocerasus* **'Otto Luyken'**, grades of plant at final assessment
From left to right: grade 1, 2, 3, 4, 5, 6, 7, 8 and 9

Plate 5: Grades of **liverwort infestation** at final assessment
From left to right: 0, 1, 2, 3, 4 and 5

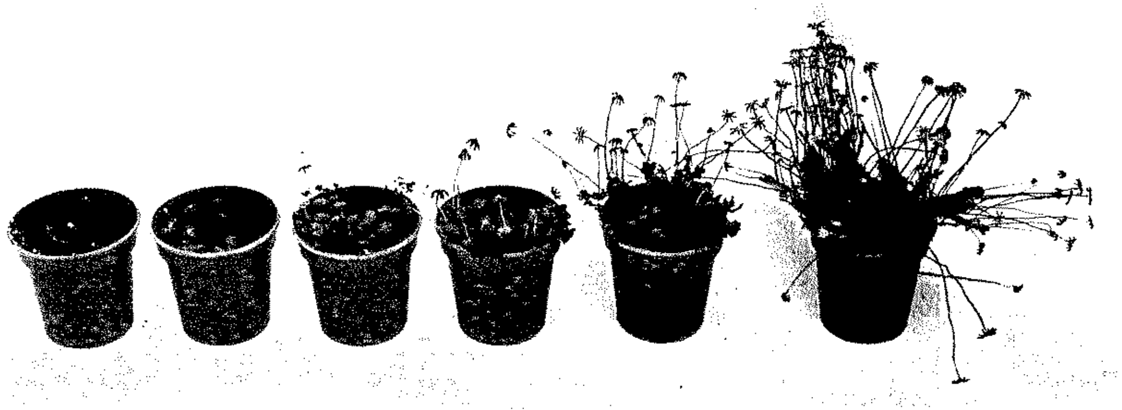


Plate 6: General view of overhead irrigated gravel bed in low humidity tunnel

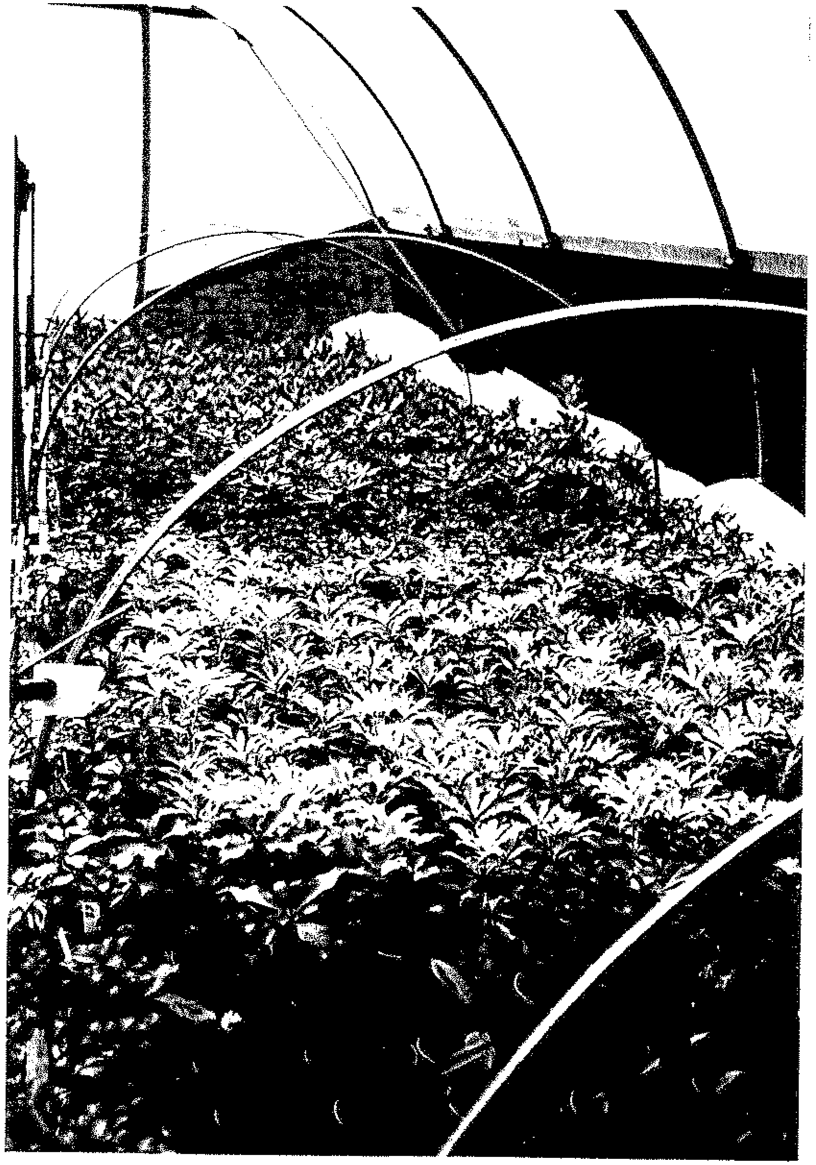
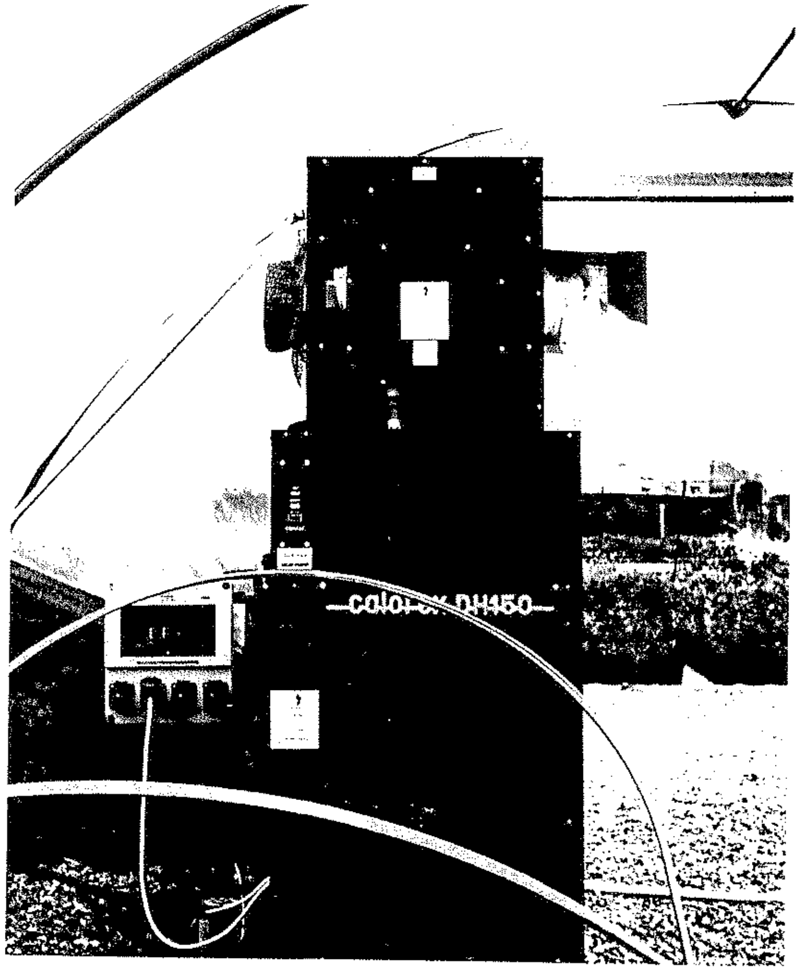


Plate 7: General view of Calorex DH150 dehumidifier



APPENDIX I: MIXING PROCEDURES FOR 'OPEN' AND 'POOR' STRUCTURED GROWING MEDIA

1. 'OPEN' MIX

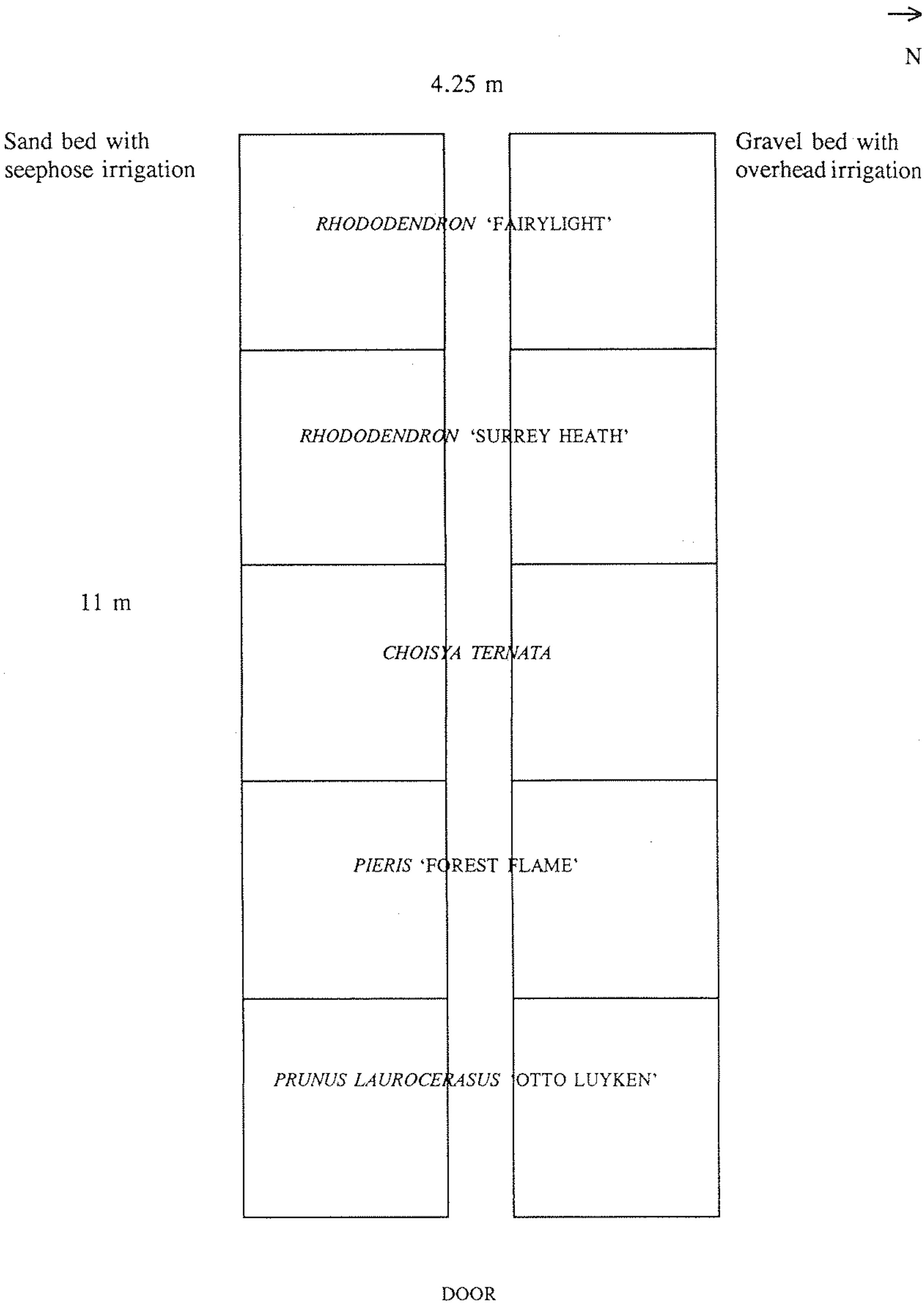
300 litre bale of Irish Shamrock moss peat loaded on to conveyor belt of a Turners Triple Two compost mixer, and broken down using the mixer set for 15 seconds. The Controlled Release Fertilizer and the limestone was then added (according to treatment) and mixed for a further 15 seconds. Water was then added for the final 30 seconds of mixing (giving a total mixing time of 1 minute).

2. 'POOR' MIX

The Irish Shamrock moss peat was sieved twice prior to mixing, firstly using a 14 mm sieve, and secondly using a 8 mm sieve, to give a very fine mix.

300 litres of sieved mix was loaded into the compost mixer, using the conveyor belt and mixed for 60 seconds. The required Controlled Release Fertilizer and limestone was added, and mixed for a further 60 seconds. Water was then added for 30 seconds, followed by a further 90 seconds of mixing (giving a total mixing time of 4 minutes).

APPENDIX II: Plot layout within tunnels



COMMERCIAL - IN CONFIDENCE

APPENDIX III

HORTICULTURE RESEARCH INTERNATIONAL

EFFORD

Customer Ref................ Telephone: 0203 696512 Fax: 0203 696360

HRI Ref: HNS 49 Date: 23 November 1992 Researcher: Miss Lyn Andrews

Horticulture Research International ("**HRI**") hereby offer to carry out the programme of work ("the Work") entitled:

INFLUENCE OF HUMIDITY AND OTHER STRESS FACTORS ON PLANT GROWTH ....("title of the work")

described in the attached schedule ("the Schedule") for:

ELECTRICITY ASSOCIATION TECHNOLOGY LTD .... ("the Customer")

of: **FARM ELECTRIC CENTRE, NAC, STONELEIGH, KENILWORTH, WARWICKSHIRE CV8 2LS**

....(Registered Office or other address)

subject to the Conditions overleaf.

HRI estimate that their charges for the work will be **£3,500** Sterling (exclusive of VAT) and that the Work will be completed within the timescales given in the attached Schedule. This offer which remains valid until **10.12.92** may be accepted by the Customer by returning one signed original of this document to:

Name: MISS M A SCOTT

Address: HRI EFFORD, LYMINGTON, HAMPSHIRE, SO41 OLZ

Tel: 0590 673341 Fax: 0590 671553

Offer authorised by:

Signed.......[signature].......Position HEAD OF STATION Date 25/4/92

duly authorised representative of **HRI**

Offer accepted by:

Signed.......[signature].......Position MANAGER Date 11/12/92

duly authorised representative of the **Customer**

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

PROPOSAL

1. **TITLE OF PROJECT**

Contract No: HNS/49
Contract Date: 2.4.93

INFLUENCE OF HUMIDITY AND OTHER STRESS FACTORS ON PLANT GROWTH

2. **BACKGROUND AND COMMERCIAL OBJECTIVE**

Problems of leaf disorders (distortion, tip cupping/burning, chlorosis) have been recorded on young evergreen plants grown overwinter under protection. Various theories as to the cause have been investigated, including exposure to herbicides, but no definite conclusions have been reached. Another theory is that the problem might be linked to trace element deficiency, particularly calcium, brought on as a result of low transpiration rates linked to slow growth/high humidities at this time of year under protection which will limit transport of calcium via the xylem system. Unlike protected crops, most HNS tunnels are unheated and relative humidity (RH) builds up, such that in the early mornings dew point can be reached on occasion. Plant stress, particularly root stress, also appears to be involved, symptoms having occurred where poor root development was related to potting too firm in mixes with low AFP, or where nutrient levels were relatively high. Current lime recommendations are based on work in the 1970's and in the main are for the inclusion of magnesian limestone. However, new CRF formulations include magnesium in the granule and the whole topic of type and rate of lime to use needs reappraising with these newer CRF formulations, especially as too high a magnesium level can affect uptake of calcium.

Dehumidification offers an opportunity to investigate these theories further, as well as exploring effects of RH on overall plant quality.

This would be a joint project with the Electricity Association who are prepared to supply the dehumidification equipment and the associated technology and expertise.

3. **POTENTIAL FINANCIAL BENEFIT TO THE INDUSTRY**

The current value of the liner industry is around £25 million. Obviously not all species or areas are affected by the problem (at least not visibly), but it has been serious in some situations, more so with some subjects than others, ie. *Rhododendron*, *Pieris* and other evergreens, all high value crops. Linked to this is the potential for reduced fungicide application and consequent saving in labour.

4. **SCIENTIFIC/TECHNICAL TARGET OF THE WORK**

To investigate factors which may have an influence on leaf disorder problems on young evergreens overwinter, including humidity, root stress linked with poorly structured mixes and nutrient regime.

5. **CLOSELY RELATED WORK - COMPLETED OR IN PROGRESS**

Closely related trials in other sectors include the MAFF-commissioned programme on humidity studies on tomatoes (K101B), where calcium uptake as influenced by relative humidity has been studied, and in pot plants (K102-9D) where quality of plant growth under varying winter RH has been investigated. Both of these projects are at Efford.

6. **DESCRIPTION OF THE WORK**

Three small sealed tunnels would be required for this preliminary proposal. These would be unheated.

<u>Proposed treatments</u>:

Relative Humidity:	Ambient RH High RH (enhanced with fog to maintain 90+% RH) Low RH (Dehumidification to reduce RH below 80%)
Structure of Mix:	'Poor' (9-10% AFP) } using sieved Shamrock } medium Irish } Sphagnum Peat to } provide mixes of 'Open' (18-20% AFP) } appropriate AFP
Lime Source:	Calcium carbonate } at 1.5kg/m^3 of mix Magnesian limestone }
Fertilizer:	Osmocote Plus 12-14 month 'Autumn' at standard rate and 30% above standard rate (rate will depend on species).
Species:	Range of evergreen species which have shown problems previously. These include: *Choisya ternata*, *Pieris* 'Forest Flame', *Prunus laurocerasus* 'Otto Luyken', *Rhododendron* 'Fairylight' & *Rhododendron* 'Surrey Heath'
<u>Assessments</u>:	Vigour and quality scores, plus photographs as appropriate. Disease incidence. Foliage/media analyses at intervals.

7. **COMMENCEMENT DATE AND DURATION**

Start date 01.11.92; duration 8 months.

8. **STAFF RESPONSIBILITIES**

Miss Lyn Andrews in liaison with Miss M A Scott.

9. **LOCATION**

HRI-Efford

10. **COSTS**

Joint funding between Electricity Association and HDC proposed

11. **PAYMENT**

On each quarter day the Council will pay to the Contractor i accordance with the following schedule:

Quarter/Year	1992	1993
1	-	
2	-	
3	-	-
4		-

Contract No: HNS/49

TERMS AND CONDITIONS

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

Signed for the Contractor(s)

Signature............[illegible]............

Position..Commercial and Marketing Manager HSI

Date............13/9/93............

Signed for the Contractor(s)

Signature..

Position..

Date..

Signed for the Council

Signature............[illegible]............

Position.........CHIEF EXECUTIVE.........

Date............2.4.93............