CONTRACT REPORT

INFLUENCE OF HUMIDITY AND OTHER STRESS FACTORS ON PLANT GROWTH

Undertaken for HDC and EA Technology Ltd

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AUTHENTICATION

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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HDC HNS49a

Influence of humidity and other stress factors on plant growth

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Hewton Trees & Shrubs

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CONTENTS

SUMMARY

The work carried out in this Project in 1993/94 evaluated the effect of three different humidity regimes on the incidence of disease (during the winter/spring period) on newly potted liners of *Cistus*, *Hebe*, *Rhododendron* and Rose. Interactions with growing system and chemicals used for vine weevil control ('suSCon Green') and weed control ('Venzar') were also investigated.

The three humidity regimes used - 'low' (<80%), 'ambient', and 'high' (>95%) - were achieved in three small single span tunnels (11m x 4.25m). A Munters M300 dehumidifier was used to reduce the relative humidity (RH), and a fogging system to increase the RH. Each tunnel contained an overhead irrigated gravel bed and a sand bed irrigated by seephose. Chemical treatments included 'suSCon Green' incorporated into the growing media (at 750g/m^3) and 'Venzar' (at 1.4g or 2.8g/10m^2) applied as an overall spray in 2.5 litres water/10m^2. Half of the replicates of *Hebe* 'Miss E Fittall' were treated with 'Aliette' at fortnightly intervals from February to control downy mildew, whilst the remainder were left unsprayed. One of the three replicates of each *Rhododendron* cultivar, 'El Camino' and 'Gartendirektor Glocker' was sprayed with 'Nimrod' at 2-week intervals from late May to control powdery mildew, whilst the other two were left unsprayed.

Reduction of RH to <80% significantly reduced the incidence of downy mildew (*Peronospora sparsa*) and black spot (*Diplocarpon rosae*) on Rose 'Royal Worcester'. The only plants of this species remaining marketable at the final assessment were those grown in the 'low' humidity tunnel. Extensive leaf drop occurred in the 'ambient' and particularly the 'high' humidity regimes, especially on plants grown on the overhead irrigated gravel beds.

A similar trend was noted with downy mildew (*Peronospora grisea*) on *Hebe* 'Miss E Fittall', with the disease being much more widespread in the 'high' humidity regime, and on overhead irrigated gravel beds. A preliminary assessment in February (when plants were ready for sale) showed very little disease present in the 'low' humidity tunnel, but higher levels in the other two regimes. In late February plants were 'stopped' to encourage a second flush of growth and a spray programme of 'Aliette' commenced on half of the replicates. By the final assessment in mid May, sequential sprays of 'Aliette' had markedly reduced disease levels, but complete control was not achieved. The spray programme was most effective in the 'low' humidity regime where the pressure of the disease was less.

Since the development and spread of black spot and the two species of downy mildew involved are favoured by high humidities it is not surprising that disease levels were much lower on plants in the 'low' humidity regime, and on plants grown on seephose irrigated sand beds.

No disease problems were recorded on plants of *Cistus* 'Silver Pink'.

In contrast to the downy mildews, powdery mildews prefer drier conditions, and powdery mildew (*Oidium* spp) became obvious on *Rhododendron* plants towards the end of the trial, particularly in the 'low' humidity tunnel when temperatures increased from May onwards. *R.* 'El Camino' appeared to be more susceptible to infection than 'Gartendirektor Glocker'.

No obvious signs of phytotoxicity were recorded as a result of the use of 'suSCon Green' or 'Venzar' on the five species/cultivars tested.

'Venzar' gave good control of moss, particularly in pots grown on sand beds, with seephose irrigation, and in the 'low' and 'ambient' humidities where conditions were less favourable for moss growth than in the 'high' humidity tunnel. Other weeds, including liverwort, were not prevalent.

The merits of dehumidification are discussed together with the costs involved.

INTRODUCTION

The majority of nursery stock liners are grown 'cold' in polythene tunnels, with only sufficient heat to provide frost protection over the winter period. Ventilation is frequently minimal, and high humidities often prevail, favouring the development of diseases such as downy mildews and *Botrytis*. Growing systems within the polythene tunnel may also affect the incidence of disease (and weeds, including moss and liverwort) as well as overall plant quality. Drained sand beds watered by seephose to provide capillary irrigation generally produce a better quality plant than overhead irrigated gravel beds.

Work in the first year of this Project (1992/93) evaluated the effect of a number of potential stress factors on plant growth, in an attempt to determine the cause of the leaf distortion/ scorching frequently reported by the industry on liners of certain evergreen species such as *Choisya*, *Pieris* and *Rhododendron*. Relative humidity, growing system, nutrition and growing media structure were investigated, but none of the treatments resulted in any abnormal foliar symptoms. However, plant growth was generally better in the 'low' humidity regime, (although this may have been due, at least in part, to the slightly higher air temperature resulting from the dehumidification process), and the incidence of weeds, particularly liverwort, was less widespread.

The lower humidities resulting from dehumidification may also be of benefit in reducing the occurrence of diseases such as *Botrytis* and *Peronospora* spp (downy mildews) which thrive in moist conditions, and an investigation of the effect of a range of relative humidities on disease incidence formed the basis of the work carried out in 1993/94.

With increasing pressure to reduce the use of pesticides, and the decreasing number of chemicals available, manipulation of environmental conditions may offer an alternative method of controlling some of these diseases, and possibly even weed growth especially moss and liverwort, if it is economically viable.

'Venzar' (lenacil) has shown promise for moss/liverwort control under protection in Project HNS35b but further work on efficacy and safety on a wider range of species is required, together with information on possible interactions with other chemicals (e.g. 'suSCon Green' used for vine weevil control) under different relative humidities.

Work to date in Project HNS15b has shown that certain species (eg *Hypericum* 'Hidcote') appear to be sensitive to 'suSCon Green' incorporated into the growing media for vine weevil control. The use of growing media with and without 'suSCon Green' incorporated in this trial allowed additional information to be gained on the safety of this material for a wider range of species, grown on sand and gravel beds under a range of humidity conditions.

As in the previous year, work carried out in 1993/94 was jointly funded through the Horticultural Development Council and Electricity Association Technology Ltd.

OBJECTIVES

To investigate the effect of different humidity regimes on the incidence of disease (during the winter period) on newly potted liners of several HNS species, and to evaluate the phytotoxicity (if any) of 'Venzar' (used for the control of weeds, including moss and liverwort) and 'suSCon Green' (used for vine weevil control).

MATERIALS AND METHODS

Treatments

1. Target humidities

a) maximum of 80%, achieved by using a Munters M300 dehumidifier (supplied by Electricity Association Technology Ltd).

b) ambient.

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

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

2. Growing system

a) sand bed with seephose irrigation.

b) gravel bed with overhead irrigation.

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. Chemical incorporation into the growing media for vine weevil control

a) chlorpyrifos as 'suSCon Green' incorporated at 750g/m^3 prior to potting.

b) no 'suSCon Green' incorporated.

Note: Not applicable to roses which were supplied already potted as liners.

4. Chemical application for liverwort control

a) lenacil as 'Venzar' applied as an overall spray at 1.4g in 2.5 litres water/10m² (to all species) and 2.8g in 2.5 litres water/10m² (roses only) after potting.

b) no 'Venzar' applied.

5. Chemical control of diseases (*Hebe and Rhododendron only*)

Hebe: (for control of downy mildew)

a) fosetyl-aluminium as 'Aliette' applied as a foliar spray at 14 day intervals at 0.15g in 40ml water/m² (7 sprays applied, commencing 18 February 1994)

b) no 'Aliette' applied.

Rhododendron: (for control of powdery mildew)

a) bupirimate as 'Nimrod' applied as a foliar spray at 14 day intervals at 3.8ml/litre (2 sprays applied, commencing 27 May 1994)

b) no 'Nimrod' applied

6. Species

Rose 'Royal Worcester'
Hebe 'Miss E Fittall'
Cistus 'Silver Pink'
Rhododendron 'El Camino'
Rhododendron 'Gartendirektor Glocker'

Experimental design

The humidity regimes and growing systems were not replicated. The remaining treatments were replicated as detailed on page 7 according to species:

Rose 'Royal Worcester': 6 replicates of i) untreated control (no 'Venzar')
ii) 'Venzar' at 2.8g/10m²
and 12 replicates of iii) 'Venzar' at 1.4g/10m² *(the experimental design allowed for 6 of these replicates to be given a second spray of 'Venzar' if necessary. However, relatively few weed seeds germinated and a further treatment was not required)*

***Hebe* 'Miss E Fittall'**: 6 replicates of i) untreated control (no 'Venzar' or 'suSCon Green')
ii) 'Venzar' only (no 'suSCon Green')
iii) 'suSCon Green' only (no 'Venzar')
iv) 'Venzar' and 'suSCon Green'
Replicates 1, 3 and 5 were given a disease control programme (5a, page 6) from 18 February, (after 'stopping'), and the remaining replicates left unsprayed.

Cistus* 'Silver Pink'**: as ***Hebe, but with no disease control programme applied.

Rhododendron* 'El Camino'**: 3 replicates of treatments i)-iv) as detailed for ***Hebe with replicate 2 given a disease control programme from 27 May, and replicates 1 and 3 left unsprayed.

***Rhododendron* 'Gartendirektor Glocker'**: as *R.* 'El Camino' above

The plot layout within the tunnels is given in Appendix IV (page 64).

Trial site

The three small tunnels (orientated east-west) were fully clad in polythene, with doors at both ends. 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 northern tunnel contained the CF-2 fogging system, and the southern the M300 dehumidifier. The centre tunnel was the ambient humidity 'control'.

Husbandry

Rooted cuttings of ***Hebe*** were potted on 4 November, and ***Cistus*** on 9 November 1993. Micropropagated plants of both ***Rhododendron*** cultivars were potted on 3 November. Plants of all three species were potted into 9cm pots using a peat based growing media containing the additions shown in Table 1.

Table 1: Additions to growing media used for potting on rooted cuttings (*Cistus* and *Hebe*) and micropropagated plugs (*Rhododendron*) at the commencement of the trial

Species	Growing system	Quantity added kg/m³ of peat: magnesian limestone	Quantity added kg/m³ of peat: * controlled release fertiliser
Cistus and *Hebe*	sand bed	1.5	3.5
	gravel bed	1.5	4.0
Rhododendron	sand bed	1.0	2.5
	gravel bed	1.0	3.0

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

Note 1: 'suSCon Green' was added according to treatment

Note 2: Rose liners bought in already potted

After potting, plants were kept in a glasshouse (heated to provide frost protection only) for 2-3 weeks prior to moving to the three treatment tunnels.

2.8kW Hotbox fan heaters were installed in each tunnel and set to provide sufficient heat for frost protection only.

Hebe plants were stopped in early February to encourage another flush of new growth on which to make a final assessment of disease later in the spring. Plants of *Cistus* were similarly 'stopped' in early April.

Assessments

Environmental records

The air temperature (°C) and relative humidity (%) were recorded 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 by the two types of irrigation system in each of the three tunnels was recorded (using a Kent water meter) throughout the trial period.

Plant Growth Records

1. Rose 'Royal Worcester'

The number of dead, dying, marketable and unmarketable plants were recorded on 30 April 1994.

Percentage leaf drop was also estimated at this time, using five categories: nil, <25%, 25-50%, 50-75% and >75%.

Many of the leaves remaining on plants at the end of the trial were marked with dark chocolate brown/black lesions. The extent of this spotting was assessed using four categories: nil, slight, moderate and severe. Downy mildew (*Peronospora sparsa*) was identified as the most prevalent pathogen but black spot (*Diplocarpon rosae*) and *Botrytis* were also present.

The number and type of weeds present was also recorded, together with the presence of moss and liverwort.

2. *Hebe* 'Miss E Fittall'

The incidence of downy mildew (*Peronospora grisea*) was recorded on the first flush of growth (i.e. 'old' growth) and the second flush of growth (i.e. 'new' growth) on 14 May 1994, using five categories: nil, slight (<10% leaves affected), moderate (10-50% leaves affected), moderately severe (50-75% leaves affected) and severe (75-100% leaves affected).

The number of dead plants was recorded and plant vigour was scored on a 1-5 scale:

1: 1 or 2 weak spindly shoots growing away, virtually all leaves shed from old growth.
2. 3 or more weak shoots growing away, a few leaves remaining on old growth.
3. 1-5 shoots growing away with moderate vigour.
4. >5 shoots growing away with moderate vigour.
5. >5 shoots growing away vigorously.

The number of weed free pots was recorded, together with the number and types of weed present.

3. *Cistus* 'Silver Pink'

The number of marketable, unmarketable and dead plants were recorded on 30 May 1994.

The number of shoots/plant and the length of the longest shoot/plant was also recorded, together with the number and type of weeds present (including moss and liverwort).

4. *Rhododendron* 'El Camino' and 'Gartendirektor Glocker'

The growth stage of plants of both cultivars was assessed on 18 June 1994 using five categories (where 1 = least advanced and 5 = most advanced) (Plate 13, page 45).

The incidence of powdery mildew (*Oidium* spp) on the upper and lower leaf surfaces of both old and young growth was estimated using five categories: nil, 1-25%, 25-50%, 50-75% and 75-100%.

The number and type of weeds present (including moss and liverwort) was also recorded.

RESULTS

Environmental records

Problems were encountered with the Munters M300 dehumidifier in the early part of the trial, with the target RH only being achievable accompanied by large temperature differentials. This, however, proved to be the result of a mechanical defect which was rectified by early February 1994.

Temperature and RH readings for two typical 24 hour periods on 22 February and 21 April 1994 are shown in Tables 2 and 3 respectively. On 22 February the fogging system and the dehumidifier were running throughout. On 21 April, when temperatures were higher, the humidity control equipment was switched off from 0700-1800 hours and the doors on the 3 tunnels were left open to provide ventilation.

Averaged over the two separate 24 hour sample periods, the air temperatures in the 3 humidity regimes were very similar. The % RH in the 'ambient' tunnel was over 90% for most of the 24 hour period on 22 February, when the tunnel doors remained closed all day. The dehumidifier reduced the % RH in the 'low' tunnel to, on average, about 25% lower than that in the 'ambient' tunnel.

In contrast, on 21 April when air temperatures were higher, particularly during the day, the % RH in the three tunnels fell to around 50% when the tunnel doors were opened to allow ventilation.

Table 2: **Air temperatures (°C) and Relative Humidity (%) at hourly intervals from 00.13 to 23.13 hours on 22 February 1994**

Time	Air temperature (°C) Humidity regime			Relative Humidity (%) Humidity regime		
	'Low'	'Ambient'	'High'	'Low'	'Ambient'	'High'
00.13	2.3	3.0	3.7	67.5	94.4	99.6
01.13	1.8	2.8	3.5	66.8	93.6	99.8
02.13	1.8	2.7	3.3	72.0	93.4	99.8
03.13	1.8	2.8	3.4	68.1	93.6	99.9
04.13	1.8	2.9	3.6	68.0	94.0	100.0
05.13	1.9	2.9	3.8	62.2	94.4	100.0
06.13	1.9	3.0	3.7	64.0	94.7	100.0
07.13	2.1	3.1	3.7	66.4	95.0	100.0
08.13	2.9	3.6	4.0	58.5	94.6	100.0
09.13	4.9	4.8	4.8	45.0	94.2	100.0
10.13	7.0	7.4	6.7	55.9	86.6	94.5
11.13	9.3	9.7	8.8	55.6	82.9	90.6
12.13	10.3	10.5	9.6	56.2	81.2	87.9
13.13	7.6	7.8	7.3	68.5	88.3	94.0
14.13	7.4	7.4	6.9	64.9	87.2	93.3
15.13	6.9	6.6	6.4	61.0	90.9	96.0
16.13	5.7	5.4	5.4	72.0	93.2	97.4
17.13	5.0	4.7	4.8	69.6	94.9	98.6
18.13	4.7	4.3	4.5	70.7	96.4	99.4
19.13	4.6	4.2	4.4	67.1	97.1	99.7
20.13	4.5	4.1	4.3	67.4	97.5	99.9
21.13	4.8	4.2	4.4	68.6	97.9	100.0
22.13	5.0	4.5	4.6	68.4	98.1	100.0
23.13	5.3	4.6	4.7	66.4	98.3	100.0
Mean	4.6	4.9	5.0	64.6	93.0	97.9

Table 3: Air temperatures (°C) and Relative Humidity (%) at hourly intervals from 00.31 to 23.31 hours on 21 April 1994

Time	Air temperature (°C) Humidity regime			Relative Humidity (%) Humidity regime		
	'Low'	'Ambient'	'High'	'Low'	'Ambient'	'High'
00.31	4.6	4.8	5.2	68.8	98.1	99.6
01.31	5.1	5.2	5.5	76.2	98.3	99.6
02.31	3.4	3.9	4.4	68.3	97.7	99.3
03.31	4.3	4.5	4.8	74.1	98.3	99.7
04.31	4.3	4.6	4.8	80.7	98.3	99.7
05.31	3.8	4.3	4.6	76.3	98.3	99.3
06.31	8.5	9.0	8.8	75.4	96.4	98.1
---------->	Tunnel doors opened and machines switched off					
07.31	16.0	16.5	16.0	62.0	70.3	73.5
08.31	17.3	16.4	16.5	56.9	66.9	69.3
09.31	22.4	21.4	21.7	46.3	56.9	57.1
10.31	17.3	16.9	17.0	60.4	70.0	71.5
11.31	26.0	24.3	25.5	38.1	48.4	46.9
12.31	33.0	30.3	32.7	31.7	38.6	35.0
13.31	20.4	20.1	21.9	46.0	59.8	51.6
14.31	18.4	18.8	18.6	47.8	54.7	52.4
15.31	18.4	18.9	18.0	50.6	56.2	59.3
16.31	15.4	15.6	14.6	54.5	58.4	67.0
17.31	13.2	13.1	12.6	57.1	61.9	67.1
---------->	Tunnel doors closed and machines switched on					
18.31	12.0	11.8	11.5	79.1	87.0	93.9
19.31	8.7	9.3	9.4	77.7	93.2	97.5
20.31	7.1	8.0	8.3	73.7	95.4	98.6
21.31	8.3	8.7	8.9	82.1	96.9	99.3
22.31	9.0	9.4	9.6	78.8	97.5	99.4
23.31	8.4	8.9	9.1	65.3	97.2	99.0
Mean	12.7	12.7	12.9	63.7	78.9	80.6

Irrigation water applied

The quantity of water applied using seephose and overhead irrigation in each of the tunnels is given in Tables 4 and 5. More water was applied using the overhead irrigation system in the 'low' and 'high' humidity regimes than through the seephose in the same tunnels. However, the reverse was found in the 'ambient' tunnel, and based on results with the other two regimes this would appear to be an anomaly.

In both growing systems less water was required in the 'high' humidity regime than in the other two tunnels.

Table 4: Quantity of water applied (litres)/month using seephose irrigation on sand beds

Month	Humidity regime		
	'Low'	'Ambient'	'High'
December '93	263	13	Nil
January '94	Nil	Nil	Nil
February	157	195	Nil
March	561	615	Nil
April	1397	1368	701
May	916	1594	1293
Total	3294	3785	1994

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

Month	Humidity regime		
	'Low'	'Ambient'	'High'
December '93	56	18	Nil
January '94	Nil	Nil	Nil
February	127	160	Nil
March	688	530	157
April	1733	1216	915
May	1462	1320	1811
Total	4066	3244	2883

Growth records, disease assessments and weed scores

Rose 'Royal Worcester' (Plates 1-8, pages 37-40)

With this species the effect of humidity regime on plant growth was obvious on both sand and gravel beds. Only plants grown in the 'low' humidity tunnel remained marketable by the final assessment (Figures 1 and 2, Appendix II, Tables 13 and 14, page 47). Extensive leaf drop had occurred in the other two tunnels, particularly in the 'high' humidity regime, being most marked on plants grown in the gravel beds. On the remaining leaves, leaf spotting was widespread, except in the 'low' humidity regime.

The pathogen identified as being responsible for the majority of the 'spotting' on the leaves was downy mildew (*Peronospora sparsa*), although traces of black spot (*Diplocarpon rosae*) and *Botrytis* were also present. All of these diseases are favoured by conditions of high humidity and were much less prevalent in the 'low' humidity regime.

A half to two thirds of plants on sand beds in the 'high' humidity tunnel were dying/dead by the end of the trial, compared to over 90% on gravel beds in the same tunnel. The mortality rate was slightly lower in the 'ambient' tunnel.

'Venzar' gave good control of weeds and moss, particularly at the higher rate, with no obvious evidence of phytotoxicity (Table 6).

Humidity regime influenced weed/moss growth in pots not treated with 'Venzar', with markedly fewer 'clean' pots in the 'ambient' and 'high' humidity regimes.

Figure 1: Rose 'Royal Worcester'; sand bed with seephose irrigation % marketability and plant survival

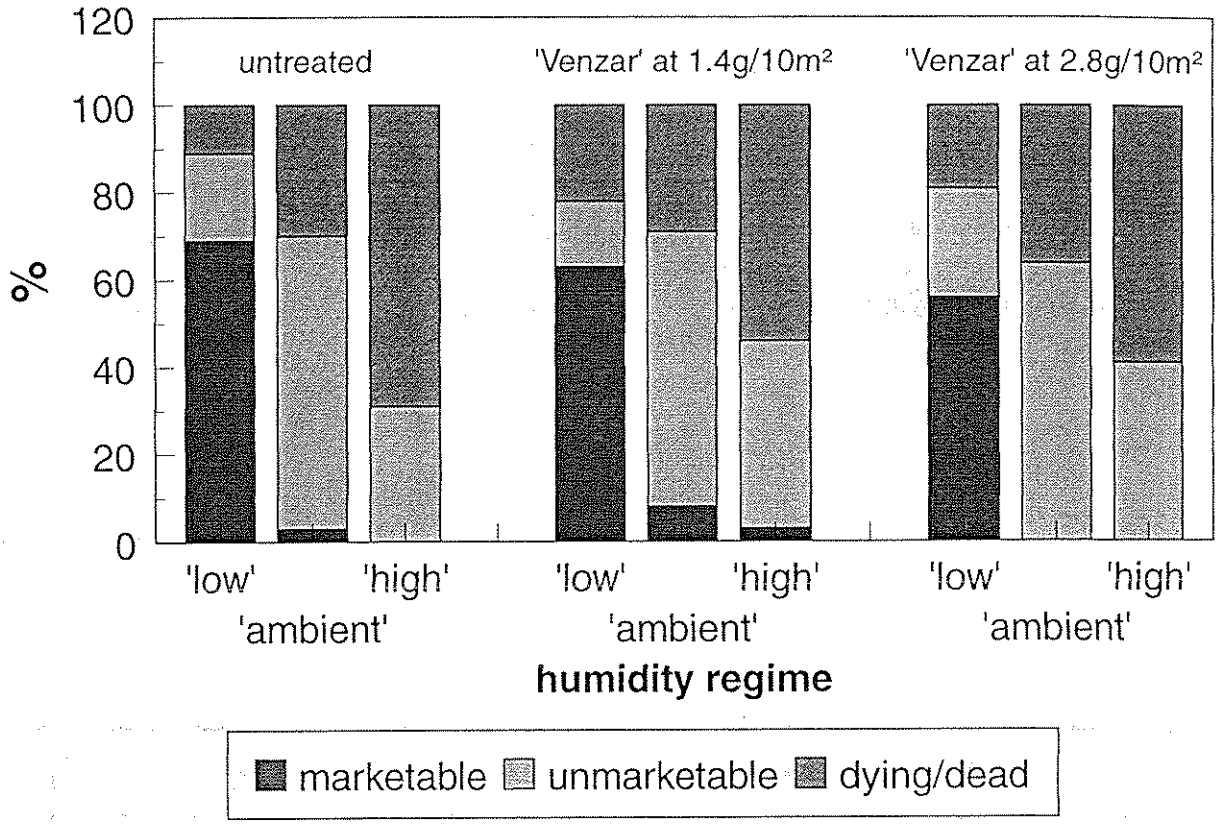


Figure 2: Rose 'Royal Worcester'; gravel bed with overhead irrigation % marketability and plant survival

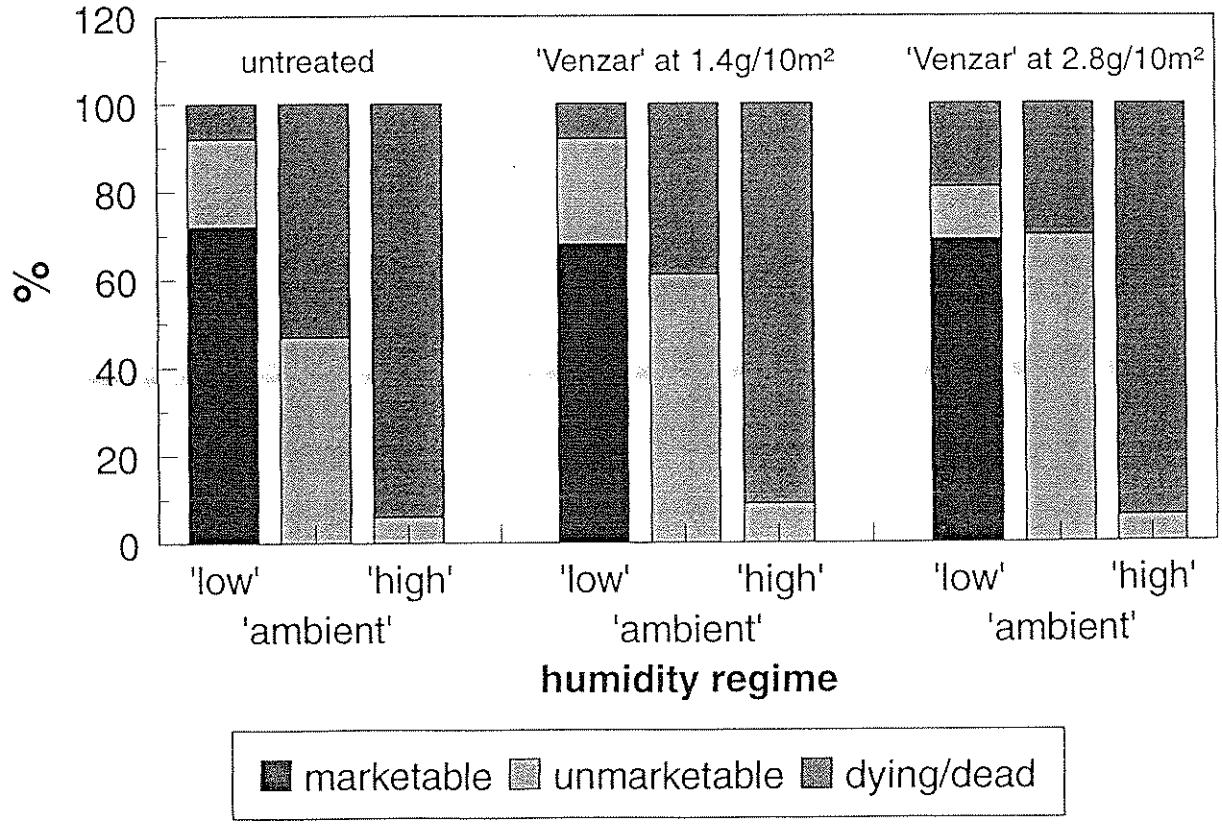


Table 6: Rose 'Royal Worcester'; percentage pots with no weeds, moss or liverwort

Treatment	Humidity regime	Growing system	% clean pots
Untreated control (no 'Venzar')	'low'	sand bed with	64%
	'ambient'	seephose	14%
	'high'	irrigation	8%
	'low'	gravel bed with	50%
	'ambient'	overhead	14%
	'high'	irrigation	0%
'Venzar' at 1.4g/10m²	'low'	sand bed with	90%
	'ambient'	seephose	90%
	'high'	irrigation	88%
	'low'	gravel bed with	89%
	'ambient'	overhead	88%
	'high'	irrigation	79%
'Venzar' at 2.8g/10m²	'low'	sand bed with	100%
	'ambient'	seephose	97%
	'high'	irrigation	86%
	'low'	gravel bed with	97%
	'ambient'	overhead	94%
	'high'	irrigation	92%

Figure 3: Hebe 'Miss E Fittall'; sand bed with seephose irrigation

no disease control programme applied
% plants with vigour scores of 3-5

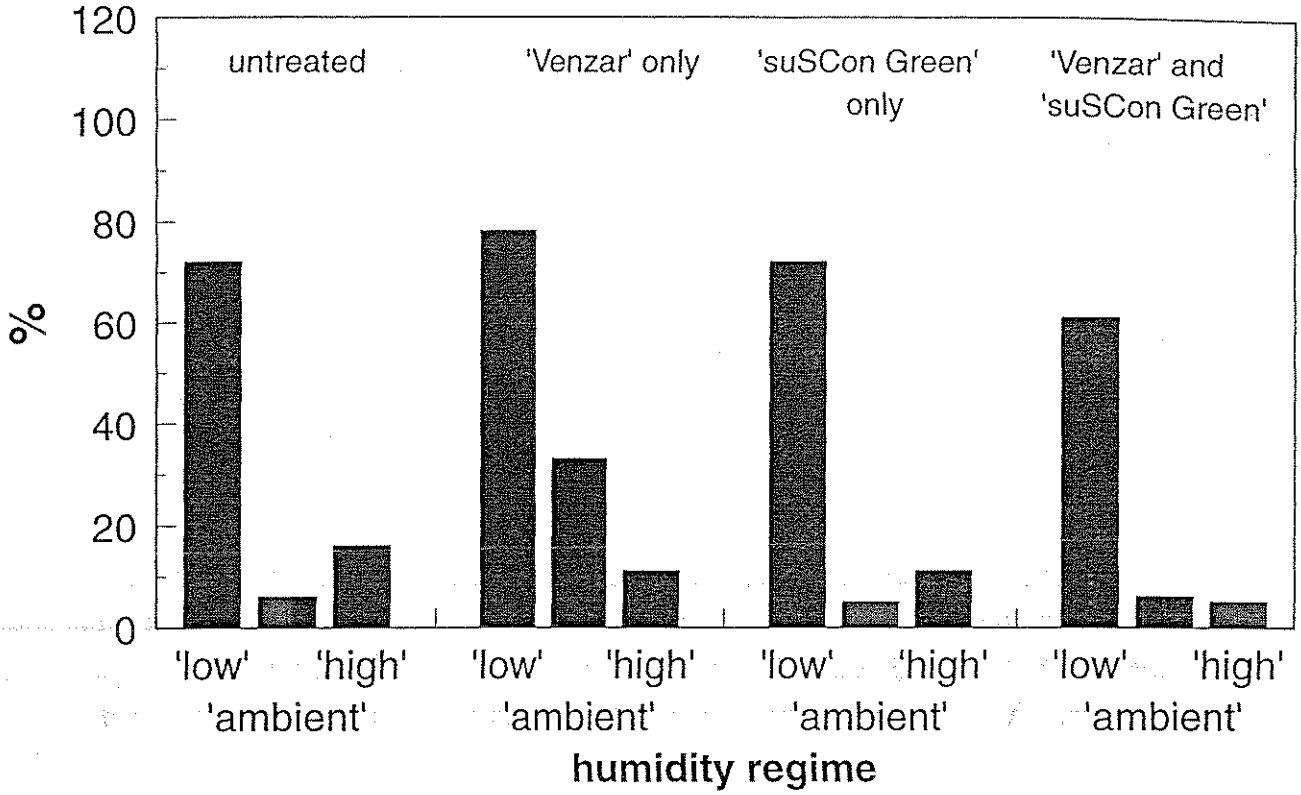


Figure 4: Hebe 'Miss E Fittall'; sand bed with seephose irrigation

disease control programme applied
% plants with vigour scores of 3-5

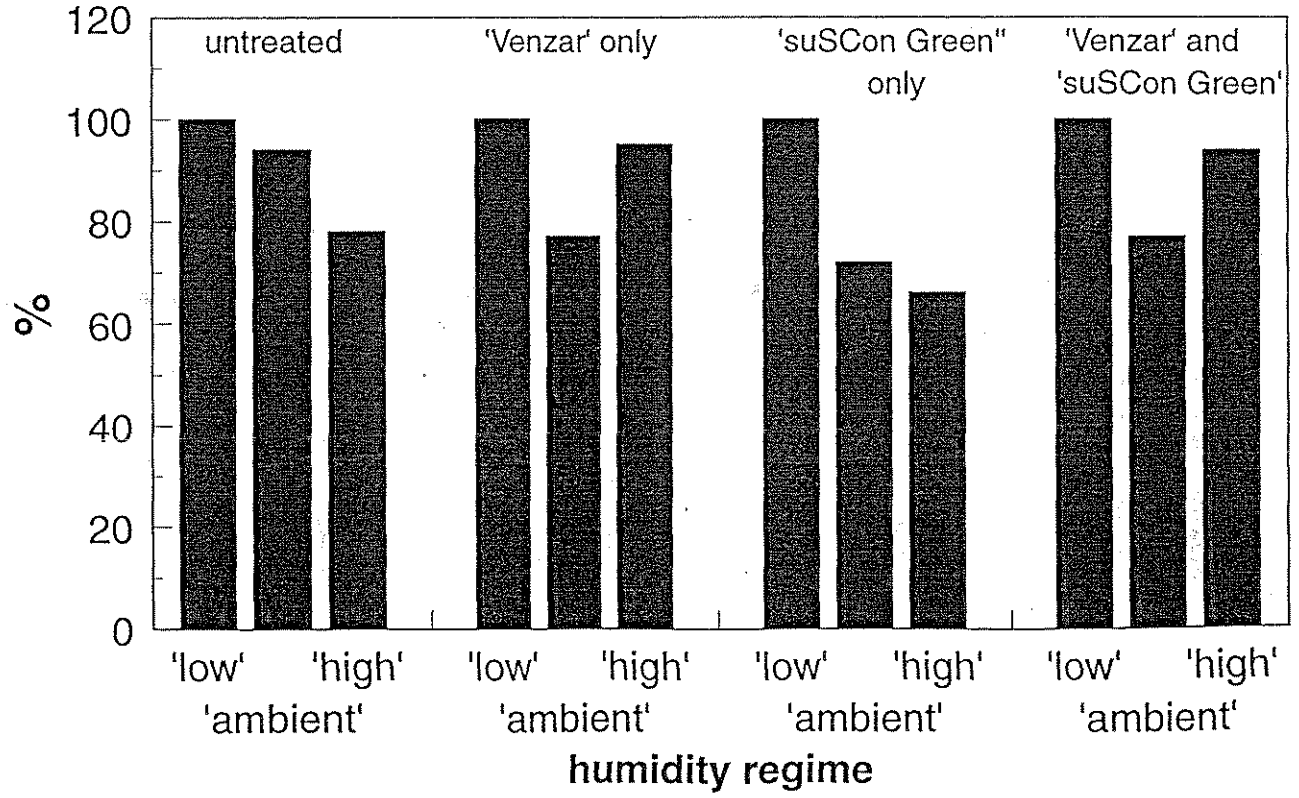


Figure 5: Hebe 'Miss E Fittall'; gravel bed with overhead irrigation

no disease control programme applied
% plants with vigour scores of 3-5

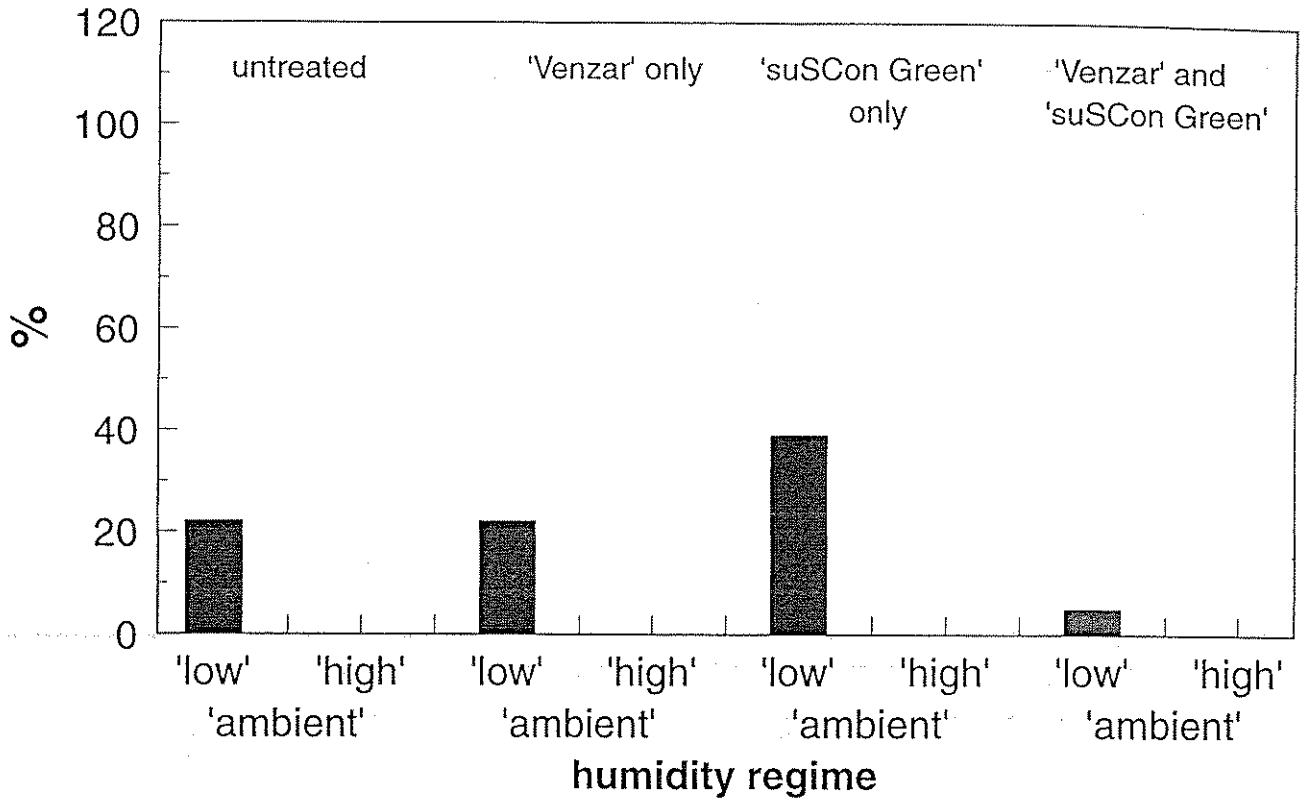


Figure 6: Hebe 'Miss E Fittall' gravel bed with overhead irrigation

disease control programme applied
% plants with vigour scores of 3-5

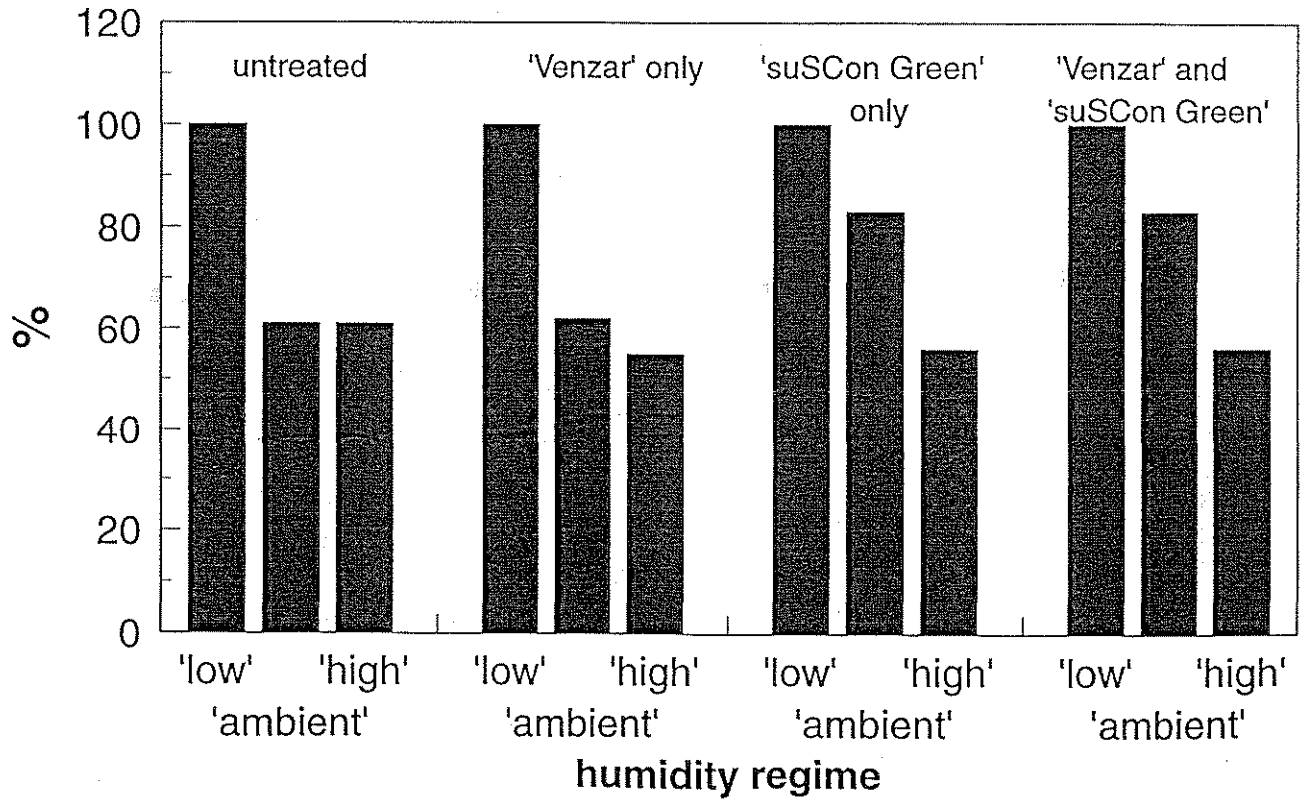


Table 7: ***Hebe*** **'Miss E Fittall': percentage pots with no weeds, moss or liverwort**

Treatment	Humidity regime	Growing system	% clean pots
Untreated control (no 'Venzar' or 'suSCon Green')	'low'	sand bed with seephose irrigation	39%
	'ambient'		36%
	'high'		17%
	'low'	gravel bed with overhead irrigation	28%
	'ambient'		8%
	'high'		3%
'Venzar' only (no 'suSCon Green')	'low'	sand bed with seephose irrigation	100%
	'ambient'		97%
	'high'		78%
	'low'	gravel bed with overhead irrigation	89%
	'ambient'		75%
	'high'		50%
'suSCon Green' only (no 'Venzar')	'low'	sand bed with seephose irrigation	19%
	'ambient'		31%
	'high'		14%
	'low'	gravel bed with overhead irrigation	19%
	'ambient'		6%
	'high'		6%
'Venzar' and 'suSCon Green'	'low'	sand bed with seephose irrigation	97%
	'ambient'		100%
	'high'		86%
	'low'	gravel bed with overhead irrigation	92%
	'ambient'		69%
	'high'		36%

Cistus **'Silver Pink'**

Although cuttings with sizeable root systems were potted and held in a frost protected glasshouse for two weeks prior to moving out into the trial tunnels, subsequent survival and growth was very variable, both within and between humidity regimes.

Untreated control plants (i.e. no 'Venzar' or 'suSCon Green') performed equally poorly on both sand beds and gravel beds, irrespective of humidity regime, yielding small, weakly growing plants, the majority of which were unmarketable (Tables 8 and 9).

The most marketable plants were found where 'suSCon Green' was incorporated into the growing media - 72% and 64% of the plants were recorded as marketable on sand beds in 'low' and 'high' humidities. The highest % marketable plants was recorded in 'ambient' and 'high' humidities, on gravel beds, with 'suSCon Green' incorporated into the potting mix. This was reflected in the higher number of shoots/plant and longer shoots. In contrast, growth was poor on similarly treated plants grown in a 'low' humidity regime. No vine weevil larvae were found in the growing media, and it is difficult to explain the improved plant growth in this treatment.

When 'Venzar' and 'suSCon Green' were used together, the best growth was recorded on plants grown on gravel beds with overhead irrigation in 'low' and 'high' RH.

'Venzar' gave very good control of moss, particularly in pots grown on sand beds with seephose irrigation, and in the 'low' and 'ambient' humidities, but was less effective in the 'high' humidity environment where conditions favoured moss growth (Table 10). Weed seedlings were not widespread. The most prevalent weeds were seedling heathers, although a few plants of Hairy Bittercress and Groundsel were also recorded. Only 3 pots were found to carry liverwort, and in very small quantities - these were growing in the 'high' humidity environment in pots treated with 'Venzar'.

Table 8: ***Cistus*** **'Silver Pink'; sand bed with seephose irrigation, % plant survival and marketability, mean number of shoots/plant and mean length of longest shoot/plant**

Treatment	Humidity regime	% plants marketable	% plants unmarketable	% plants dead	Mean no. shoots/plant	Mean length (cm) of longest shoot/plant
Untreated control (no 'Venzar', no 'suSCon Green')	'low'	17%	75%	8%	2.7	11.5
	'ambient'	14%	72%	14%	2.1	9.4
	'high'	22%	67%	11%	2.4	11.7
'Venzar' only (no 'suSCon Green')	'low'	17%	72%	11%	2.4	10.0
	'ambient'	33%	59%	8%	3.0	13.6
	'high'	33%	42%	25%	3.6	15.2
'suSCon Green' only (no 'Venzar')	'low'	72%	22%	6%	4.9	20.7
	'ambient'	36%	61%	3%	3.3	15.8
	'high'	64%	28%	8%	4.2	22.0
'Venzar' and 'suSCon Green'	'low'	22%	70%	8%	2.5	11.5
	'ambient'	6%	80%	14%	1.8	9.7
	'high'	56%	36%	8%	4.3	21.0

Table 9: ***Cistus*** **'Silver Pink'; gravel bed with overhead irrigation, % plant survival and marketability, mean number of shoots/plant and mean length of longest shoot/plant**

Treatment	Humidity regime	% plants marketable	% plants unmarketable	% plants dead	Mean no. shoots/plant	Mean length (cm) of longest shoot/plant
Untreated control (no 'Venzar', no 'suSCon Green')	'low'	17%	69%	14%	2.6	12.0
	'ambient'	11%	86%	3%	1.9	9.9
	'high'	14%	75%	11%	1.9	10.4
'Venzar' only (no 'suSCon Green')	'low'	11%	89%	0%	2.3	9.0
	'ambient'	30%	56%	14%	3.4	16.4
	'high'	33%	50%	17%	3.0	17.1
'suSCon Green' only (no 'Venzar')	'low'	17%	75%	8%	2.5	9.2
	'ambient'	97%	3%	0%	6.6	25.9
	'high'	100%	0%	0%	5.7	26.6
'Venzar' and 'suSCon Green'	'low'	81%	16%	3%	5.5	23.7
	'ambient'	33%	56%	11%	3.3	16.1
	'high'	94%	6%	0%	5.3	27.2

Table 10: ***Cistus*** **'Silver Pink'; percentage pots with no weeds, moss or liverwort**

Treatment	Humidity regime	Growing system	% clean pots
Untreated control (no 'Venzar' or 'suSCon Green')	'low'	sand bed with seephose irrigation	69%
	'ambient'		50%
	'high		28%
	'low'	gravel bed with overhead irrigation	19%
	'ambient'		14%
	'high'		3%
'Venzar' only (no 'suSCon Green')	'low'	sand bed with seephose irrigation	97%
	'ambient'		83%
	'high'		72%
	'low'	gravel bed with overhead irrigation	72%
	'ambient'		83%
	'high'		25%
'suSCon Green' only (no 'Venzar')	'low'	sand bed with seephose irrigation	19%
	'ambient'		39%
	'high'		28%
	'low'	gravel bed with overhead irrigation	6%
	'ambient'		3%
	'high'		3%
'Venzar' and 'suSCon Green'	'low'	sand bed with seephose irrigation	94%
	'ambient'		97%
	'high'		81%
	'low'	gravel bed with overhead irrigation	75%
	'ambient'		67%
	'high'		44%

***Hebe* 'Miss E Fittall'** (Plates 9-12, pages 41-44)

As with the roses, humidity regime and growing system significantly influenced the level of downy mildew (*Peronospora grisea*) present.

Little, if any, downy mildew was obvious on plants in the 'low' humidity regime in February, but higher levels were recorded in the 'ambient' and 'high' humidity tunnels. Plants were 'stopped' at this stage to encourage a new flush of growth.

In mid May assessments of disease were made on both 'young' and 'old' growth, the 'young' growth being that occurring after the February 'stop'. Less downy mildew was recorded on 'old' growth in the 'low' humidity regime, irrespective of growing system and 'Venzar' and 'suSCon Green' treatment (Appendix II, Tables 15-18, pages 48-51).

Where a disease control programme was not applied, the disease had spread to most of the 'young' growth by the final assessment, even in the 'low' humidity regime, although here it was not so severe. In addition, unsprayed plants grown on sand beds were more vigorous than their counterparts grown on gravel beds, probably as a result of less disease infection.

Plants given a programme of 'Aliette' sprays carried less disease on the new growth particularly in the 'low' humidity regime, and this was reflected in the vigour scores (Figures 3-6, Appendix II, Table 19, page 52).

More plants (approximately one third) treated with 'Venzar' or 'suSCon Green' alone or in combination died on gravel beds in the 'high' humidity regime than in other treatments. A similar mortality occurred on both sand and gravel beds in the 'high' humidity regime where plants were treated with both 'Venzar' and 'suSCon Green' This may have been a result of a combination of 'stress' factors, i.e. chemical application, high humidity and high levels of disease.

'Venzar' gave good control of moss and weeds, particularly in pots grown on sand beds, and in the 'low' and 'ambient' humidity regimes (Table 7, page 21). Moss was the most prevalent 'weed'. Other much less common weeds were seedling heathers and sedge. Liverwort was only found in very small quantities in half a dozen pots not treated with 'Venzar' in the 'high' humidity tunnel.

***Rhododendron* 'El Camino' and 'Gartendirektor Glocker'** (Plates 13 and 14)

Powdery mildew development is favoured by drier conditions and did not become evident on plants until May, when air temperatures had improved. The highest % infection was recorded on plants of *R.* 'El Camino' grown on sand beds in the 'low' humidity regime. 100% infection was recorded on the underside of 'old' leaves in these conditions, and some disease was also present on the upper leaf surfaces.

Generally, good disease control was achieved on the new flush of growth by the sprays of 'Nimrod' applied - except on plants grown on sand beds in the 'low' humidity tunnel, where the conditions were most favourable for the development and spread of the disease.

Powdery mildew levels were markedly lower on plants of *R.* 'Gartendirektor Glocker'.

There was a trend for growth of plants of both cultivars being more advanced on sand than gravel beds, irrespective of humidity regime (Figures 7, 8, 9 and 10).

Neither 'Venzar' nor 'suSCon Green' treatment adversely affected plant growth, or resulted in any symptoms of phytotoxicity.

The most prevalent 'weed' was moss which was particularly widespread in the 'high' humidity regime. Good control was achieved on pots of 'El Camino' using 'Venzar' in the 'low' humidity tunnel (Table 11, page 28). Control was less effective in the 'ambient' humidity tunnel, irrespective of growing system. 'Venzar' gave good control of moss on pots of 'Gartendirektor Glocker' grown on sand beds in all 3 humidity regimes. With both cultivars, 'Venzar' proved ineffective in controlling moss in pots grown on overhead irrigated gravel beds in the 'high' humidity regime.

Liverwort was not a problem in pots of 'Gartendirektor Glocker' but was more prevalent in pots of 'El Camino', particularly those grown on overhead irrigated gravel beds, and in 'high' humidity. 'Venzar' appeared to give good control, especially in the 'low' and 'ambient' regimes.

Figure 7: Rhododendron 'El Camino'; sand bed with seephose irrigation

% plants at growth stages 3-5

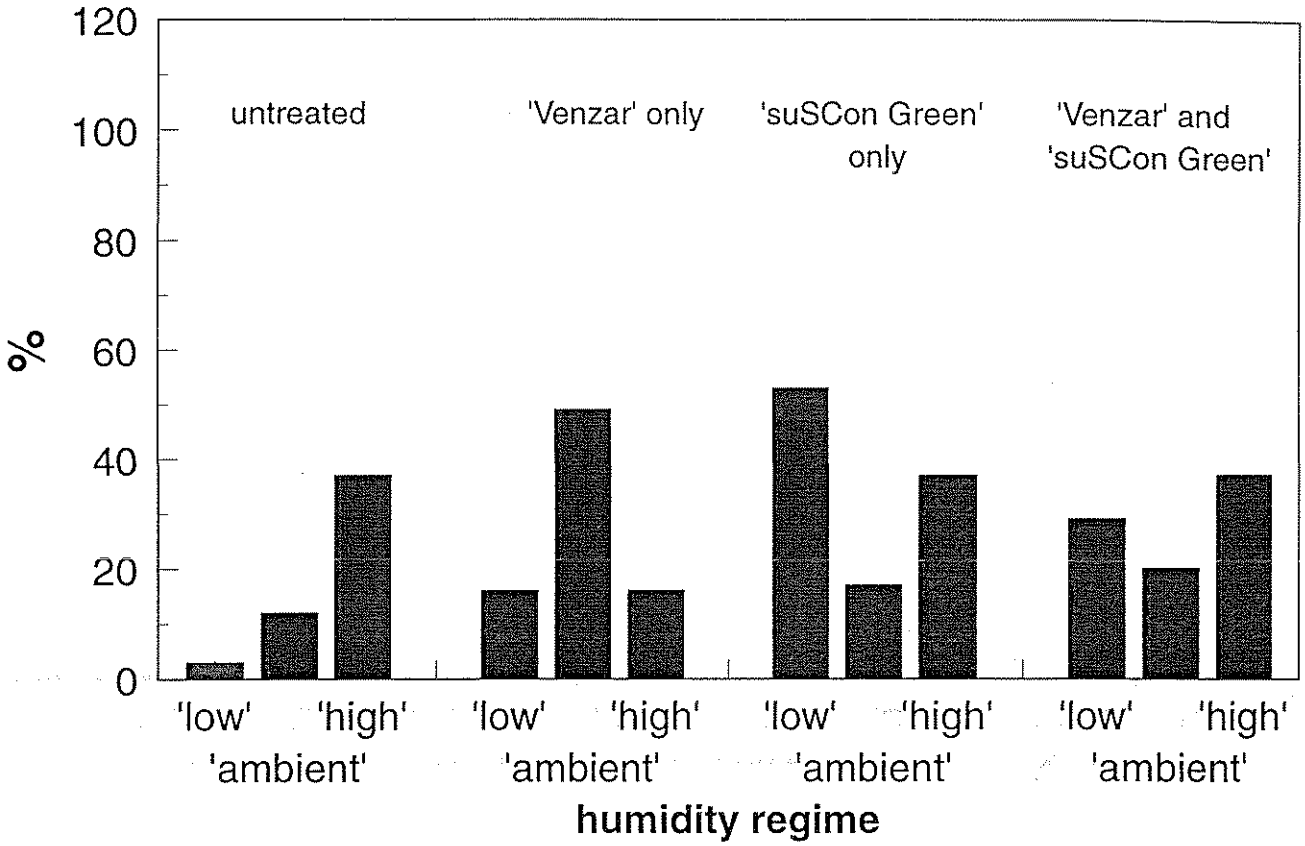


Figure 8: Rhododendron 'El Camino' gravel bed with overhead irrigation

% plants at growth stages 3-5

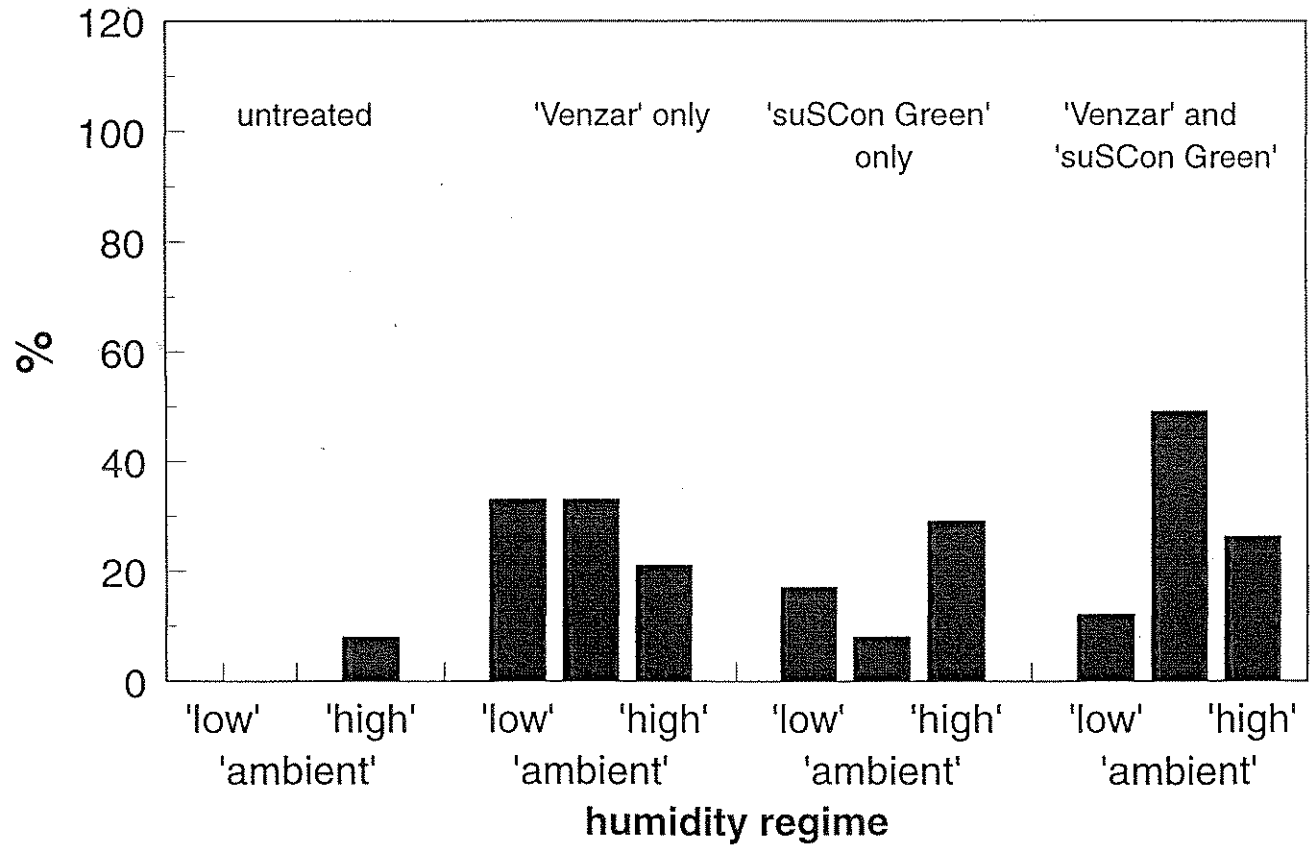


Table 11: ***Rhododendron*** **'El Camino': percentage pots with no weeds, moss or liverwort, and percentage pots with liverwort**

Treatment	Humidity regime	Growing system	% clean pots	% pots with liverwort
Untreated (no 'Venzar' or 'suSCon Green')	'low'	sand bed with seephose irrigation	6%	17%
	'ambient'		0%	0%
	'high		0%	28%
	'low'	gravel bed with overhead irrigation	11%	50%
	'ambient'		0%	33%
	'high'		0%	17%
'Venzar' only (no 'suSCon Green')	'low'	sand bed with seephose irrigation	83%	0%
	'ambient'		56%	0%
	'high'		56%	11%
	'low'	gravel bed with overhead irrigation	89%	0%
	'ambient'		61%	6%
	'high'		0%	6%
'suSCon Green' only (no 'Venzar')	'low'	sand bed with seephose irrigation	6%	6%
	'ambient'		6%	0%
	'high'		0%	33%
	'low'	gravel bed with overhead irrigation	0%	39%
	'ambient'		0%	33%
	'high'		0%	17%
'Venzar' and 'suSCon Green'	'low'	sand bed with seephose irrigation	83%	0%
	'ambient'		89%	0%
	'high'		50%	6%
	'low'	gravel bed with overhead irrigation	78%	0%
	'ambient'		50%	11%
	'high'		0%	6%

Figure 9: R. 'Gartendirektor Glocker'; sand bed with seephose irrigation
% plants at growth stages 3-5

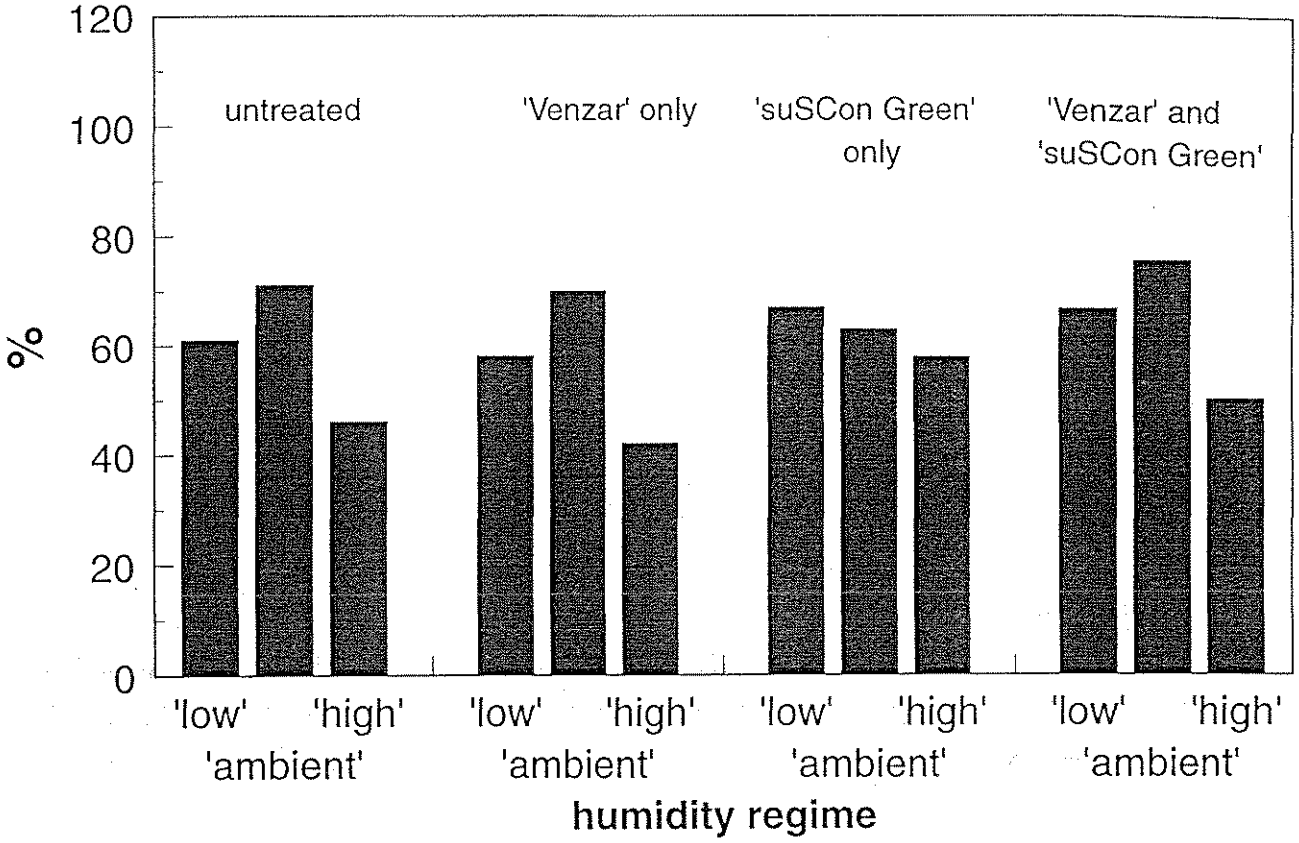


Figure10: R. 'Gartendirektor Glocker'; gravel bed with overhead irrigation
% plants at growth stages 3-5

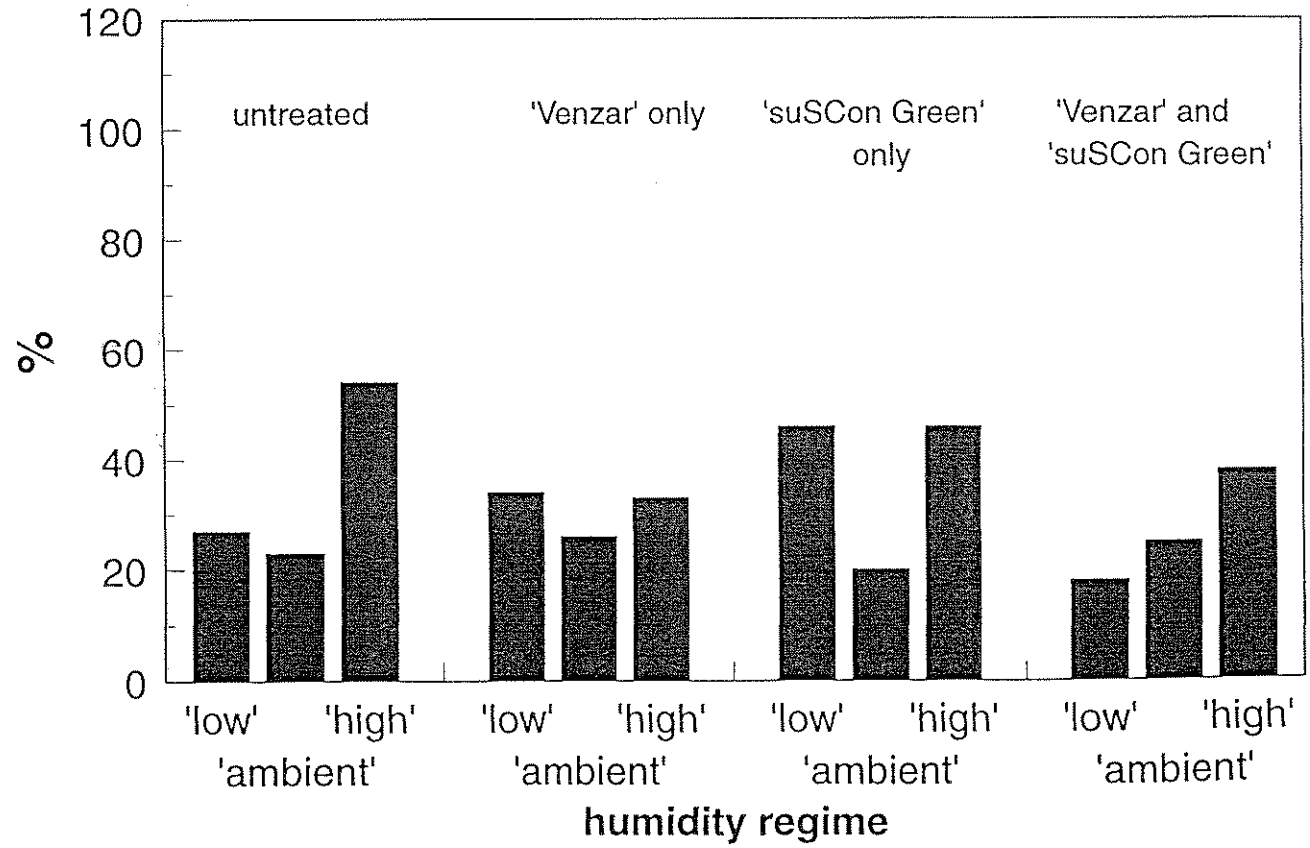


Table 12: ***Rhododendron*** **'Gartendirektor Glocker': percentage pots with no weeds, moss or liverwort, and percentage pots with liverwort**

Treatment	Humidity regime	Growing system	% clean pots	% pots with liverwort
Untreated control (no 'Venzar' or 'suSCon Green')	'low'	sand bed with	22%	0%
	'ambient'	seephose	6%	0%
	'high	irrigation	6%	0%
	'low'	gravel bed with	50%	0%
	'ambient'	overhead	6%	0%
	'high'	irrigation	0%	0%
'Venzar' only (no 'suSCon Green')	'low'	sand bed with	78%	0%
	'ambient'	seephose	94%	0%
	'high'	irrigation	89%	0%
	'low'	gravel bed with	100%	0%
	'ambient'	overhead	94%	0%
	'high'	irrigation	44%	0%
'suSCon Green' only (no 'Venzar')	'low'	sand bed with	6%	0%
	'ambient'	seephose	0%	0%
	'high'	irrigation	0%	0%
	'low'	gravel bed with	6%	11%
	'ambient'	overhead	0%	0%
	'high'	irrigation	6%	0%
'Venzar' and 'suSCon Green'	'low'	sand bed with	83%	0%
	'ambient'	seephose	89%	0%
	'high'	irrigation	83%	0%
	'low'	gravel bed with	72%	0%
	'ambient'	overhead	89%	0%
	'high'	irrigation	33%	0%

DISCUSSION

Work carried out in 1993/94 constituted the second year of investigation into the effect of RH on plant growth. This year the main objective of the trial was to determine the effect of RH on the incidence of disease over the winter and early spring period, together with any interactions of RH with growing systems, and chemicals used for control of vine weevil and weed growth.

The target RHs in the 'low' and 'high' humidity treatments were readily achieved after some initial difficulties with the rented M300 dehumidifier in the 'low' humidity tunnel. The M300 machine is a desiccant wheel type dehumidifier and replaced the DH150 machine used last year. (The DH150 is a refrigerant dehumidifier and the principle of operation does not lend itself well to operation in low air temperatures).

Air temperatures in the three tunnels were very similar, with the Hotbox heaters providing sufficient heat for frost protection. Although heating was not required during the day, the fans in the heaters were left running to give air movement throughout the tunnels. This air movement may have helped to reduce the incidence of disease, although a direct comparison with tunnels without fans would be necessary to prove this. The results obtained from this work relate directly to the RHs recorded. The tunnels used were smaller than many used in the industry, and larger tunnels with a greater air volume may provide lower humidities under similar conditions. This requires investigation, together with the effect of air movement using fans on RH in these larger tunnels, as a potentially cheaper alternative to dehumidification.

The effect of RH on the incidence of disease was obvious. The only disease present on *Hebe* was downy mildew, but black spot and some secondary infection with *Botrytis* occurred on Rose. Since all of these diseases are favoured by high humidity conditions it was not surprising that much lower levels were recorded in the 'low' humidity regime. Downy mildew infections on plants grown in the 'ambient' and 'high' humidity regimes were so severe that the majority of Rose and *Hebe* plants in these tunnels were unmarketable.

No fungicide sprays were applied to Rose in order to monitor the incidence of the disease. However, a range of fungicides for the control of downy mildew on Roses grown out of doors is being evaluated in Project HNS53. The most promising of these materials needs evaluating on plants grown under protection, and any interaction with varying RH determined.

Downy mildew infection began early on *Hebe*. Plants were ready for 'sale' by February, at which time plants in the 'low' humidity regime showed little or no disease, whereas symptoms were obvious to a greater or lesser extent in the other two regimes. At this stage plants were 'stopped' and disease monitored on the subsequent flush of growth. As with Rose, the influence of the 'low' humidity regime on reducing downy mildew was striking, particularly in

combination with the sand bed growing system. The spray programme of 'Aliette' gave some control of downy mildew on *Hebe* in all humidity regimes, but was most effective in the 'low' humidity tunnel where the infection pressure was not so high.

Growing system also influenced the amount of disease present, with overhead irrigation on gravel beds (providing a very damp micro-environment) favouring higher levels of infection. Each bed contained a sand and gravel bed, and although 180° sprinklers were used to avoid 'overspill' onto the adjacent sand bed, it is inevitable that the overhead irrigation applied affected the humidity around the plants on the sand bed to some extent. It is reasonable to suggest that the benefits of growing on sand beds could have been partially masked by the influence of the neighbouring overhead irrigated gravel beds on the localised RH.

In contrast to downy mildews, powdery mildew on Rhododendrons developed to a greater extent in the drier conditions of the 'low' humidity regime. However, this was not observed until late in the spring, by which time plants would normally have moved on into the next phase of production.

No disease occurred on plants of *Cistus*, but the performance of plants of this species was poor overall, irrespective of humidity regime/treatment. The growth of plants of this species appeared to be favoured by conditions of high humidity, but no explanation can be offered for this. Indeed the opposite may have been expected since some species with glaucous foliage do not grow well in humid conditions, especially during the propagation stage. Neither is an explanation readily available for the improved performance of plants treated with 'Venzar' or 'suSCon Green', compared to the untreated control plants.

Previous work in Project HNS15b had shown evidence of phytotoxicity from 'suSCon Green' on some species, e.g. *Hypericum* 'Hidcote'. However, no obvious phytotoxicity symptoms developed on any of the 4 test subjects treated with 'suSCon Green' on either growing system or any of the humidity regimes, indicating that the material appears safe to use at the recommended rate on these species at a relatively early stage of growth.

Similarly 'Venzar' treated plants grew well, with no visual signs of damage. 'Venzar' gave excellent control of weeds and particularly moss, especially on pots grown on sand beds in the 'low' humidity tunnel where admittedly the conditions would not have been particularly favourable for the growth of moss or liverwort, both preferring moist conditions. Liverwort was not a major problem in this trial, but where it did occur (on pots of *Rhododendron* 'El Camino') 'Venzar' gave good though not complete control. 'Venzar' currently carries approval (OLA 0704/93) for use on protected herbs and can therefore be used under protection 'at Growers' Risk' although small scale crop safety tests would be essential before treating large areas.

The cost of installing and running a dehumidification unit capable of servicing a single span tunnel 18m long x 4.2m wide over the winter period are shown below. (Costings kindly supplied by Chris Plackett from Electricity Association Technology Ltd).

Purchase cost:	£3,700*
Average running cost/day:	£1.75
Average annual maintenance costs:	£100

* The capital cost can be depreciated over five years.

Assuming that the equipment is used daily (as required to reduce humidity levels) from the beginning of November to the end of March, annual running costs amount to £263. Although these costs may seem high at face value, when spread across a population of 9cm pots in an 18m x 4.2m tunnel, the cost/plant may not be excessive, particularly bearing in mind savings in fungicides, improvements in plant quality (including a higher percentage of 'Class I' plants) and potential reduction in weeds/moss/liverwort.

Many models of dehumidifier produce heat as a 'by-product' of the dehumidification process and this heat could be used within the tunnel, reducing the cost of additional heating for frost protection. The installation of a dehumidification unit may be worth considering for specialist growers of crops where diseases favoured by high humidity conditions are a major problem, or in areas of the country where humidity levels are especially high over the winter period.

Work is to continue for a third year.

CONCLUSIONS

- Reduction of RH to $<80\%$ resulted in a significant reduction in the incidence of downy mildew and black spot on Rose 'Royal Worcester', and of downy mildew on *Hebe* 'Miss E Fittall'.

- Plants of Rose and *Hebe* grown on seephose irrigated sand beds carried less disease than those grown on overhead irrigated gravel beds.

- 'Aliette' applied at 14 day intervals gave good control of downy mildew on *Hebe* on sand beds in the 'low' and 'ambient' humidity tunnels, but was less effective on plants on 'gravel' beds, especially in the 'high' humidity regime where infection pressure was greater.

- 'Venzar' gave good control of moss and liverwort in 'low' and 'ambient' humidity conditions, but was less effective in the 'high' humidity regime where the environment was more favourable for the growth/spread of these two weeds.

- No obvious signs of phytotoxicity resulted from treatment with 'Venzar' or 'suSCon Green'.

RECOMMENDATIONS FOR FURTHER WORK

- Factors such as plant spacing and foliar feeds, known to have an effect on the spread of certain diseases (e.g. effects of spacing on downy mildew of Rose) require investigation, both in 'ambient' humidities and in combination with dehumidification.

- Work to date has been carried out in relatively small, low tunnels in order to determine the main effects of varying relative humidities. The relative humidities ~~occur~~ within a range of different sized tunnels (containing different volumes of air) need recording, to determine whether dehumidification would be beneficial, or whether air movement using fans (a potentially cheaper alternative) would achieve a similar result.

- An economic appraisal of the use of a dehumidifier is required, taking into account the potential improvements in plant quality.

- Determination of the threshold RHs above which specific diseases become a major problem, with a view to determining the level of dehumidification required.

ACKNOWLEDGEMENTS

Grateful thanks are due to Dr Tim Pettitt (HRI Efford) for his help with disease identification, and for his guidance in defining the assessment categories for the various diseases.

APPENDIX I

Plate 1: Layout of species within polythene tunnel; sand bed with seephose irrigation on left and gravel bed with overhead irrigation on the right (*Photograph taken late January 1994*)

Plate 2: Rose 'Royal Worcester': close-up of foliage on plants grown in 'low' humidity regime (*photograph taken late April 1994*)

LHS plants grown on sand bed with seephose irrigation

RHS plants grown on gravel bed with overhead irrigation (note deposit on leaves)

Plate 3: Rose 'Royal Worcester' on sand bed in 'low' humidity tunnel (*photograph taken late April 1994*)

Plate 4: Rose 'Royal Worcester' on gravel bed in 'low' humidity tunnel (*photograph taken late April 1994*)

Note inferior plant quality compared to Plate 3

Plate 5: Rose 'Royal Worcester' on sand bed in 'high' humidity tunnel (*photograph taken late April 1994*)

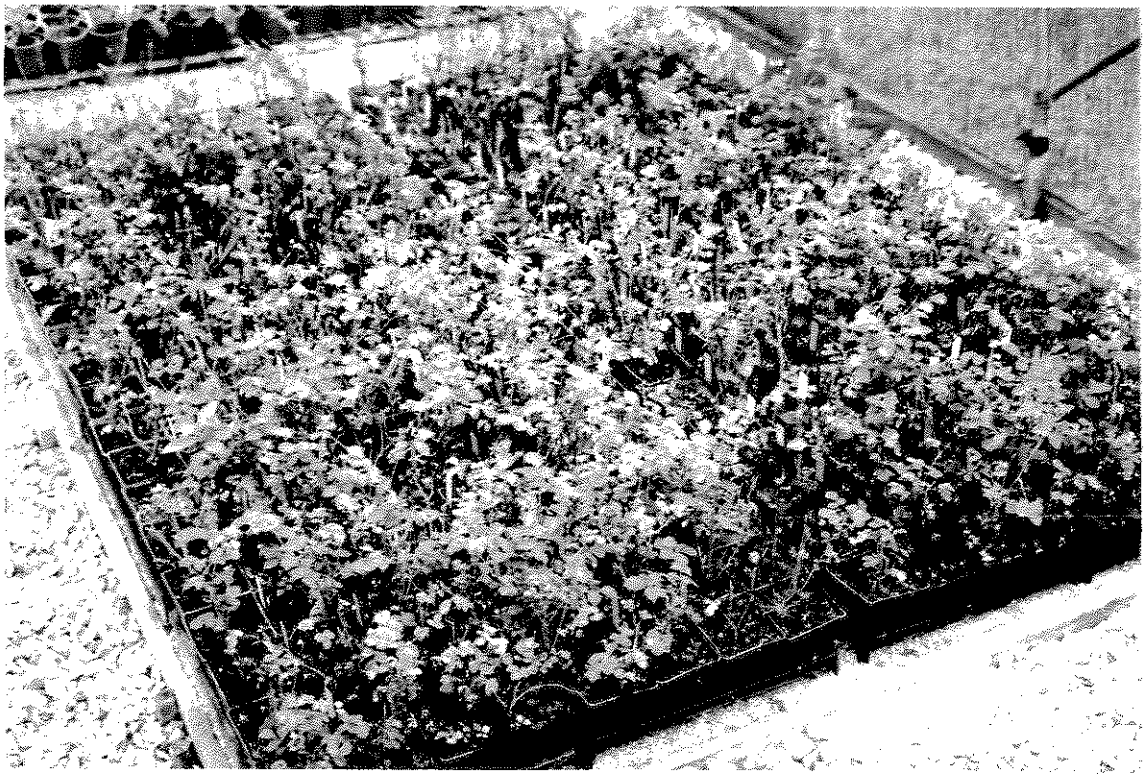


Plate 6: Rose 'Royal Worcester' on gravel bed in 'high' humidity tunnel (*photograph taken late April 1994*)

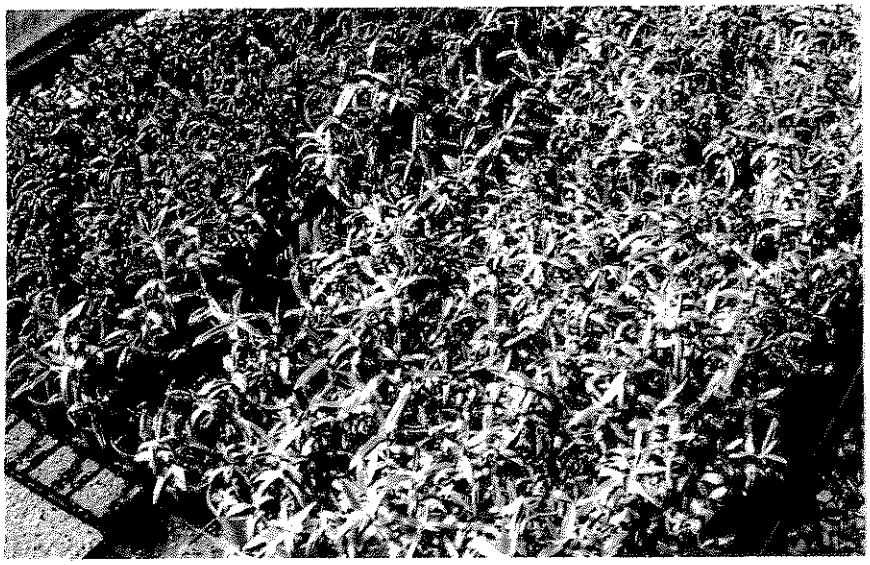
Plate 7: Rose 'Royal Worcester', typical plant from gravel bed in 'high' humidity tunnel (*photograph taken late April 1994*)

Plate 8: Rose 'Royal Worcester, typical plant from gravel bed in 'high' humidity tunnel (*photograph taken late April 1994*)

COMMERCIAL – IN CONFIDENCE

Plate 9: *Hebe* 'Miss E Fittall', plants grown on sand beds with seephose irrigation *(photograph taken 10 March 1994)*

'low' humidity tunnel

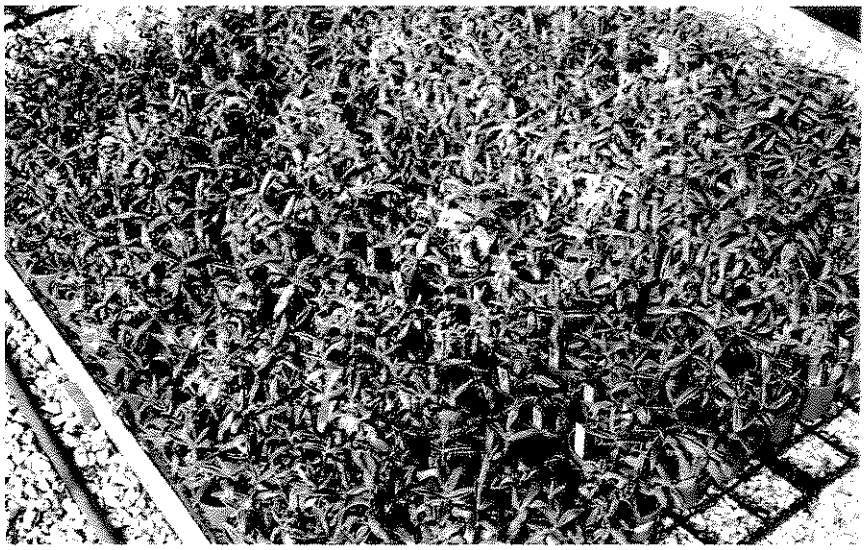


'ambient' humidity tunnel

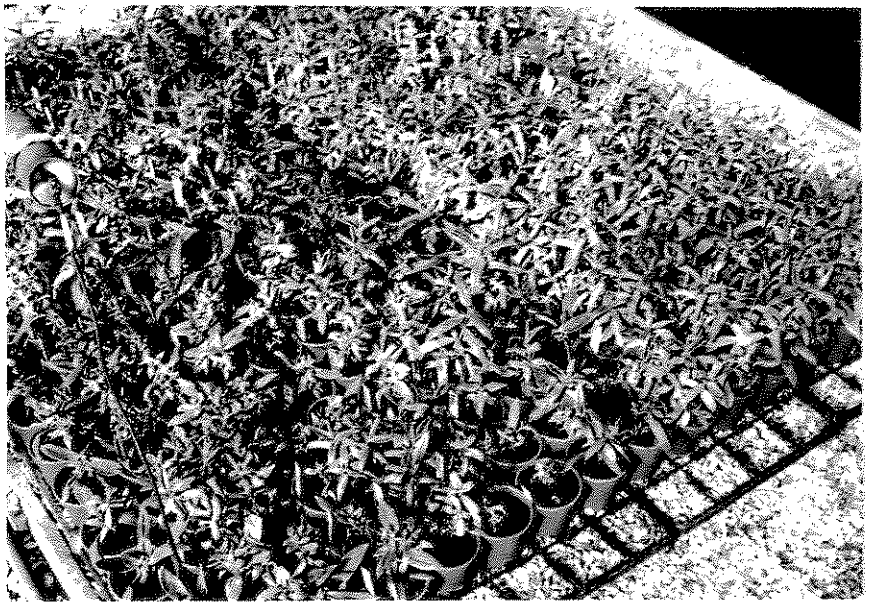
'high' humidity tunnel

Plate 10: *Hebe* 'Miss E Fittall', plants grown on gravel beds with overhead irrigation (*photograph taken 10 March 1994*)

'low' humidity tunnel



'ambient' humidity tunnel



'high' humidity tunnel

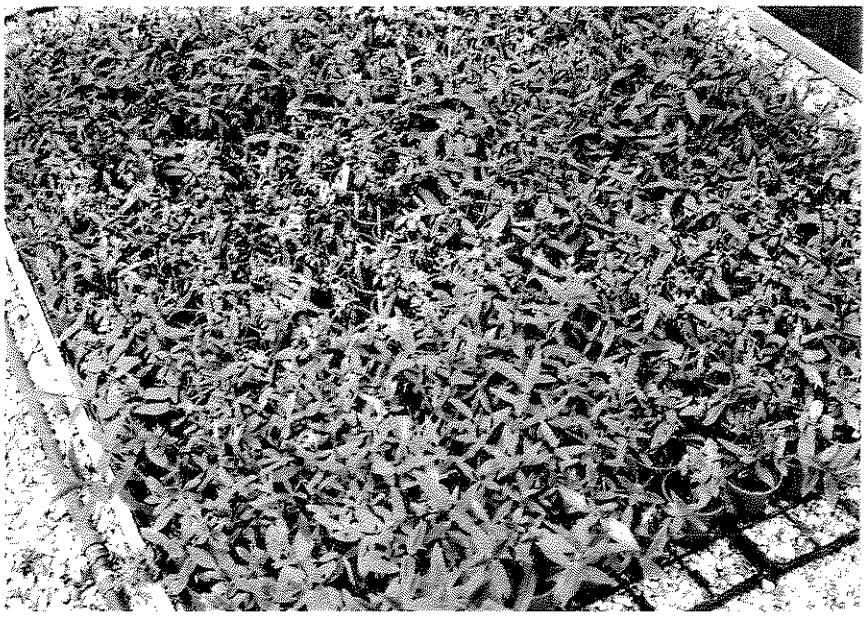
Plate 11: *Hebe* 'Miss E Fittall', plants grown on sand beds with seephose irrigation; showing sprayed and unsprayed replicates (*photograph taken 4 May 1994*)

'low' humidity tunnel

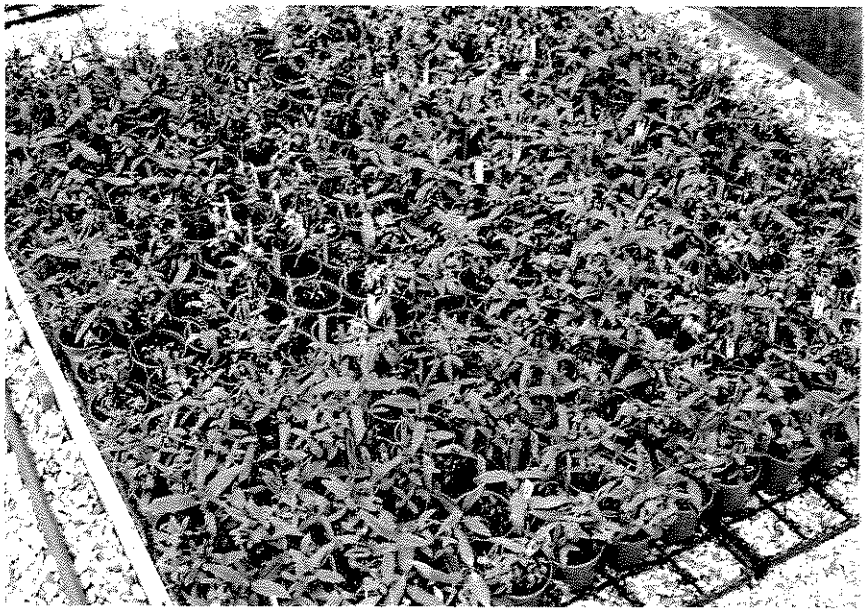
'ambient' humidity tunnel

'high' humidity tunnel

Plate 12: *Hebe* 'Miss E Fittall', plants grown on gravel beds with overhead irrigation, showing sprayed and unsprayed replicates (*photograph taken 4 May 1994*)



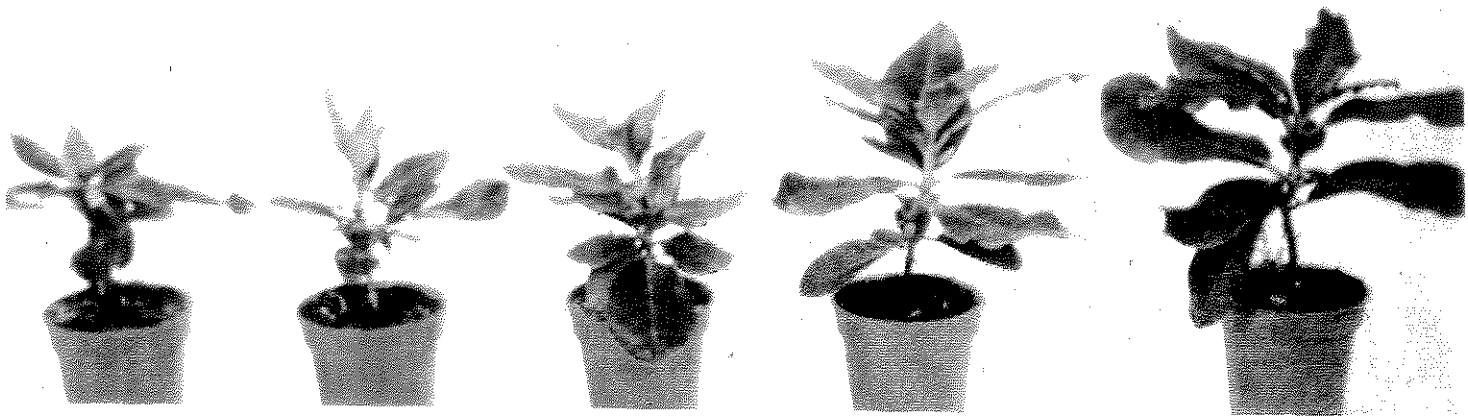
'low' humidity tunnel



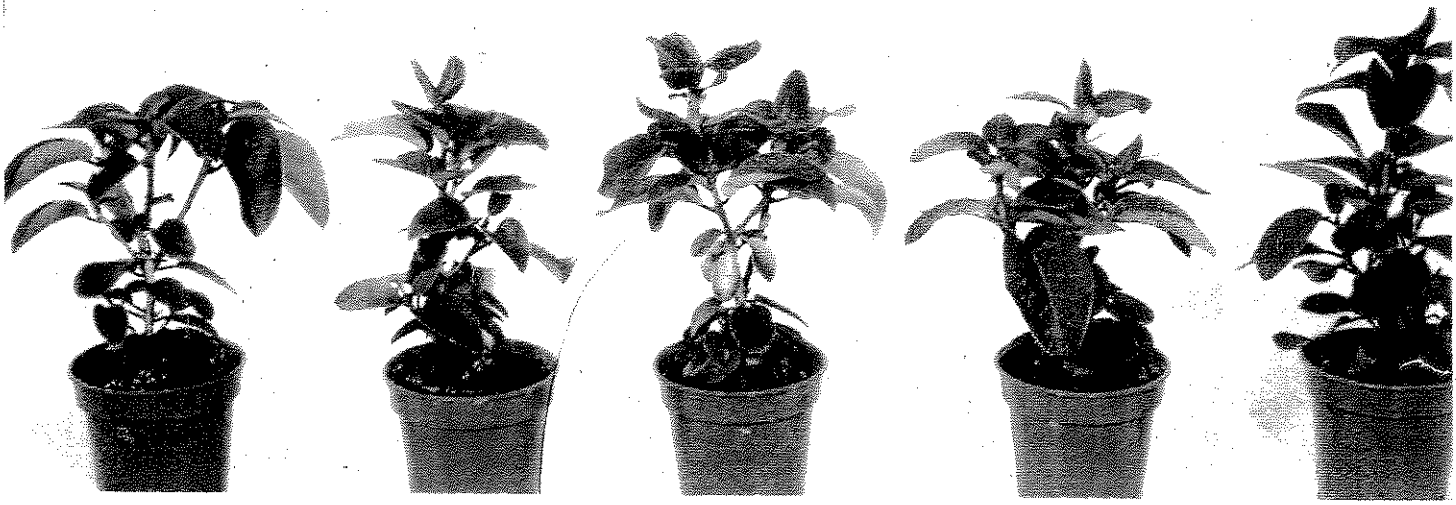
'ambient' humidity tunnel

'high' humidity tunnel

Plate 13: Growth stages of *Rhododendron*, from left to right 1-5
Below: *R.* 'El Camino'



Below: *R.* 'Gartendirektor Glocker'



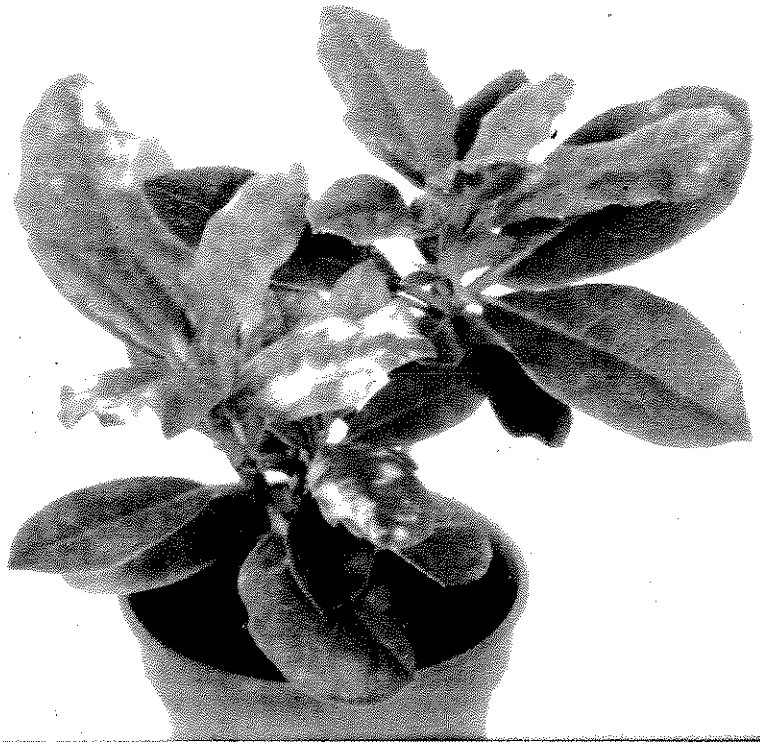


Plate 14: Powdery mildew infection on plants of *R.* 'El Camino' grown in 'low' humidity regime

APPENDIX II

Table 13: Rose 'Royal Worcester'; sand bed with seephose irrigation; % plant survival and marketability, % leaf drop and leaf spotting

Treatment	Humidity regime	% plants				% leaf drop (% plants in each category)					Leaf spotting			
		marketable	unmarketable	dying	dead	Nil	<25%	25-50%	50-75%	>75%	Nil	Slight	Moderate	Severe
Untreated control (no 'Venzar')	'low'	69%	20%	0%	11%	94%	6%	0%	0%	0%	100%	0%	0%	0%
	'ambient'	3%	67%	0%	30%	4%	60%	28%	8%	0%	0%	40%	56%	4%
	'high'	0%	31%	25%	44%	0%	40%	20%	10%	30%	10%	30%	45%	15%
'Venzar' at 1.4g/10m²	'low'	63%	15%	0%	22%	100%	0%	0%	0%	0%	100%	0%	0%	0%
	'ambient'	8%	63%	0%	29%	4%	66%	18%	12%	0%	10%	41%	37%	12%
	'high'	3%	43%	32%	22%	0%	41%	20%	11%	28%	3%	54%	23%	20%
'Venzar' at 2.8g/10m²	'low'	56%	25%	0%	19%	100%	0%	0%	0%	0%	100%	0%	0%	0%
	'ambient'	0%	64%	0%	36%	0%	65%	30%	5%	0%	13%	48%	26%	13%
	'high'	0%	41%	28%	31%	0%	36%	24%	12%	28%	4%	40%	36%	20%

Table 14: Rose 'Royal Worcester'; gravel bed with overhead irrigation; % plant survival and marketability, % leaf drop and % leaf spotting

Treatment	Humidity regime	% plants				% leaf drop (% plants in each category)					Leaf spotting			
		marketable	unmarketable	dying	dead	Nil	<25%	25-50%	50-75%	>75%	Nil	Slight	Moderate	Severe
Untreated control (no 'Venzar')	'low'	72%	20%	0%	8%	97%	3%	0%	0%	0%	79%	21%	0%	0%
	'ambient'	0%	47%	0%	53%	0%	12%	35%	29%	24%	0%	53%	12%	35%
	'high'	0%	6%	50%	44%	0%	0%	5%	15%	80%	5%	40%	25%	30%
'Venzar' at 1.4g/10m²	'low'	68%	24%	0%	8%	89%	11%	0%	0%	0%	73%	27%	0%	0%
	'ambient'	0%	61%	0%	39%	0%	14%	27%	36%	23%	13%	25%	37%	25%
	'high'	0%	9%	40%	51%	0%	0%	8%	23%	69%	0%	31%	31%	38%
'Venzar' at 2.8g/10m²	'low'	69%	12%	0%	19%	90%	10%	0%	0%	0%	72%	28%	0%	0%
	'ambient'	0%	70%	0%	30%	0%	20%	36%	24%	20%	12%	12%	36%	40%
	'high'	0%	6%	69%	25%	0%	0%	7%	15%	78%	18%	26%	30%	26%

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Table 15: ***Hebe*** **'Miss E Fittall': Disease assessments on 'young' and 'old' growth and vigour scores of untreated 'control' plants (i.e. no 'Venzar' and no 'suSCon Green')**

Humidity regime	Growing system	Disease score on first flush or 'old' growth (% plants in each category)				Disease score on new flush of growth (% plants in each category)					Vigour score (% plants in each category)					
		Slight	Mod	Mod-Severe	Severe	Nil	Slight	Mod	Mod-Severe	Severe	Dead	1	2	3	4	5
No disease control sprays applied																
'low'	sand bed with	0%	6%	28%	66%	0%	33%	56%	0%	11%	0%	11%	17%	33%	33%	6%
'ambient'	seephose	0%	0%	7%	93%	0%	0%	0%	13%	87%	17%	55%	22%	0%	6%	0%
'high'	irrigation	0%	0%	7%	93%	0%	0%	0%	20%	80%	17%	50%	17%	16%	0%	0%
'low'	gravel bed with	0%	12%	12%	76%	0%	0%	29%	59%	12%	6%	11%	55%	22%	6%	0%
'ambient'	overhead	0%	0%	0%	100%	0%	0%	0%	13%	87%	11%	72%	17%	0%	0%	0%
'high'	irrigation	0%	0%	13%	87%	0%	0%	0%	50%	50%	11%	61%	28%	0%	0%	0%
Disease control programme applied																
'low'	sand bed with	0%	39%	22%	39%	44%	56%	0%	0%	0%	0%	0%	0%	6%	22%	72%
'ambient'	seephose	0%	0%	11%	89%	0%	17%	72%	11%	0%	0%	0%	6%	22%	61%	11%
'high'	irrigation	0%	0%	22%	78%	0%	39%	50%	11%	0%	0%	0%	22%	28%	44%	6%
'low'	gravel bed with	17%	22%	44%	17%	33%	61%	6%	0%	0%	0%	0%	0%	17%	50%	33%
'ambient'	overhead	0%	18%	18%	64%	0%	29%	59%	12%	0%	6%	11%	22%	33%	28%	0%
'high'	irrigation	0%	6%	12%	82%	6%	29%	41%	12%	12%	6%	17%	16%	28%	33%	0%

Disease score:
- Slight: <10% leaves affected
- Moderate: 10-50% leaves affected
- Moderately severe: 50-75% leaves affected
- Severe: 75-100% leaves affected

Vigour score:
- 1: 1 or 2 weak spindly shoots growing away, virtually all leaves shed from old growth
- 2: 3 or more weak shoots growing away, a few leaves remaining on old growth
- 3: 1-5 shoots growing away with moderate vigour
- 4: >5 shoots growing away with moderate vigour
- 5: >5 shoots growing away vigorously

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Table 16: *Hebe* **'Miss E Fittall': Disease assessments on 'young' and 'old' growth and vigour scores of plants treated with 'Venzar' (no 'suSCon Green')**

Humidity regime	Growing system	Disease score on first flush or 'old' growth (% plants in each category)					Disease score on new flush of growth (% plants in each category)				Vigour score (% plants in each category)					
		Slight	Mod	Mod-Severe	Severe	Nil	Slight	Mod	Mod-Severe	Severe	Dead	1	2	3	4	5
No disease control sprays applied																
'low'	sand bed with	0%	17%	39%	44%	5%	33%	28%	28%	6%	0%	5%	17%	39%	39%	0%
'ambient'	seephose	0%	0%	6%	94%	0%	0%	6%	35%	59%	6%	22%	39%	27%	6%	0%
'high'	irrigation	0%	0%	0%	100%	0%	0%	0%	27%	73%	39%	28%	22%	11%	0%	0%
'low'	gravel bed with	0%	6%	25%	59%	0%	6%	19%	62%	13%	12%	22%	44%	22%	0%	0%
'ambient'	overhead	0%	0%	0%	100%	0%	0%	0%	31%	69%	11%	78%	11%	0%	0%	0%
'high'	irrigation	0%	0%	13%	87%	0%	0%	0%	47%	53%	17%	61%	22%	0%	0%	0%
Disease control programme applied																
'low'	sand bed with	0%	28%	50%	22%	33%	67%	0%	0%	0%	0%	0%	0%	6%	28%	66%
'ambient'	seephose	0%	6%	29%	65%	0%	41%	35%	24%	0%	6%	0%	17%	28%	38%	11%
'high'	irrigation	0%	0%	17%	83%	0%	67%	33%	0%	0%	0%	0%	5%	28%	50%	17%
'low'	gravel bed with	0%	11%	39%	50%	11%	67%	22%	0%	0%	0%	0%	0%	5%	50%	45%
'ambient'	overhead	0%	0%	13%	87%	0%	44%	44%	12%	0%	11%	5%	22%	33%	29%	0%
'high'	irrigation	0%	22%	11%	67%	0%	22%	61%	17%	0%	0%	17%	28%	28%	22%	5%

Disease score:
- Slight: <10% leaves affected
- Moderate: 10-50% leaves affected
- Moderately severe: 50-75% leaves affected
- Severe: 75-100% leaves affected

Vigour score:
- 1: 1 or 2 weak spindly shoots growing away, virtually all leaves shed from old growth
- 2: 3 or more weak shoots growing away, a few leaves remaining on old growth
- 3: 1-5 shoots growing away with moderate vigour
- 4: >5 shoots growing away with moderate vigour
- 5: >5 shoots growing away vigorously

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Table 17: *Hebe* **'Miss E Fittall': Disease assessments on 'young' and 'old' growth and vigour scores of plants treated with 'suSCon Green' (no 'Venzar')**

Humidity regime	Growing system	Disease score on first flush or 'old' growth (% plants in each category)					Disease score on new flush of growth (% plants in each category)				Vigour score (% plants in each category)					
		Slight	Mod	Mod-Severe	Severe	Nil	Slight	Mod	Mod-Severe	Severe	Dead	1	2	3	4	5
No disease control sprays applied																
'low'	sand bed with	0%	18%	41%	41%	6%	24%	53%	12%	5%	6%	0%	22%	44%	17%	11%
'ambient'	seephose	0%	0%	6%	94%	0%	6%	0%	28%	66%	0%	39%	56%	5%	0%	0%
'high'	irrigation	0%	0%	27%	73%	0%	0%	0%	13%	87%	17%	55%	17%	11%	0%	0%
'low'	gravel bed with	0%	33%	28%	39%	0%	17%	33%	39%	11%	0%	11%	50%	28%	11%	0%
'ambient'	overhead	0%	0%	0%	100%	0%	0%	0%	35%	65%	6%	61%	33%	0%	0%	0%
'high'	irrigation	0%	0%	50%	50%	8%	0%	8%	50%	34%	33%	56%	11%	0%	0%	0%
Disease control programme applied																
'low'	sand bed with	0%	39%	17%	44%	39%	61%	0%	0%	0%	0%	0%	0%	22%	28%	50%
'ambient'	seephose	0%	0%	35%	65%	0%	29%	65%	6%	0%	6%	0%	22%	61%	11%	0%
'high'	irrigation	0%	0%	23%	77%	0%	53%	41%	6%	0%	6%	6%	22%	16%	44%	6%
'low'	gravel bed with	0%	11%	56%	33%	22%	72%	6%	0%	0%	0%	0%	0%	22%	50%	28%
'ambient'	overhead	0%	6%	23%	71%	0%	29%	59%	12%	0%	6%	5%	6%	33%	50%	0%
'high'	irrigation	0%	0%	12%	88%	6%	23%	59%	6%	6%	6%	16%	22%	28%	28%	0%

Disease score:
- Slight: <10% leaves affected
- Moderate: 10-50% leaves affected
- Moderately severe: 50-75% leaves affected
- Severe: 75-100% leaves affected

Vigour score:
- 1: 1 or 2 weak spindly shoots growing away, virtually all leaves shed from old growth
- 2: 3 or more weak shoots growing away, a few leaves remaining on old growth
- 3: 1-5 shoots growing away with moderate vigour
- 4: >5 shoots growing away with moderate vigour
- 5: >5 shoots growing away vigorously

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Table 18: *Hebe* **'Miss E Fittall': Disease assessments on 'young' and 'old' growth and vigour scores of plants treated with 'Venzar' and 'suSCon Green'**

Humidity regime	Growing system	Disease score on first flush or 'old' growth (% plants in each category)					Disease score on new flush of growth (% plants in each category)					Vigour score (% plants in each category)					
		Slight	Mod	Mod-Severe	Severe	Nil	Slight	Mod	Mod-Severe	Severe	Dead	1	2	3	4	5
No disease control sprays applied																	
'low'	sand bed with	0%	18%	23%	59%	18%	18%	46%	18%	0%	6%	5%	28%	44%	17%	0%
'ambient'	seephose	0%	0%	6%	94%	0%	0%	12%	18%	70%	6%	44%	44%	0%	6%	0%
'high'	irrigation	0%	0%	0%	100%	0%	0%	0%	36%	64%	39%	39%	17%	5%	0%	0%
'low'	gravel bed with	0%	0%	13%	87%	0%	0%	20%	47%	33%	17%	28%	50%	5%	0%	0%
'ambient'	overhead	0%	6%	13%	81%	0%	0%	13%	13%	74%	11%	67%	22%	0%	0%	0%
'high'	irrigation	0%	0%	17%	83%	0%	0%	17%	25%	58%	33%	61%	6%	0%	0%	0%
Disease control programme applied																	
'low'	sand bed with	6%	22%	17%	55%	11%	83%	6%	0%	0%	0%	0%	0%	22%	39%	39%
'ambient'	seephose	0%	0%	0%	100%	0%	12%	70%	18%	0%	6%	6%	11%	22%	44%	11%
'high'	irrigation	0%	0%	11%	89%	0%	33%	67%	0%	0%	0%	0%	6%	44%	44%	6%
'low'	gravel bed with	0%	17%	44%	39%	28%	50%	22%	0%	0%	0%	0%	0%	39%	39%	22%
'ambient'	overhead	0%	0%	6%	94%	0%	39%	55%	6%	0%	0%	0%	17%	22%	55%	6%
'high'	irrigation	0%	12%	38%	50%	0%	44%	50%	0%	6%	11%	5%	28%	17%	33%	6%

Disease score:
- Slight: <10% leaves affected
- Moderate: 10-50% leaves affected
- Moderately severe: 50-75% leaves affected
- Severe: 75-100% leaves affected

Vigour score:
- 1: 1 or 2 weak spindly shoots growing away, virtually all leaves shed from old growth
- 2: 3 or more weak shoots growing away, a few leaves remaining on old growth
- 3: 1-5 shoots growing away with moderate vigour
- 4: >5 shoots growing away with moderate vigour
- 5: >5 shoots growing away vigorously

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Table 19: ***Hebe*** **'Miss E Fittall': Percentage plants with vigour scores of 3-5, summarised according to treatment**

Humidity regime	Growing system	Untreated control (no 'Venzar' or 'suSCon Green')	'Venzar' only (no 'suSCon Green')	'suSCon Green' only (no 'Venzar')	'Venzar' and 'suSCon Green'
No disease control sprays applied					
'low'	sand bed with	72%	78%	72%	61%
'ambient'	seephose	6%	33%	5%	6%
'high'	irrigation	16%	11%	11%	5%
'low'	gravel bed with	22%	22%	39%	5%
'ambient'	overhead	0%	0%	0%	0%
'high'	irrigation	0%	0%	0%	0%
Disease control programme applied					
'low'	sand bed with	100%	100%	100%	100%
'ambient'	seephose	94%	77%	72%	77%
'high'	irrigation	78%	95%	66%	94%
'low'	gravel bed with	100%	100%	100%	100%
'ambient'	overhead	61%	62%	83%	83%
'high'	irrigation	61%	55%	56%	56%

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Table 20: ***Rhododendron*** **'El Camino': Disease assessments on 'young' and 'old' growth on untreated control plants (i.e. not treated with 'Venzar' or 'suSCon Green')**

Humidity regime	Growing system	Powdery mildew infection on old leaves underside Nil	1-25%	25-50%	50-75%	75-100%	top surface	Powdery mildew infection on young leaves underside Nil	1-25%	25-50%	50-75%	75-100%	top surface Nil	1-25%
No disease control sprays applied														
'low'	sand bed	0%	0%	0%	8%	92%	20%	0%	100%	0%	0%	0%	100%	0%
'ambient'	with seephose	0%	8%	0%	42%	50%	15%	100%	0%	0%	0%	0%	100%	0%
'high'	irrigation	8%	92%	0%	0%	0%	1%	100%	0%	0%	0%	0%	100%	0%
'low'	gravel bed	8%	92%	0%	0%	0%	6%	NA	NA	NA	NA	NA	NA	NA
'ambient'	with overhead	0%	0%	25%	25%	50%	13%	NA	NA	NA	NA	NA	NA	NA
'high'	irrigation	25%	75%	0%	0%	0%	0%	NA	NA	NA	NA	NA	NA	NA
Disease control programme applied														
'low'	sand bed	0%	0%	17%	0%	83%	22%	NA	NA	NA	NA	NA	NA	NA
'ambient'	with seephose	50%	50%	0%	0%	0%	2%	100%	0%	0%	0%	0%	100%	0%
'high'	irrigation	67%	33%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%
'low'	gravel bed	83%	17%	0%	0%	0%	0%	NA	NA	NA	NA	NA	NA	NA
'ambient'	with overhead	17%	83%	0%	0%	0%	0%	NA	NA	NA	NA	NA	NA	NA
'high'	irrigation	33%	67%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%

NA: Not applicable

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Table 21: *Rhododendron* **'El Camino': Disease assessments on 'young' and 'old' growth on plants treated with 'Venzar' (no 'suSCon Green')**

Humidity regime	Growing system	Powdery mildew infection on old leaves						Powdery mildew infection on young leaves					
			underside				top		underside				top
		Nil	1-25%	25-50%	50-75%	75-100%	surface	Nil	1-25%	25-50%	50-75%	75-100%	surface
No disease control sprays applied													
'low'	sand bed	0%	0%	17%	17%	66%	27%	100%	0%	0%	0%	0%	50%
'ambient'	with seephose	0%	0%	17%	33%	50%	20%	75%	0%	25%	0%	0%	0%
'high'	irrigation	17%	83%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%
'low'	gravel bed	34%	50%	8%	8%	0%	4%	100%	0%	0%	0%	0%	0%
'ambient'	with overhead	0%	8%	33%	17%	42%	0%	100%	0%	0%	0%	0%	0%
'high'	irrigation	8%	92%	0%	0%	0%	<1%	100%	0%	0%	0%	0%	0%
Disease control programme applied													
'low'	sand bed	0%	0%	0%	0%	100%	22%	0%	100%	0%	0%	0%	10%
'ambient'	with seephose	50%	33%	17%	0%	0%	0%	100%	0%	0%	0%	0%	0%
'high'	irrigation	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%
'low'	gravel bed	67%	33%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%
'ambient'	with overhead	83%	17%	0%	0%	0%	1%	100%	0%	0%	0%	0%	0%
'high'	irrigation	50%	50%	0%	0%	0%	<1%	100%	0%	0%	0%	0%	0%

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Table 22: ***Rhododendron*** **'El Camino': Disease assessments on 'young' and 'old' growth on plants treated with 'suSCon Green' only (no 'Venzar')**

Humidity regime	Growing system	Powdery mildew infection on old leaves						Powdery mildew infection on young leaves						
		underside					top surface	underside					top surface	
		Nil	1-25%	25-50%	50-75%	75-100%		Nil	1-25%	25-50%	50-75%	75-100%	Nil	1-25%
No disease control sprays applied														
'low'	sand bed	0%	0%	9%	16%	75%	24%	20%	80%	0%	0%	0%	40%	60%
'ambient'	with seephose	0%	9%	9%	25%	57%	13%	75%	25%	0%	0%	0%	75%	25%
'high'	irrigation	17%	83%	0%	0%	0%	<1%	100%	0%	0%	0%	0%	100%	0%
'low'	gravel bed	67%	33%	0%	0%	0%	5%	100%	0%	0%	0%	0%	100%	0%
'ambient'	with overhead	0%	8%	17%	25%	50%	7%	100%	0%	0%	0%	0%	100%	0%
'high'	irrigation	42%	58%	0%	0%	0%	1%	100%	0%	0%	0%	0%	100%	0%
Disease control programme applied														
'low'	sand bed	0%	0%	0%	0%	100%	12%	50%	50%	0%	0%	0%	50%	50%
'ambient'	with seephose	0%	100%	0%	0%	0%	0%	NA	NA	NA	NA	NA	NA	NA
'high'	irrigation	67%	33%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%
'low'	gravel bed	67%	33%	0%	0%	0%	2%	100%	0%	0%	0%	0%	100%	0%
'ambient'	with overhead	0%	100%	0%	0%	0%	1%	NA	NA	NA	NA	NA	NA	NA
'high'	irrigation	33%	67%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%

NA: Not applicable

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Table 23: *Rhododendron* **'El Camino': Disease assessments on 'young' and 'old' growth on plants treated with 'Venzar' and 'suSCon Green'**

Humidity regime	Growing system	Powdery mildew infection on old leaves						Powdery mildew infection on young leaves							
		underside					top surface	underside					top surface		
		Nil	1-25%	25-50%	50-75%	75-100%		Nil	1-25%	25-50%	50-75%	75-100%	Nil	1-25%	25-50%
No disease control sprays applied															
'low'	sand bed	0%	0%	17%	8%	75%	13%	100%	0%	0%	0%	0%	67%	33%	0%
'ambient'	with seephose	0%	0%	9%	33%	58%	19%	80%	20%	0%	0%	0%	80%	20%	0%
'high'	irrigation	25%	75%	0%	0%	0%	<1%	100%	0%	0%	0%	0%	100%	0%	0%
'low'	gravel bed	0%	100%	0%	0%	0%	6%	100%	0%	0%	0%	0%	100%	0%	0%
'ambient'	with overhead	0%	9%	9%	16%	66%	17%	38%	25%	25%	12%	0%	63%	12%	25%
'high'	irrigation	8%	92%	0%	0%	0%	<1%	100%	0%	0%	0%	0%	100%	0%	0%
Disease control programme applied															
'low'	sand bed	0%	0%	0%	0%	100%	33%	0%	100%	0%	0%	0%	0%	0%	100%
'ambient'	with seephose	0%	83%	17%	0%	0%	1%	NA	NA	NA	NA	NA	NA	NA	NA
'high'	irrigation	17%	83%	0%	0%	0%	<1%	100%	0%	0%	0%	0%	100%	0%	0%
'low'	gravel bed	83%	17%	0%	0%	0%	<1%	100%	0%	0%	0%	0%	100%	0%	0%
'ambient'	with overhead	0%	66%	17%	17%	0%	3%	100%	0%	0%	0%	0%	100%	0%	0%
'high'	irrigation	67%	33%	0%	0%	0%	2%	100%	0%	0%	0%	0%	100%	0%	0%

NA: Not applicable

COMMERCIAL – IN CONFIDENCE

Table 24: ***Rhododendron*** **'El Camino': Growth stage assessments summarised according to treatment**

Treatment	Humidity regime	Growing system	Growth stage* (% plants in each category) 1	2	3	4	5
Untreated control (no 'Venzar' or 'suSCon Green')	'low'	sand bed with	55%	42%	3%	0%	0%
	'ambient'	seephose	30%	58%	8%	4%	0%
	'high'	irrigation	59%	4%	9%	8%	20%
	'low'	gravel bed with	80%	20%	0%	0%	0%
	'ambient'	overhead	70%	30%	0%	0%	0%
	'high'	irrigation	75%	17%	0%	0%	8%
'Venzar' only (no 'suSCon Green')	'low'	sand bed with	46%	38%	0%	8%	8%
	'ambient'	seephose	21%	30%	41%	8%	0%
	'high'	irrigation	46%	38%	12%	4%	0%
	'low'	gravel bed with	59%	8%	4%	0%	29%
	'ambient'	overhead	46%	21%	4%	8%	21%
	'high'	irrigation	75%	4%	4%	8%	9%
'suSCon Green' only (no 'Venzar')	'low'	sand bed with	34%	13%	4%	16%	33%
	'ambient'	seephose	63%	20%	12%	5%	0%
	'high'	irrigation	38%	25%	8%	4%	25%
	'low'	gravel bed with	66%	17%	4%	13%	0%
	'ambient'	overhead	54%	38%	8%	0%	0%
	'high'	irrigation	63%	8%	20%	4%	5%
'Venzar' and 'suSCon Green'	'low'	sand bed with	30%	41%	20%	4%	5%
	'ambient'	seephose	42%	38%	16%	4%	0%
	'high'	irrigation	42%	21%	4%	13%	20%
	'low'	gravel bed with	79%	9%	8%	4%	0%
	'ambient'	overhead	38%	13%	16%	0%	33%
	'high'	irrigation	62%	12%	9%	0%	17%

* See Plate 13, page 45

Table 25: *Rhododendron* **'Gartendirektor Glocker': Disease assessments on 'young' and 'old' growth on 'control plants' (i.e. no 'Venzar' or 'suSCon Green')**

Humidity regime	Growing system	Powdery mildew infection on old leaves						Powdery mildew infection on young leaves						
			underside				top surface		underside				top surface	
		Nil	1-25%	25-50%	50-75%	75-100%		Nil	1-25%	25-50%	50-75%	75-100%	Nil	1-25%
No disease control sprays applied														
'low'	sand bed	33%	67%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%
'ambient'	with seephose	58%	42%	0%	0%	0%	0%	56%	44%	0%	0%	0%	100%	0%
'high'	irrigation	66%	34%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%
'low'	gravel bed	83%	17%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%
'ambient'	with overhead	67%	33%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%
'high'	irrigation	42%	58%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%
Disease control programme applied														
'low'	sand bed	50%	50%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%
'ambient'	with seephose	83%	17%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%
'high'	irrigation	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%
'low'	gravel bed	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%
'ambient'	with overhead	60%	40%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%
'high'	irrigation	100%	0%	0%	0%	0%	6%	100%	0%	0%	0%	0%	100%	0%

COMMERCIAL – IN CONFIDENCE

Table 26: *Rhododendron* **'Gartendirektor Glocker': Disease assessments on 'young' and 'old' growth on plants treated with 'Venzar' (no 'suSCon Green')**

Humidity regime	Growing system	Powdery mildew infection on old leaves underside					top surface	Powdery mildew infection on young leaves underside					top surface	
		Nil	1-25%	25-50%	50-75%	75-100%		Nil	1-25%	25-50%	50-75%	75-100%	Nil	1-25%
No disease control sprays applied														
'low'	sand bed	25%	75%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%
'ambient'	with seephose	8%	84%	8%	0%	0%	1%	100%	0%	0%	0%	0%	100%	0%
'high'	irrigation	42%	58%	0%	0%	0%	0%	87%	13%	0%	0%	0%	100%	0%
'low'	gravel bed	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%
'ambient'	with overhead	58%	42%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%
'high'	irrigation	17%	83%	0%	0%	0%	0%	NA	NA	NA	NA	NA	NA	NA
Disease control programme applied														
'low'	sand bed	17%	83%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%
'ambient'	with seephose	67%	33%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%
'high'	irrigation	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%
'low'	gravel bed	83%	17%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%
'ambient'	with overhead	83%	17%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%
'high'	irrigation	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%

NA: Not applicable

COMMERCIAL – IN CONFIDENCE

Table 27: ***Rhododendron*** **'Gartendirektor Glocker': Disease assessments on 'young' and 'old' growth on plants treated with 'suSCon Green' only (no 'Venzar')**

Humidity regime	Growing system	Powdery mildew infection on old leaves						Powdery mildew infection on young leaves						
		underside					top surface	underside					top surface	
		Nil	1-25%	25-50%	50-75%	75-100%		Nil	1-25%	25-50%	50-75%	75-100%	Nil	1-25%
No disease control sprays applied														
'low'	sand bed	25%	75%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%
'ambient'	with seephose	42%	50%	8%	0%	0%	0%	86%	14%	0%	0%	0%	86%	14%
'high'	irrigation	67%	33%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%
'low'	gravel bed	92%	8%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%
'ambient'	with overhead	58%	42%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%
'high'	irrigation	42%	58%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%
Disease control programme applied														
'low'	sand bed	33%	67%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%
'ambient'	with seephose	83%	17%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%
'high'	irrigation	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%
'low'	gravel bed	50%	50%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%
'ambient'	with overhead	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%
'high'	irrigation	50%	50%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%

COMMERCIAL – IN CONFIDENCE

Table 28: *Rhododendron* **'Gartendirektor Glocker': Disease assessments on 'young' and 'old' growth on plants treated with 'Venzar' and 'suSCon Green'**

Humidity regime	Growing system	Powdery mildew infection on old leaves						Powdery mildew infection on young leaves						
		underside					top surface	underside					top surface	
		Nil	1-25%	25-50%	50-75%	75-100%		Nil	1-25%	25-50%	50-75%	75-100%	Nil	1-25%
No disease control sprays applied														
'low'	sand bed	50%	50%	0%	0%	0%	1%	100%	0%	0%	0%	0%	100%	0%
'ambient'	with seephose	33%	67%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%
'high'	irrigation	92%	8%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%
'low'	gravel bed	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%
'ambient'	with overhead	50%	50%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%
'high'	irrigation	17%	83%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%
Disease control programme applied														
'low'	sand bed	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%
'ambient'	with seephose	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%
'high'	irrigation	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%
'low'	gravel bed	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%
'ambient'	with overhead	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%
'high'	irrigation	33%	67%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100%	0%

COMMERCIAL - IN CONFIDENCE

Table 29: ***Rhododendron*** **'Gartendirektor Glocker': Growth stage assessments summarised according to treatment**

Treatment	Humidity regime	Growing system	Growth stage* (% plants in each category) 1	2	3	4	5
Untreated control (no 'Venzar' or 'suSCon Green')	'low'	sand bed with	33%	0%	12%	25%	30%
	'ambient'	seephose	29%	0%	17%	4%	50%
	'high'	irrigation	54%	0%	0%	8%	38%
	'low'	gravel bed with	45%	28%	19%	4%	4%
	'ambient'	overhead	69%	8%	9%	0%	14%
	'high'	irrigation	46%	0%	0%	8%	46%
'Venzar' only (no 'suSCon Green')	'low'	sand bed with	42%	0%	13%	21%	24%
	'ambient'	seephose	17%	13%	20%	29%	21%
	'high'	irrigation	58%	0%	17%	16%	9%
	'low'	gravel bed with	66%	0%	16%	18%	0%
	'ambient'	overhead	62%	12%	0%	9%	17%
	'high'	irrigation	54%	13%	8%	9%	16%
'suSCon Green' only (no 'Venzar')	'low'	sand bed with	21%	12%	8%	9%	50%
	'ambient'	seephose	33%	4%	0%	17%	46%
	'high'	irrigation	42%	0%	8%	9%	41%
	'low'	gravel bed with	50%	4%	8%	17%	21%
	'ambient'	overhead	38%	42%	0%	8%	12%
	'high'	irrigation	42%	12%	0%	21%	25%
'Venzar' and 'suSCon Green'	'low'	sand bed with	33%	0%	8%	34%	25%
	'ambient'	seephose	16%	8%	13%	38%	25%
	'high'	irrigation	50%	0%	0%	21%	29%
	'low'	gravel bed with	69%	13%	13%	5%	0%
	'ambient'	overhead	75%	0%	4%	0%	21%
	'high'	irrigation	54%	8%	17%	9%	12%

* See Plate 13 (page 45)

APPENDIX III

Crop Diary

1993

3	November	Potted micropropagated plants of *Rhododendron*
4	November	Potted rooted cuttings of *Hebe* 'Miss E Fittall'
9	November	Potted rooted cuttings of *Cistus* 'Silver Pink'
21	November	'Venzar' applied according to treatment
23	November	Moved plants out into trial tunnels
14	December	'Pirimor' to *Hebe*

1994

24	January	'Pirimor' to *Hebe*
16	February	'Stopped' *Hebe* plants
18	February	'Aliette' to *Hebe* (1st spray)
3	March	'Aliette' to *Hebe* (2nd spray)
11	March	'Pirimor' to all species
18	March	'Aliette' to *Hebe* (3rd spray)
31	March	'Aliette' to *Hebe* (4th spray)
4	April	'Stopped' *Cistus* 'Silver Pink'
6	April	'Pirimor' to all species
14	April	'Aliette' to *Hebe* (5th spray)
25	April	'Pirimor' to all species
29	April	'Aliette' to *Hebe* (6th spray)
30	April	Recorded Rose 'Royal Worcester'
9	May	'Aliette' to *Hebe* (7th spray)
14	May	Recorded *Hebe* 'Miss E Fittall'
27	May	'Nimrod' to *Rhododendron* (1st spray)
30	May	Recorded *Cistus* 'Silver Pink'
12	June	'Nimrod' to *Rhododendron* (2nd spray)
18	June	Recorded *Rhododendron*

APPENDIX IV

Layout of plants within species, showing recorded and guard plants

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
	1	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
	2	x	g	g	g	g	g	g	g	g	g	g	g	g	g	g	x	
	3	x	-	-	-	-	-	-	x	x	-	-	-	-	-	-	x	
REP 1	4	x	-	-	-	-	-	-	x	x	-	-	-	-	-	-	x	REP 4
	5	x	-	-	-	-	-	-	x	x	-	-	-	-	-	-	x	
	6	x	-	-	-	-	-	-	x	x	-	-	-	-	-	-	x	
	7	x	g	g	g	g	g	g	x	x	g	g	g	g	g	g	x	
	8	x	g	g	g	g	g	g	x	x	g	g	g	g	g	g	x	
	9	x	-	-	-	-	-	-	x	x	-	-	-	-	-	-	x	
REP 2	10	x	-	-	-	-	-	-	x	x	-	-	-	-	-	-	x	REP 5
	11	x	-	-	-	-	-	-	x	x	-	-	-	-	-	-	x	
	12	x	-	-	-	-	-	-	x	x	-	-	-	-	-	-	x	
	13	x	g	g	g	g	g	g	x	x	g	g	g	g	g	g	x	
	14	x	g	g	g	g	g	g	x	x	g	g	g	g	g	g	x	
	15	x	-	-	-	-	-	-	x	x	-	-	-	-	-	-	x	
	16	x	-	-	-	-	-	-	x	x	-	-	-	-	-	-	x	
REP 3	17	x	-	-	-	-	-	-	x	x	-	-	-	-	-	-	x	REP 6
	18	x	-	-	-	-	-	-	x	x	-	-	-	-	-	-	x	
	19	x	g	g	g	g	g	g	g	g	g	g	g	g	g	g	x	
	20	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	

x = guards g = guards same treatment as plots - = plot plants

Each row of 6 recorded plants = 1 plot of a single treatment.

Treatments were randomised within each replicate and this randomisation varied on sand and gravel beds. However, the same layout was used on the sand beds and gravel beds in each tunnel, to avoid any confounding positional effects.

APPENDIX V

Contract, Schedule and Terms and Conditions

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

1. TITLE OF PROJECT **Contract No: HNS49a**

INFLUENCE OF HUMIDITY AND OTHER STRESS FACTORS ON PLANT GROWTH

2. BACKGROUND AND COMMERCIAL OBJECTIVE

Liners of a range of Hardy Nursery Stock (HNS) species are particularly prone to infection by number of diseases such as *Botrytis* during the winter period, when air temperatures are low and growth is very slow. The majority of nursery stock liners are grown 'cold' in polythene tunnels, with only sufficient heat to provide frost protection. Ventilation is often not necessary/poor, with the resulting lack of air movement often exacerbating the disease problem. With the continued market demand for top quality plants, produced with minimal losses, any component within the production system which improves the quality of the final product must be worth consideration, if it is economically viable. Growing system within the polythene tunnel may also affect the incidence of disease, as well as overall plant quality, including the growth of liverwort. Sand beds irrigated by seep hose generally produce a better quality plant than overhead irrigated gravel beds.

With increasing pressure to reduce the use of pesticides, and the decreasing number of chemicals available, manipulation of environmental conditions may offer an alternative method of controlling some of these pathogens, and possibly even liverwort.

For those diseases favoured by the high Relative Humidities (RH) prevalent in such environments over the winter period, a reduction in RH may offer one such method of control.

The three polythene tunnels used for last years dehumidification project are available for this work, and additional components of the production system could also be investigated, such as response to chemicals (eg.'suSCon Green') incorporated into/applied to the growing media for vine weevil and liverwort control.

This would be a joint project with the Electricity Association who provided the dehumidification equipment for last year's work, 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 but a range of diseases (e.g. *Botrytis*, downy mildew, powdery mildew) can cause severe loss of quality, and even plant death. Linked to this is the potential for reduced

fungicide application and consequent saving in labour. Control of vine weevil is essential as this pest becomes more widespread, if a high percentage of plant losses are to be avoided. Additional crop safety data on the use of 'suSCon Green' is required for a wider range of species, particularly young plants at a sensitive stage of growth.

4. SCIENTIFIC/TECHNICAL TARGET OF THE WORK

To investigate the effect of different humidity regimes on the incidence of disease overwinter on newly potted liners of several HNS species. To evaluate the efficacy and phytotoxicity (if any) of 'suSCon Green' (used for vine weevil control) and 'Venzar' (used for the control of liverwort).

HDC/EA funded work on the influene of dehumidification on the growth of HNS subjects was carried out in 1992/93.

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), and on 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

The three small polythene tunnels used for last year's work would be required for this work. These would be unheated, except for frost protection.

<u>Proposed treatments</u>:

Target Relative Humidity:
Ambient RH
High RH (enhanced with fog to maintain 90+% RH)
Low RH (Dehumidification to reduce RH below 80%)

Growing system:
Sand bed with seephose irrigation.
Gravel bed with overhead irrigation.

Chemical incorporation into the growing media for vine weevil control:
'suSCon Green' incorporated at 750g/m^3 growing media.
No 'suSCon Green' incorporated.

Chemical application for liverwort control:
'Venzar' applied at 1.4kg or 2.8kg/ha (depending on species) after potting.
No 'Venzar' applied.

Chemical control of diseases:
Fungicide sprays to be applied as required for each species.

No disease control sprays applied.

Species:
Cistus 'Silver Pink'
Hebe 'Miss E Fittall'
Rhododendron 'El Camino'
Rhododendron 'Gartendirektor Glocker'
Rose 'Royal Worcester'

Assessments:

Records of disease incidence and any phytotoxicity symptoms.

Score of liverwort growth at the end of the trial.

Photographic records of growth/disease incidence as appropriate.

Plant quality scores at the end of the trial.

Records of air temperature and RH throughout the trial period using a Delta T logger.

7. COMMENCEMENT DATE, DURATION AND REPORTING

Start date 01.11.93; duration 10 months. The experimental work will be completed by June 1994 and the final report will be producd by September 1994.

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.

HORTICULTURE RESEARCH INTERNATIONAL

CM3A

EFFORD

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

HRI Ref HNS49 Date 31.1.94 Researcher Lyn Andrews

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

EFFECT OF HUMIDITY AND OTHER STRESS FACTORS ON PLANT GROWTH OVERWINTER. (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 £ ..... 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 28.02.94 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 0LZ

TEL: 0590 673341 FAX: 0590 671553

Offer authorised by:

Signed ..... Position DIRECTOR Date 2.2.94

duly authorised representative of **HRI**

Offer accepted by:

Signed ..... Position MANAGER Date 24/2/94

duly authorised representative of the **Customer**