Contract report for the
Horticultural Development Council

Cyclamen: Costs and benefits of treatments for control of fusarium wilt - 1993

(PC50b)

15 April, 1994

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Dear Ed

CYCLAMEN FUSARIUM WILT (PC506)

Herewith the final report for this project. I have also sent copies to John Hickmott, John Ashdown and HRI Efford (David Hand).

It is probably worth revising and re-issuing the fact sheet on control of cyclamen fusarium wilt to incorporate the main results we obtained in 1993. Could you send me a copy of the original fact sheet and I will then revise it?

Many thanks for funding this work with us.

Yours sincerely

Tim O'Neill

T M O'NEILL

cc J Ashdown, Wolverhampton

ONEIL110

APPLICATION

The objective of the project is to define integrated strategies for achieving reliable and durable control of cyclamen fusarium wilt. Treatments include growing medium amendments and appropriate use of fungicides and biocontrol agents. Combinations of treatments have been identified which provide good control of fusarium wilt. There is opportunity for growers to apply these treatments and reduce the risk of serious losses to fusarium wilt.

ACTION POINTS FOR GROWERS

1. Growers should not rely on bark amendment alone for control of fusarium wilt. The effectiveness of a particular bark in controlling wilt is variable.

2. Treatments additional to a single, protective, drench of Bavistin or equivalent MBC fungicide are required to give effective control of fusarium wilt. The cost of such treatments is small in relation to the potential loss if the disease occurs.

3. Suggested treatments include amendment of peat with 1% Ocean Supermix (crushed crab shells) and/or drenching plants twice with Octave. Use of bark amendment may improve the control given by Ocean Supermix and Octave drenches.

4. Growers should check carefully any plants which flower early; plants affected by fusarium wilt appear to flower slightly earlier than unaffected plants. Other factors may also cause plants to flower early.

5. Plants showing symptoms of fusarium wilt should be removed from the crop. *F. oxysporum* f.sp. *cyclaminis* can spread from affected to healthy plants, particularly on an ebb-flood bench.

6. Growers should not assume that vascular staining in the corm necessarily indicates fusarium wilt. *Botrytis cinerea* and *Cylindrocarpon destructans* may also cause vascular staining which could be confused with *F. oxysporum* f. sp. *cyclaminis*. Some corm staining may also be caused by factors other than disease.

7. Growers should consider using Mycostop for control of fusarium wilt should it become available for commercial use in the UK. Registration data for Mycostop are currently being evaluated by the Pesticide Safety Directorate.

INTRODUCTION

HDC-funded work in 1991 and 1992 (Projects PC50 and 50a) demonstrated a significant reduction in the development of cyclamen fusarium wilt when bark (various kinds), woodfibre or crab shells (chitin) were incorporated into the growing medium. Drenching plants with Octave at monthly intervals also reduced the disease, and the combined effect of bark and Octave appeared to reduce disease more than either treatment on its own. Inoculum level, inoculation site, growing medium and method of watering were found to be critical factors affecting the rate of development of fusarium wilt.

The objectives of the work described here were to investigate the costs and benefits of treatments additional to a precautionary Bavistin drench (the standard treatment) on control of wilt. Treatments were evaluated under high disease pressure by inoculating plants with a standard spore inoculum and under a lower disease pressure by (i) growing plants on an ebb-flood bench adjacent to inoculated plants and (ii) by placing wilt affected plants within a crop on capillary matting for four weeks immediately after potting.

MATERIALS AND METHODS

Variety and source of plants

Plug-grown plants of cvs. Sierra White with Eye and Zodiac were obtained from Colegraves Seeds and Royal Sluis respectively. A sample of each was examined for fusarium and other pathogens before potting.

Source and culture of fungi

A culture of *Fusarium oxysporum* f. sp. *cyclaminis* was obtained by isolation from cyclamen plants affected by wilt in 1992 on to potato dextrose agar (PDA) amended with streptomycin.

Source and grade of growing media and amendments

Growing media were prepared in a rotary mixer at HRI Efford or by hand-mixing, and samples were taken for analysis and determination of air-filled porosity (AFP) after mixing. Sources and grades of materials are listed below. Control treatments consisted of 100% peat.

Medium/ amendment	Source	Grade	Rate of use in mixes
Peat	Irish sphagnum (Shamrock)	Medium (E)	60 % (v/v)
Peat	Irish sphagnum (Shamrock)	Medium Nursery (N)	60 % (v/v)
Bark	Melcourt	Composted pine	40 % (v/v)
Chitin	Sigma Chemicals	Technical grade (E)	1 % (w/v)
Chitin	Ocean Organics	Supermix (crushed crab shells) (N)	1 % (w/v)

E - HRI Efford; N - Norfolk site

Fertiliser addition at mixing consisted of:

	kg/m³
Ammonium nitrate	0.4
Potassium nitrate	0.75
Single superphosphate	1.2
Dolomite lime	2.5
Frit WM 255	0.4

An additional 1 kg/m³ ground chalk was added to all-peat and peat-chitin composts. Additional ammonium nitrate (0.2 kg/m³) was added to peat/bark media. Plants were given liquid feed (120 ppm N; 120 ppm K_2O) from 3 weeks after potting. This was changed to 110 ppm N, 60 ppm P_2O_5 and 200 ppm K_2O from early September.

Fungicides and biocontrol agents

Product	Rate used (g/l)	Active ingredient (%)
Bavistin DF	1	50% carbendazim
Octave	1	46% prochloraz - Mn
Mycostop[a]	0.08	*Streptomyces* sp. (10^8 cfu/g)

[a] Obtained from Kemira Oy, Finland.

Products were applied as drenches poured onto the compost surface at 100 ml/plant. Water drenches were applied to plants not receiving a fungicide treatment.

Location of work and crop details

	Experiment 1	Experiment 2
Location	Norfolk	HRI Efford
Variety	Zodiac	Sierra White with Eye
Pot size	12C	13C
Watering	Ebb-flood to waste	Capillary matting
Shading	Yes	Yes
Botrytis control	Rovral & picking over	Rovral & picking over
Insecticides	Nil	Nil
Natural enemies	Nemasys	Nemasys

Treatments

The following treatments were applied:

1.	Peat	Untreated
2.	Peat + Bavistin (x1)	Standard treatment
3.	Peat + Bavistin + Octave (x2)	
4.	Peat + Bavistin + Bark (40%)	2 control components
5.	Peat + Bavistin + Chitin (10 g/l)	
6.	Peat + Bavistin + Octave (x2) + Bark	
7.	Peat + Bavistin + Bark + Chitin	3 control components
8.	Peat + Bavistin + Octave (x2) + Chitin	
9.	Peat + Bavistin + Octave (x2) + Bark + Chitin	4 control components
10.	Mycostop drenches (x 5)	1 control component

Treatment 10 was applied in Experiment 1 only

In addition there were unreplicated plots of 20 plants of peat + bark (no fungicides) and peat + chitin (ex Sigma Chemicals) inoculated with *F. oxysporum* f. sp. *cyclaminis* at the Norfolk site. There were also unreplicated plots of 10 uninoculated plants of peat (no fungicides), peat + Bavistin, peat + bark, peat + chitin and peat + bark + chitin on a side bench at the Norfolk site.

Experimental design

Experiments were arranged in randomised blocks with fourfold replication (Experiment 1) or sevenfold replication (Experiment 2). There was extra replication of the untreated plants. Plots consisted of 16 plants (8 inoculated) in Exepriment 1 and 12 plants around a central infector plant (Experiment 2). Results were analysed by analysis of variance. Angular or cubic transformation was carried out to convert data to a normal distribution. Where no suitable transformation was found, mean values were compared using a X^2 test. Where data were very sparse, treatment means are tabulated without analysis.

Inoculation of plants

Sporing cultures of *F. oxysporum* f. sp. *cyclaminis* were flooded with sterile water and the culture surface scraped with a sterile needle. The resultant spore suspension was filtered through muslin into a McCartney bottle and the concentration of spores determined with a haemocytometer. In Experiment 1, a spore suspension of *F. oxysporium* f. sp. *cyclaminis* in water was poured onto the growing medium surface around the plant edge. Suspensions were agitated frequently to maintain an even suspension.

For Experiment 2, one 'infector' plant, a cyclamen which had been inoculated with *F. oxysporum* f. sp. *cyclaminis*, was placed in the centre of each experimental plot for four weeks at the start of the experiment.

Assessments

Plants were assessed fortnightly and those with severe yellowing or wilting were removed and the corms were examined for vascular staining characteristic of fusarium wilt. Where corm staining was present but atypical of fusarium wilt, the stained tissue was examined for fungal pathogens by isolation.

Root amount (% surface area of root ball) and root discolouration (0 - 5 scale) were assessed at termination of experiments.

Plant quality was assessed according to size, shape and marketability of plants using the following key:

0 - Plant dead
1 - Sparse growth of leaves and flowers; unmarketable
2 - Small, poor shape
3 - Average shape and performance
4 - Good shape; only slight defects
5 - Very good frame; domed shape; many buds; >5 flowers.
Plant size *c.* twice pot height to top of flowers and *c.* 8 cm from canopy to flowers; *c.* 25 cm diameter.

A weighted quality index (0 - 100) was calculated according to the proportion of plants in each category.

Plant height and spread were also recorded in Experiment 2. Shelf-life was determined on 10 plants for each treatment. Plants were stood on capillary matting in trays and were hand-watered with mains water. They were illuminated for 12 hours daily using fluorescent warm white tubes (*c.* 1000 lux). Temperature was maintained at 18 - 20 °C and humidity was ambient. The numbers of live flowers and buds and yellowing leaves were recorded weekly for 3 weeks.

Crop diary

	Experiment 1 (Norfolk)	Experiment 2 (HRI Efford)
Potted	8 July	11 July
Inoculated	3 August	-
Infectors added	-	22 July
Infectors removed	-	25 August
Spaced	10 October	11 August
		25 September
Bavistin drench	15 July	16 July
Octave drenches	11 August	12 August
	7 September	13 September
Mycostop	28 July	-
	18 August	-
	8 September	-
	29 September	-
	20 October	-
Fusarium first confirmed	7 September	3 October
Quality assessment	22 December	25 November
Final assessment	22 December	21 December

RESULTS

Experiment 1

Crop nutrition

Nutrient levels of the growing media immediately after mixing were satisfactory (Table 1). The air-filled porosity (AFP) of peat was increased from 8.8 to 16.2 by addition of 40% bark. In the absence of chitin, compost pH was greatly reduced at the end of the experiment due to the unnecessarily high nitrate content. Chitin in the form of crushed crab shell applied at 10 litres/m^2 maintained growing medium pH as would be expected since it is a hard, slowly available form of lime.

Disease

No *F. oxysporum* f. sp. *cyclaminis* was found in young plants examined before potting; *Cylindrocarpon destructans* was occasionally isolated from roots. Grey mould (*Botrytis cinerea*) developed in November, causing a leaf rot, and was present on many plants by the end of the month. Damage from botrytis was kept to a low level by picking-over, spacing plants and application of Rovral sprays. Leaf yellowing suggestive of fusarium wilt was first observed four weeks after inoculation and the disease was confirmed one week later on 7 September. The incidence of affected plants increased rapidly thereafter (Figs 1 - 2). Fusarium wilt occurred first in the standard peat treatment and did not occur until three weeks later in the four-component disease control treatment (Bavistin/Octave/Bark/Chitin). The number of plants affected by wilt increased rapidly in the standard peat, Bavistin drench and bark amedment treatments and more slowly in all other treatments. The four-component disease control treatment and drenching with Mycostop were most effective. At assessment on 22 September (Table 2), the incidence of plants affected by fusarium wilt was significantly reduced by all treatments except Bavistin drench and bark amendment plus Bavistin drench. At an assessment on 20 October, 92% of plants in the standard peat had died compared to 38% in the four component disease control treatment (Table 2). By the end of the experiment most plants had died in all treatments except for the four-component treatment (22% alive) and the Mycostop treatment (19% alive).

Although there was no control with Bavistin + bark, the effect of Bavistin + Octave + chitin was considerably improved by the addition of bark (Fig 2).

Fusarium wilt was first observed in uninoculated plants on 10 November, 14 weeks after spores of *F. oxysporum* f. sp. *cyclaminis* were added to other plants on the bench. At the termination of the experiment, affected plants were present in the standard peat (12.7%), the Bavistin drench (9.8%) and peat/bark + Bavistin drench (3.1%) treatments and no others (Table 3; Figs 3 - 4).

In unreplicated plots, amendment of peat with chitin (technical grade) or bark in the absence of fungicide drenches appeared to give slight control of fusarium wilt (Fig 4A). No fusarium wilt occurred in unreplicated unicoculated plants on the side bench.

F. oxysporum f. sp. *cyclaminis* isolated from diseased plants at termination of the experiment did not grow on agar amended with benomyl at 2 mg/l or 20 mg/l.

Table 1. Nutrient levels of growing media (Experiment 1)

Growing medium	pH	P mg/l (index)	K mg/l (index)	Mg mg/l (index)	Cond. µs (index)	NO_3-N mg/l (index)	NH_4-N mg/l (index)	AFP
<u>After mixing</u>								
Peat	5.9	89 (8)	234 (4)	88 (7)	519 (4)	142 (5)	70 (2)	8.8
Peat/Bark	5.6	104 (9)	366 (5)	138 (7)	731 (6)	216 (6)	97 (2)	16.2
Peat/Chitin	6.1	84 (8)	252 (5)	68 (6)	515 (4)	150 (5)	73 (2)	-
Peat/Bark/Chitin	6.0	116 (9)	396 (5)	99 (7)	780 (6)	229 (6)	134 (3)	-
<u>22 December</u>								
Peat	4.9	39 (5)	44 (1)	137 (7)	580 (4)	339 (7)	9 (0)	-
Peat/Bark	4.9	47 (6)	94 (2)	145 (7)	588 (4)	340 (7)	7 (0)	-
Peat/Chitin	6.0	21 (4)	210 (4)	101 (7)	623 (5)	348 (7)	3 (0)	-
Peat/Bark/Chitin	6.1	31 (5)	133 (3)	141 (7)	712 (6)	392 (7)	3 (0)	-

Table 2. Effect of growing medium amendments and fungicides on cumulative incidence of fusarium wilt (Experiment 1) - 1993.

Inoculated Plants

	Treatment	% dead plants					
		7 September		22 September		6 October	
1.	Peat (control)	4.7	(4.7)	75.0	(62.3)	90.6	(77.3)
2.	P/B	0		78.1	(62.3)	93.7	(82.5)
3.	P/B/O	0		43.7	(41.2)	75.0	(60.4)
4.	P/B/Bark	0		71.9	(58.4)	93.7	(79.6)
5.	P/B/Chitin	3.1	(5.2)	43.7	(40.7)	65.6	(54.7)
6.	P/B/O/Bark	0		46.9	(42.7)	90.6	(77.3)
7.	P/B/Bark/Chitin	0		28.1	(31.6)	50.0	(45.0)
8.	P/B/O/Chitin	0		37.5	(37.5)	65.6	(58.1)
9.	P/B/O/Bark/Chitin	0		0	(0)	15.6	(16.9)
10.	Mycostop	0		9.4	(9.4)	37.5	(33.7)
	Significance	-	NS	-	***	-	***
	SED between trts	4.36	4.64	10.58	7.84	11.29	10.61
	vs control (27 df)	3.77	4.02	9.16	6.79	9.78	9.19
		20 October		17 November		22 December	
1.	Peat (control)	92.2	(78.5)	96.9	(84.8)	96.9	(84.8)
2.	P/B	93.7	(82.5)	96.9	(84.8)	96.9	(84.8)
3.	P/B/O	87.5	(75.4)	90.6	(77.3)	93.7	(82.5)
4.	P/B/Bark	93.7	(79.6)	96.9	(84.8)	96.9	(84.8)
5.	P/B/Chitin	81.2	(64.6)	96.9	(84.8)	97.1	(85.0)
6.	P/B/O/Bark	96.9	(84.8)	96.9	(84.8)	100.0	(90.0)
7.	P/B/Bark/Chitin	78.1	(65.9)	93.7	(79.6)	96.9	(84.8)
8.	P/B/O/Chitin	87.5	(75.0)	96.9	(84.8)	100.0	(90.0)
9.	P/B/O/Bark/Chitin	37.5	(33.7)	62.5	(52.9)	78.1	(66.6)
10.	Mycostop	50.0	(45.0)	78.1	(65.6)	81.2	(67.9)
	Significance	-	***	-	***	-	NS
	SED between trts.	12.42	10.95	9.24	8.60	7.87	8.19
	vs control (27 df)	10.76	9.48	8.00	7.45	6.81	7.09

P - peat; B - Bavistin; O - Octave.
Angular transformed values are shown in parenthesis.
NS - not significant; ** - significant at p = 0.01; *** - significant at p = 0.001.

Table 3. Effect of growing medium amendments and fungicides on cumulative incidence of fusarium wilt (Experiment 1) - 1993.

Uninoculated plants

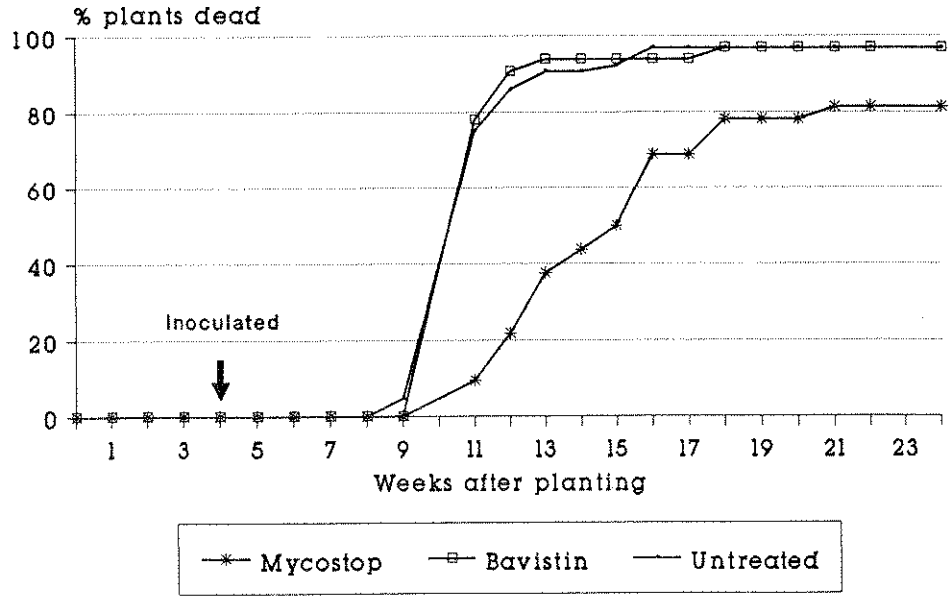
	Treatment	% dead plants		
		10 November	1 December	22 December
1.	Peat (control)	1.6	7.8	12.7
2.	P/B	0	3.6	9.8
3.	P/B/O	0	0	0
4.	P/B/Bark	0	0	3.1
5.	P/B/Chitin	0	0	0
6.	P/B/O/Bark	0	0	0
7.	P/B/Bark/Chitin	0	0	0
8.	P/B/O/Chitin	0	0	0
9.	P/B/O/Bark/Chitin	0	0	0
10.	Mycostop	0	0	0

P - peat; B - Bavistin; O - Octave

Data were too sparse for analysis; treatment means are tabulated.

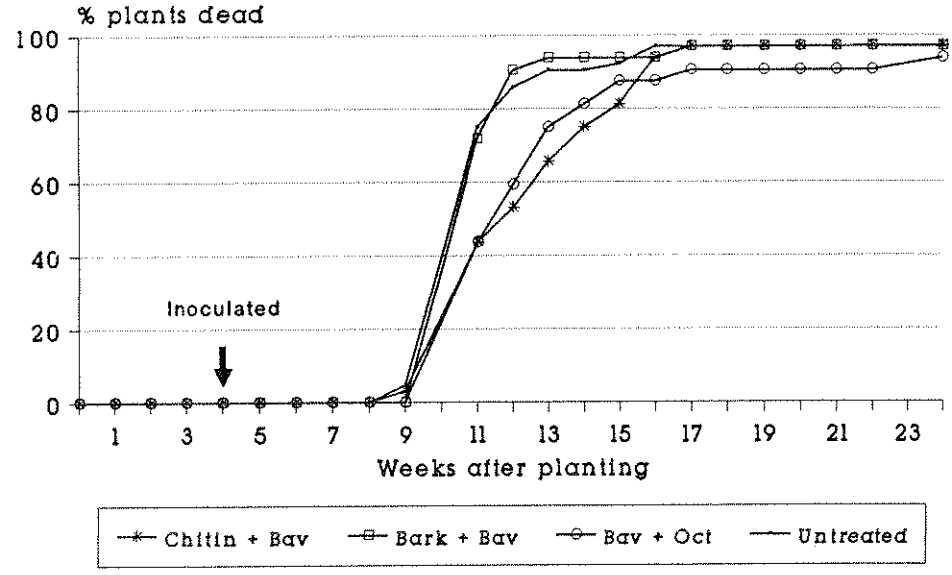
Fig 1. Cyclamen - Control of fusarium wilt - inoculated plants

One component



Cyc935

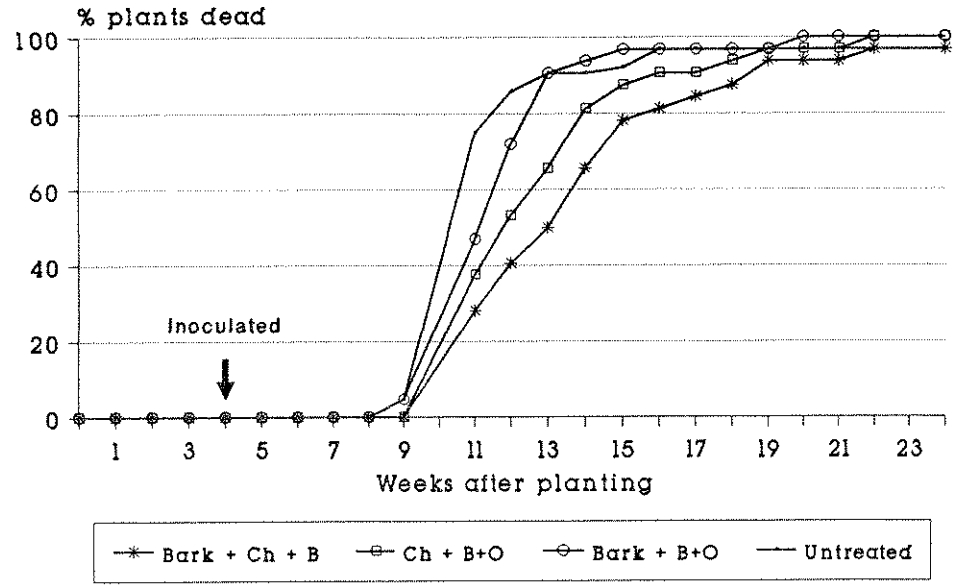
Two components



Cyc936

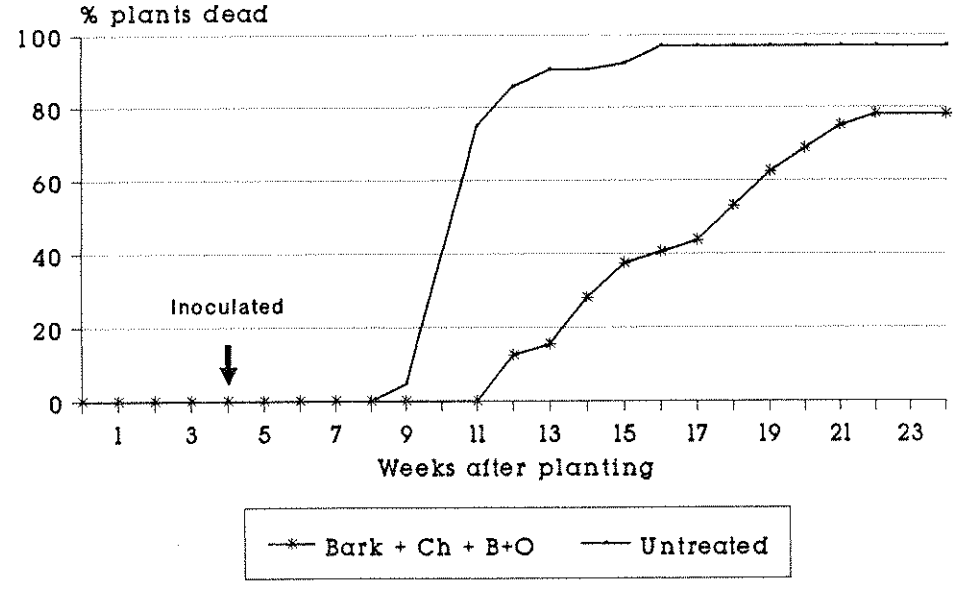
Fig 2. Cyclamen - Control of fusarium wilt - inoculated plants

Three components



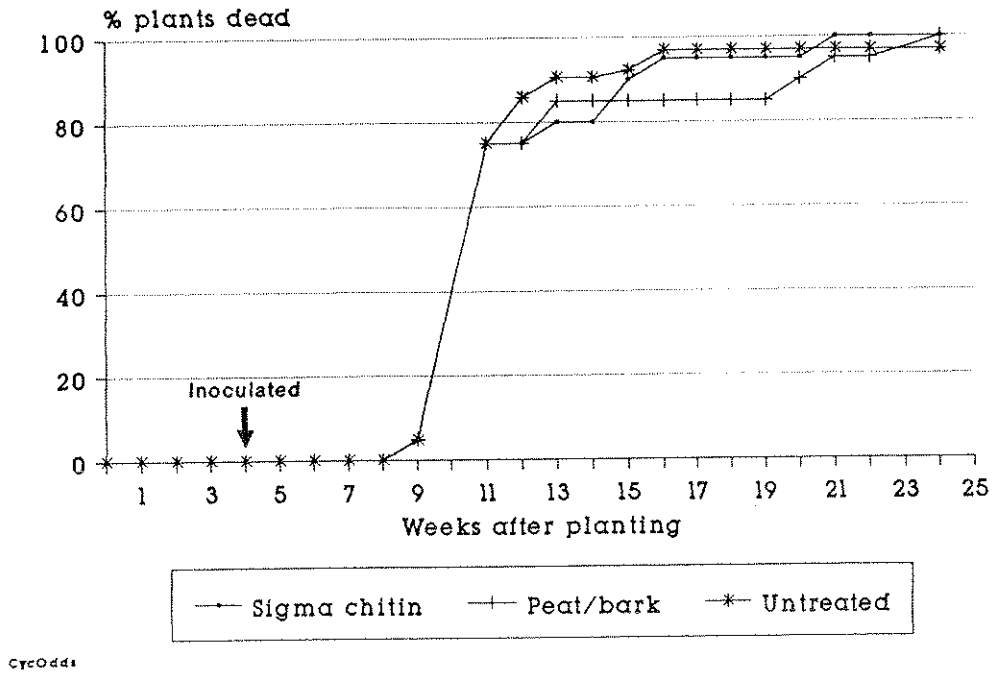
Cyc937

Four components



Cyc938

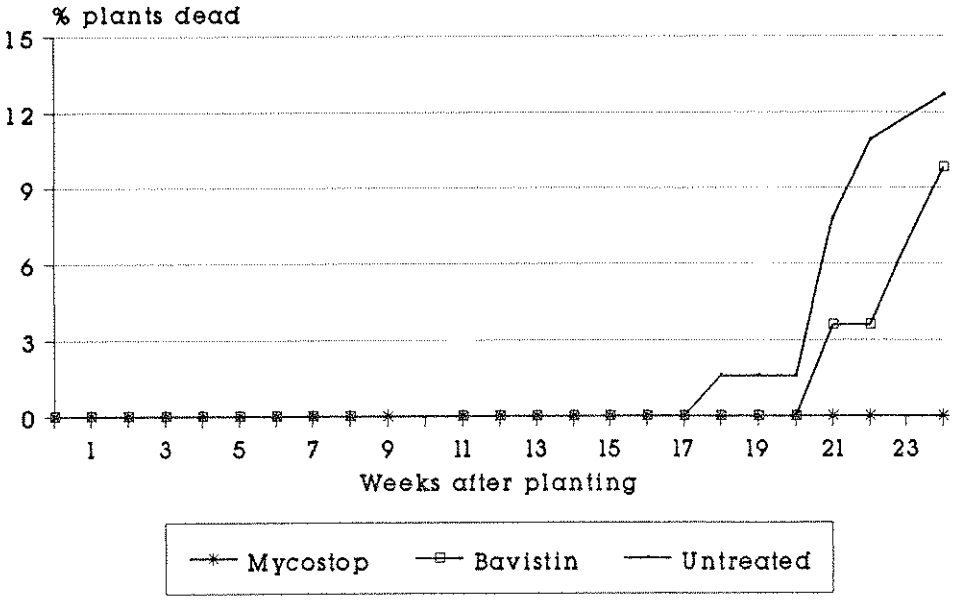
Fig 2A. Cyclamen - Control of fusarium wilt in 20 inoculated plants



CycOdds

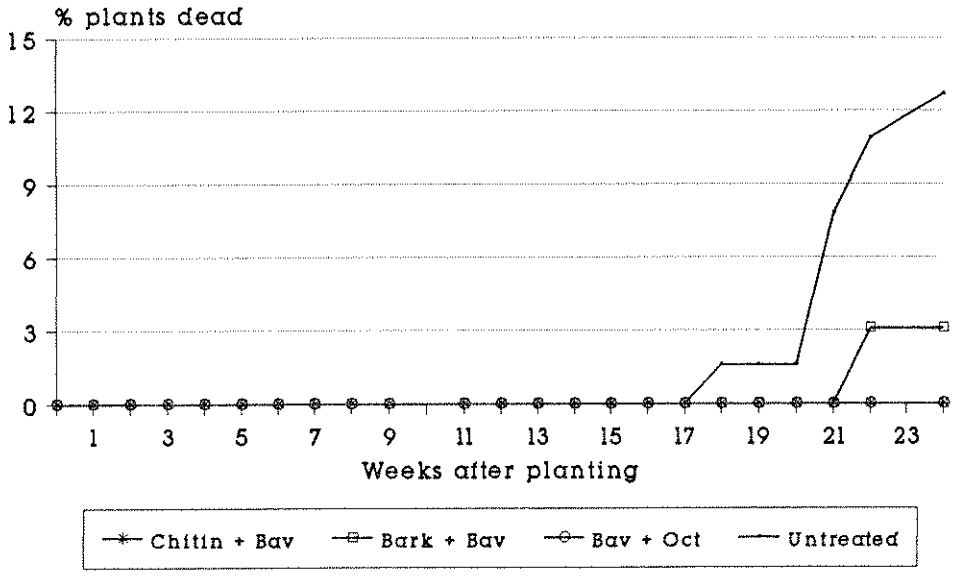
Fig 3. Cyclamen - Control of fusarium wilt - uninoculated plants

One component



Uninoc1

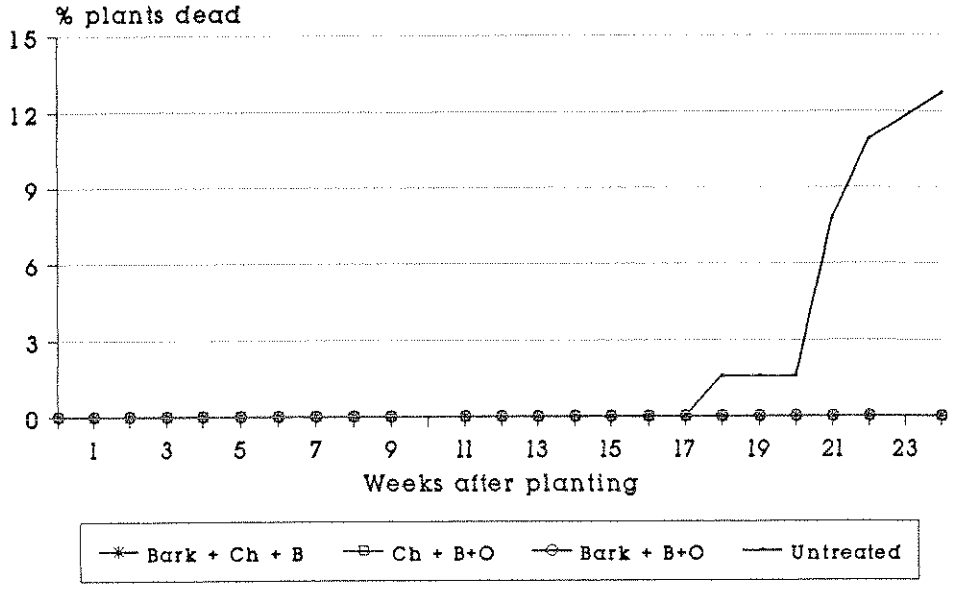
Two components



Uninoc2

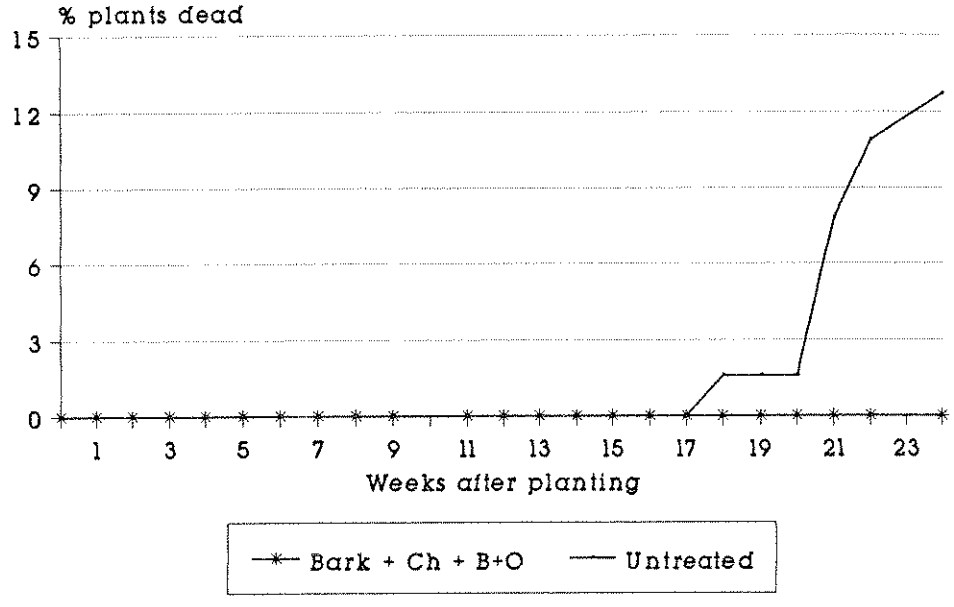
Fig 4. Cyclamen - Control of fusarium wilt - uninoculated plants

Three components



Uninoc3

Four components



Uninoc4

Plant quality

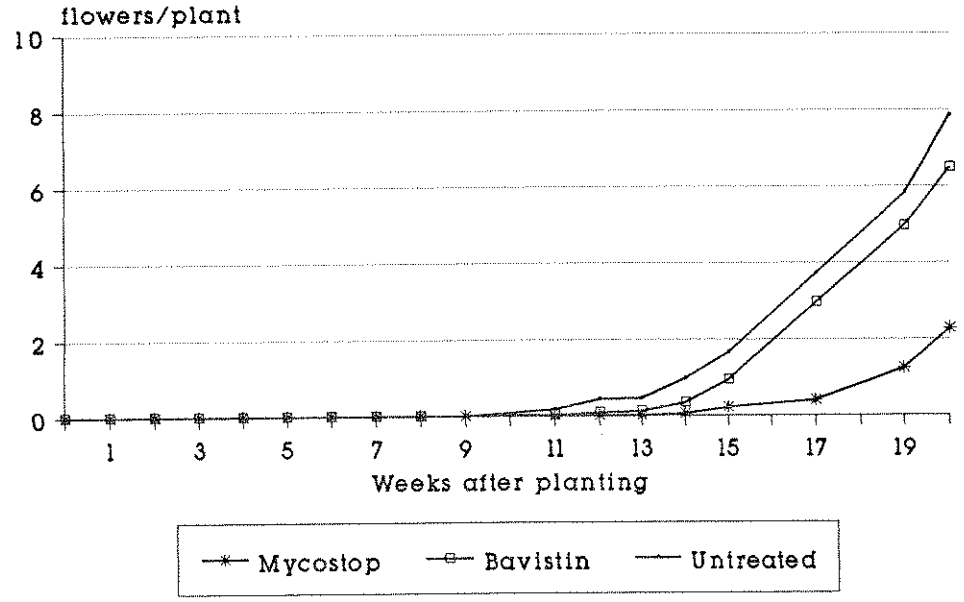
Treatments which gave good control of fusarium wilt also slightly delayed flowering compared to untreated inoculated plants. This was particularly noticeable with the Mycostop and the four-component control treatment (Figs 5 -6). At termination of the experiment there were no significant differences in plant quality (Table 4). The extent of roots on the outside of root balls was low in all treatments, ranging from 3.2% (maximum disease control) to 10.7% (standard peat) (Table 4). Root extent was slightly but significantly reduced in three of the four Octave treatments. Many of the surviving plants showed grey or brown discoloured areas within the corms, especially near the tops, but this was not related to treatment. *Botrytis cinerea* and *Cylindrocarpon destructans* were frequently isolated from stained tissue (Table 5). A few corms showed an orange-brown vascular staining and *F. oxysporum* was isolated from these.

Microbiological analysis of growing media

At termination of the experiment both bark and chitin amendments appeared to be associated with increased numbers of actinomycetes in growing media although the figures were variable. The number of colonies of *Trichoderma* spp. isolated was not obviously related to treatment (Table 6).

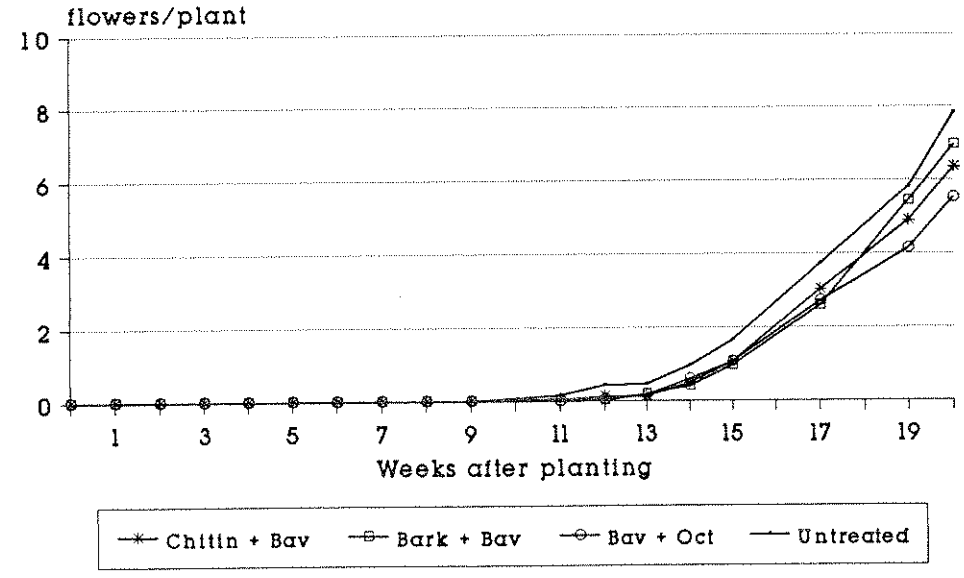
Fig 5. Cyclamen - Effect of treatments on flowering

One component



UniFlo1

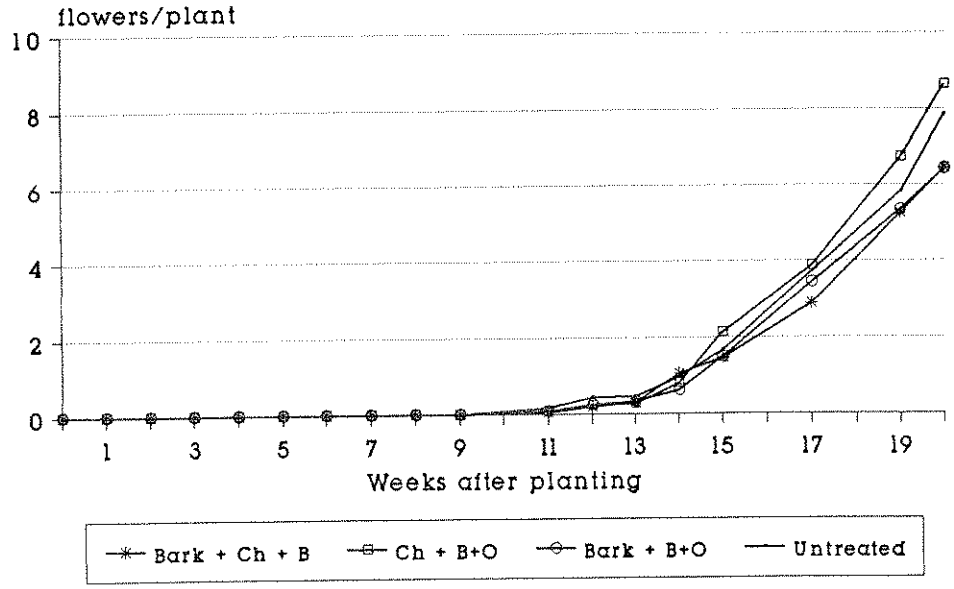
Two components



Uniflo2

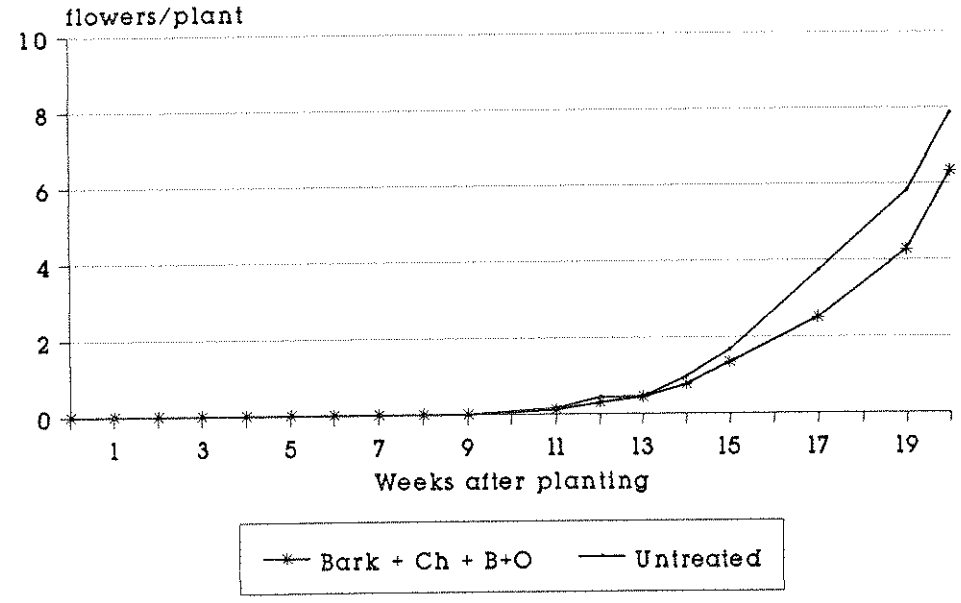
Fig 6. Cyclamen - Effect of treatments on flowering

Three components



Unflo3

Four components



Unflo4

Table 4. Effect of treatments on plant quality and root extent (Experiment 1) - 22 December 1993.

	Treatment	Quality index (0 - 100)	Root extent (%)
1.	Peat (control)	75.4	10.7
2.	P/B	71.6	9.5
3.	P/B/O	66.4	7.5
4.	P/B/Bark	74.4	10.4
5.	P/B/Chitin	75.7	5.8
6.	P/B/O/Bark	71.5	6.1
7.	P/B/Bark/Chitin	73.7	5.2
8.	P/B/O/Chitin	78.9	3.3
9.	P/B/O/Bark/Chitin	71.8	3.2
10.	Mycostop	63.3	9.8
	Significance	NS	***
	SED between trts.	5.30	1.53
	vs control (27 df)	4.59	1.32
Uninoculated plants on side bench (10 plants)			
1.	Peat (no fungicides)	77.5	8.1
2.	Peat/Bavistin	65.0	5.0
3.	Peat/Bark	74.3	3.6
4.	Peat/Chitin	80.0	4.3
5.	Peat/Bark/Chitin	71.4	2.1

P - peat; B - Bavistin; O - Octave
NS - not significant *** - significant at p = 0.001

Table 5. Isolation from stained corm tissue (Experiment 1) - 22 December 1993.

Symptom	No. of samples	Fungi isolated (No. of samples)
Corm top		
Grey/brown flecks	3	Nil (3)
Grey streaks	4	Botrytis (4), Cylindrocarpon (3)
Browning below petiole	4	Nil (2), Cylindrocarpon (1), Botrytis (2)
Browning of vascular traces	3	Fusarium (2), Botrytis (1), Cylindrocarpon (1)
Extensive brown rot	4	Botrytis (4)

Table 6. Effect of growing medium amendments on numbers of colony forming units of actinomycetes and *Trichoderma* spp. - December 1993.

	Growing medium	Total No. actinomycetes (per g FW)	Total No. *Trichoderma* spp. (per g FW)
Norfolk			
1.	Peat (+ Bavistin)	4.5×10^4	1.0×10^4
2.	Peat + Bark (+ Bav)	9.9×10^4	1.5×10^4
3.	Peat + Bark + Chitin	5.4×10^4	1.0×10^5
4.	Peat + Bark +Chitin (+ Bav)	1.0×10^6	0
5.	Peat + Mycostop	6.6×10^3	1.0×10^5
HRI Efford			
1.	Peat	2.6×10^4	$<1 \times 10^1$
2.	Peat (+ Bav)	2.2×10^4	1.0×10^3
3.	Peat (+ Bav + Oct)	1.5×10^4	$< 1 \times 10^1$
4.	Peat + Bark (+ Bav)	2.1×10^5	1.0×10^4
5.	Peat + Chitin (+ Bav)	1.2×10^6	1.0×10^5
6.	Peat + Bark (+ Bav + Oct)	6.4×10^5	1.0×10^4
7.	Peat + Bark + Chitin (+ B + O)	8.0×10^5	$< 1 \times 10^1$

B - Bavistin; O - Octave

RESULTS

Experiment 2

Crop nutrition

Nutrient levels of the growing media immediately after mixing were satisfactory (Table 7). There was no difference in the AFP of peat and peat/bark media at mixing. By the end of the experiment, nutrient levels were deficient. Addition of technical grade chitin prevented pH rise in this hard water area.

Disease

No fusarium or other pathogens were found in young plants before potting. A few plants died soon after potting but no fusarium was found. Fusarium wilt was first confirmed on 8 October, 11 weeks after introduction of infector plants. The incidence of affected plants increased slowly thereafter (Table 8). At the final assessment on 21 December, the incidence of affected plants ranged from nil (Bavistin + Octave drenches) to 6% (Bark + Bavistin and Octave drenches). Chitin amendment with Bavistin and Octave drenches, and bark + chitin amendment with Bavistin and Octave drenches appeared to delay disease development.

Plant Quality

None of the treatments affected plant size or quality (Table 9). Drenching with Octave slightly reduced root amount and discolouration. (Table 10).

Shelf-life

None of the treatments had a marked effect on the speed of leaf yellowing or flower death in shelf-life studies (Figs 7 - 10).

Table 7. Nutrient levels of growing media (Experiment 2).

Growing medium	pH	P mg/l (index)	K mg/l (index)	Mg mg/l (index)	Cond. µs (index)	NO_3-N mg/l (index)	NH_4-N mg/l (index)	AFP
After mixing (9 July 1993)								
Peat	5.4	86 (8)	278 (5)	104 (7)	495 (3)	165 (5)	90 (2)	11.3
Peat/Bark	5.4	79 (8)	362 (5)	118 (7)	632 (5)	209 (6)	105 (3)	11.5
Peat/Chitin	5.2	80 (8)	237 (4)	90 (7)	489 (3)	142 (5)	87 (2)	-
Peat/Bark/Chitin	5.2	85 (8)	344 (5)	110 (7)	663 (5)	200 (6)	118 (3)	-
Mid-season (20 August 1993)								
Peat	5.8	20 (4)	24 (0)	50 (5)	530 (4)	194 (5)	121 (3)	-
Peat/Bark	6.0	5 (1)	58 (2)	63 (6)	520 (4)	213 (6)	92 (2)	-
End of trial (11 January 1994)								
Peat	6.6	15 (3)	25 (0)	6 (1)	109 (0)	9 (0)	10 (0)	-
Peat/Bark	6.6	16 (3)	12 (0)	18 (3)	115 (0)	14 (0)	3 (0)	-
Peat/Chitin	5.3	12 (3)	9 (0)	32 (4)	204 (1)	90 (4)	3 (0)	-
Peat/Bark/Chitin	5.8	11 (2)	13 (0)	24 (3)	162 (1)	57 (3)	2 (0)	-

Table 8. Effect of growing medium and fungicides on cumulative incidence of fusarium wilt (Experiment 2) - 1993.

	Treatment	% dead plants	
		8 October	5 November
1.	Peat (control)	0	2.1
2.	P/B	1.2	2.4
3.	P/B/O	0	0
4.	P/B/Bark	1.2	3.6
5.	P/B/Chitin	1.2	1.2
6.	P/B/O/Bark	2.4	3.6
7.	P/B/Bark/Chitin	2.4	3.6
8.	P/B/O/Chitin	0	0
9.	P/B/O/Bark/Chitin	0	0
		26 November	17 December
1.	Peat (control)	3.1	3.1
2.	P/B	2.4	3.6
3.	P/B/O	0	0
4.	P/B/Bark	4.8	4.8
5.	P/B/Chitin	1.2	3.6
6.	P/B/O/Bark	3.6	6.0
7.	P/B/Bark/Chitin	3.6	3.6
8.	P/B/O/Chitin	1.2	3.6
9.	P/B/O/Bark/Chitin	1.2	1.2

P - peat; B - Bavistin; O - Octave

There were insufficient non-zero data values to analyse the data by analysis of variance or a non-parametric test. Treatment means are tabulated.

Table 9. Effect of growing media and fungicides on plant height, spread and quality (Experiment 2) - 25 November 1993.

	Treatment	Plant height (cm)		Plant spread (cm)	Quality score (0 - 5)
1.	Peat (control)	15.6	(15.8)	34.0	4.4
2.	P/B	15.3	(15.4)	33.3	4.4
3.	P/B/O	15.2	(15.4)	32.8	4.4
4.	P/B/Bark	16.5	(16.7)	35.4	4.8
5.	P/B/Chitin	18.0	(17.7)	36.9	4.9
6.	P/B/O/Bark	15.4	(15.9)	32.3	4.4
7.	P/B/Bark/Chitin	16.5	(17.0)	34.2	4.7
8.	P/B/O/Chitin	16.8	(15.7)	34.4	4.4
9.	P/B/O/Bark/Chitin	15.6	(15.8)	32.8	4.1
	Significance	-	NS	NS[a]	NS[a]

P - peat; B - Bavistin; O - Octave
Back-transformed mean values of cubic transformation are shown in parenthesis.
[a] No suitable transformation found; mean values compared using X^2 test.
NS - not significant

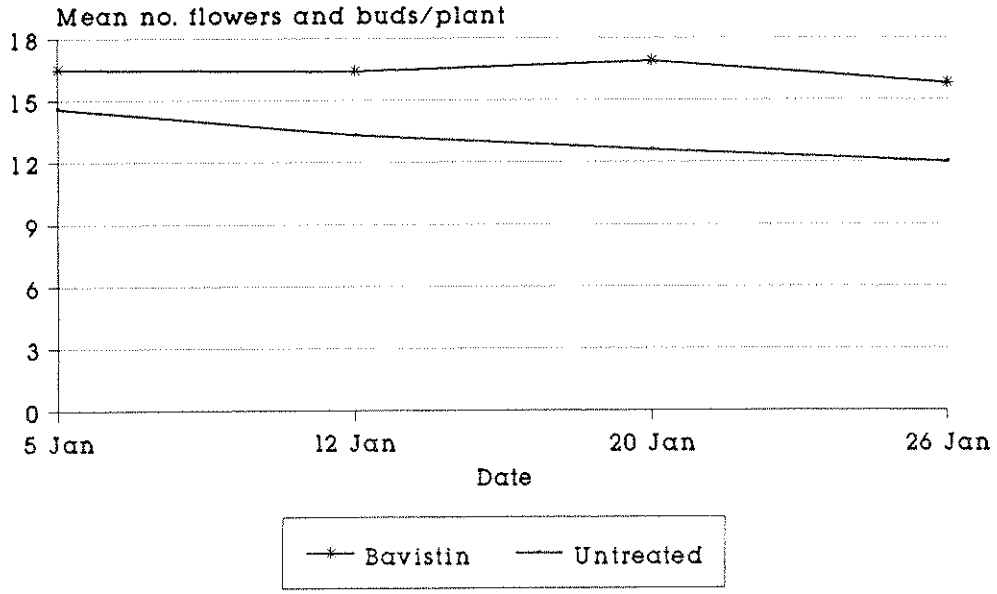
Table 10. Effect of growing media and fungicides on root amount and discolouration (Experiment 2) - 21 December 1993.

	Treatment	Root amount (% surface of root ball)	Root discolouration (0 - 5)
1.	Peat (control)	16.3	3.8
2.	P/B	16.9	3.6
3.	P/B/O	12.2	3.3
4.	P/B/Bark	18.9	3.3
5.	P/B/Chitin	20.0	4.5
6.	P/B/O/Bark	13.9	2.8
7.	P/B/Bark/Chitin	19.1	4.7
8.	P/B/O/Chitin	11.2	2.3
9.	P/B/O/Bark/Chitin	13.2	2.8
	Significance	*	**
	SED (49 df)	1.74	0.60

P - peat; B - Bavistin; O - Octave
* - significant at p = 0.05 ** - significant at p = 0.01

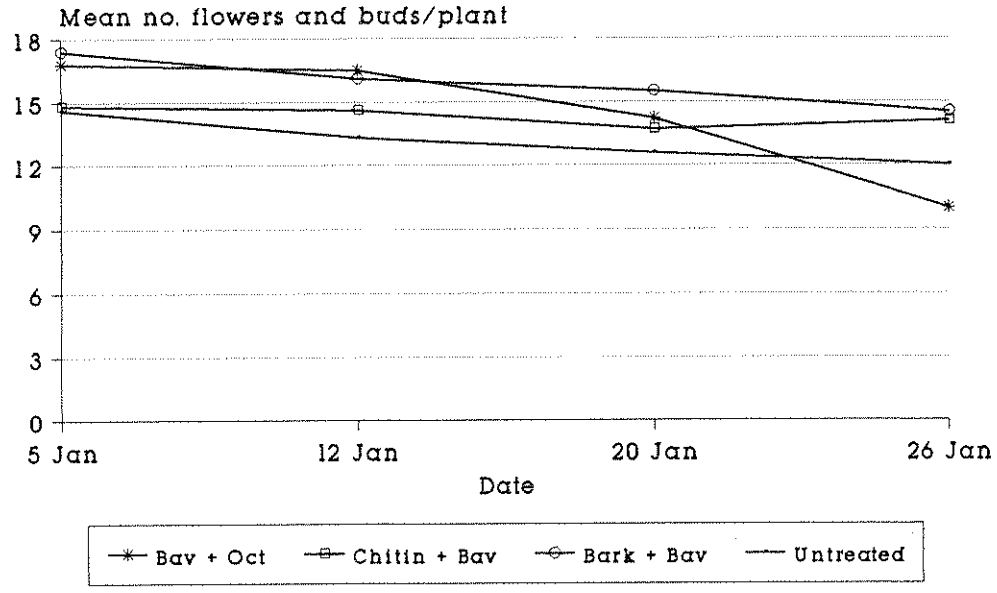
Fig 7. Effect of treatments on shelf life

1 component



Shelf1

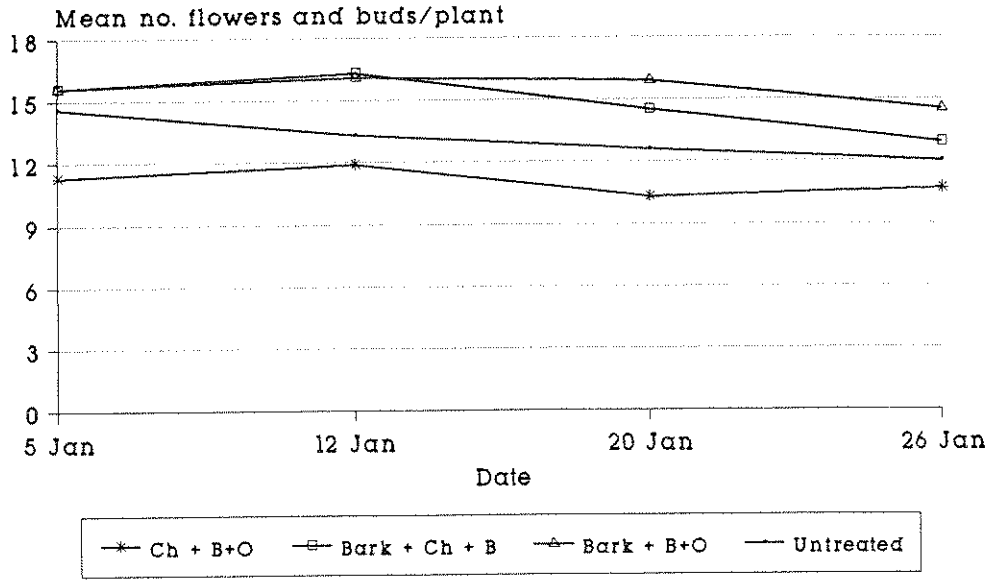
2 components



Shelf2

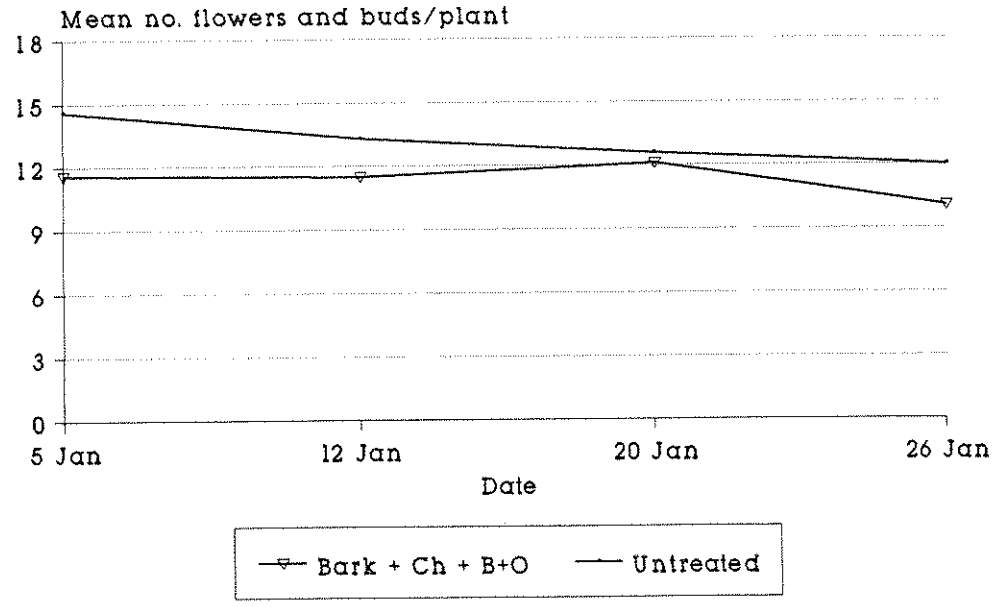
Fig 8. Effect of treatments on shelf life

3 components



Shelf3

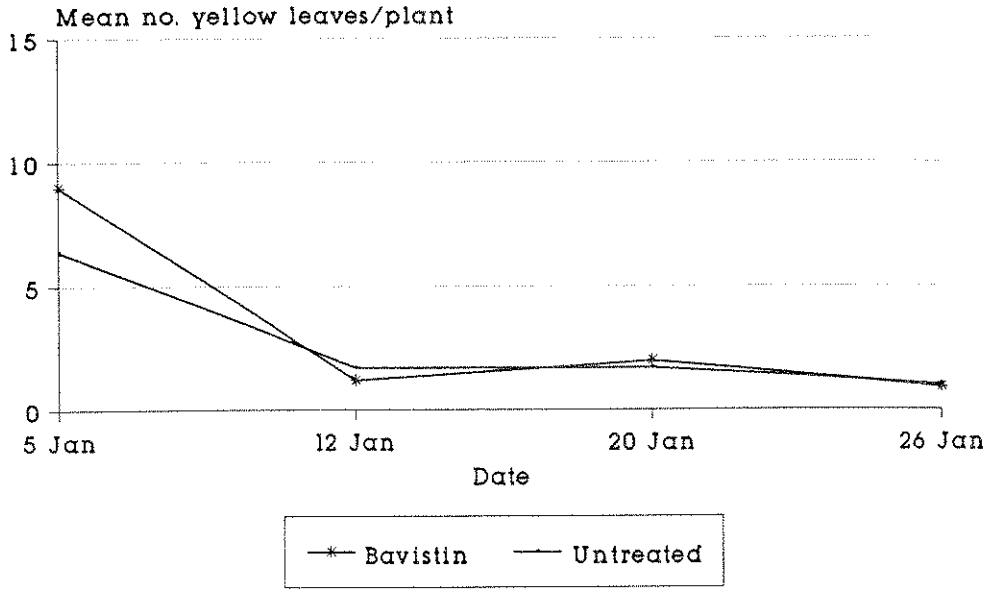
4 components



Shelf4

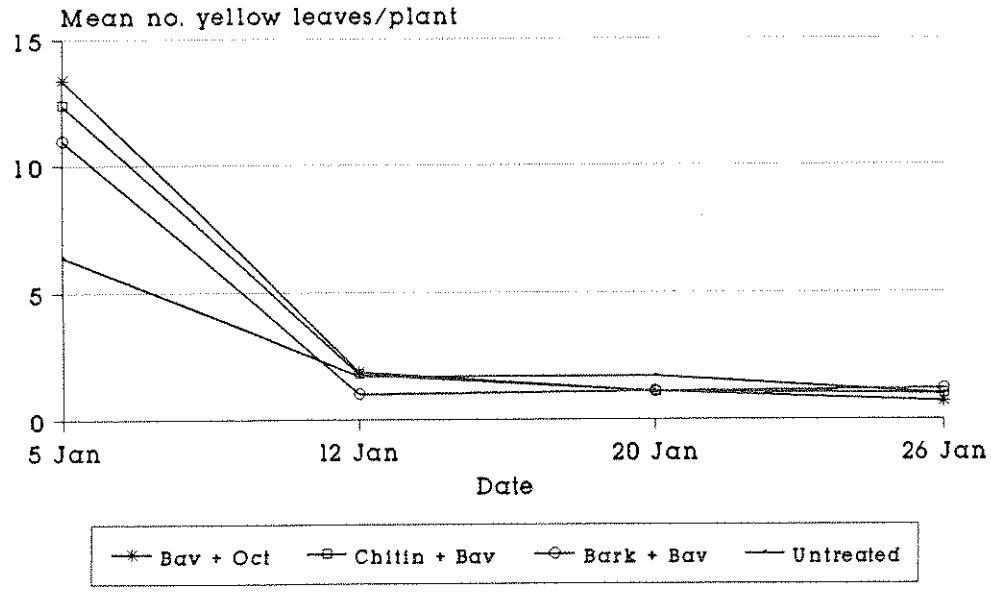
Fig 9. Effect of treatments on shelf life

1 component



Shelf1y

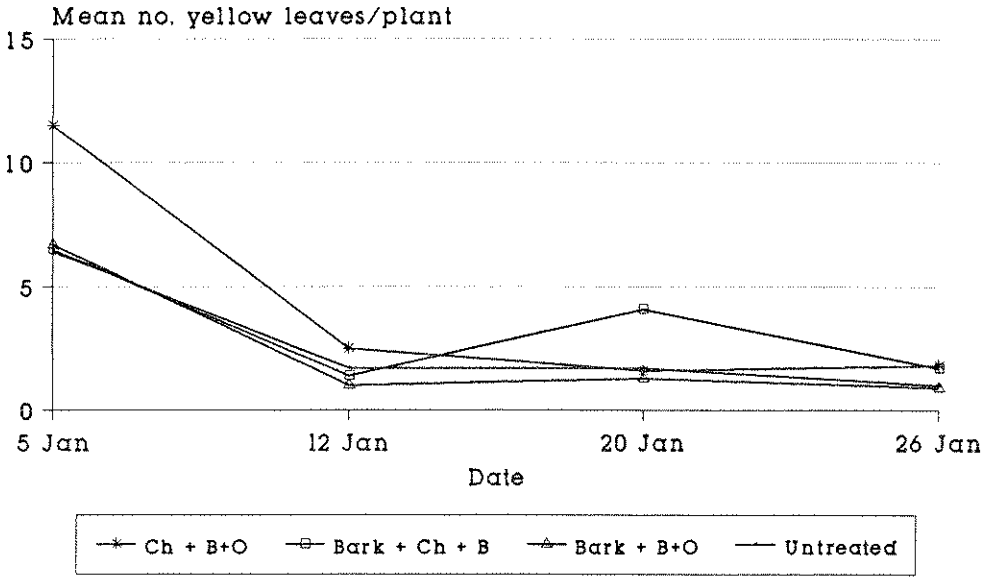
2 components



Shelf2y

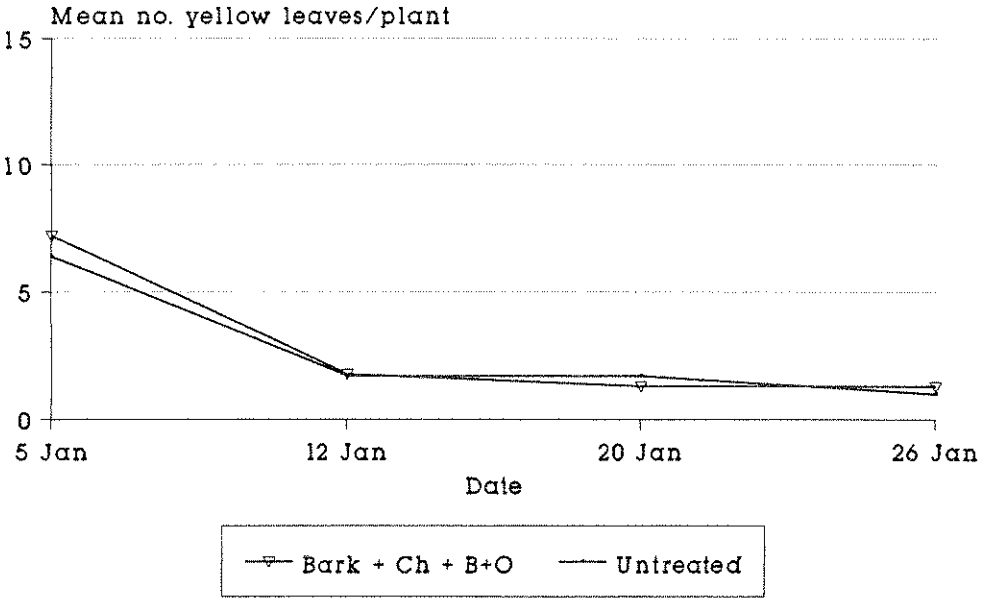
Fig 10. Efffect of treatments on shelf life

3 components



Shelf3y

4 components



Shelf4y

Cost of treatments

The approximate cost of treatments in Experiment 1, excluding cost of application, ranged from less than 1p/pot for a single drench of Bavistin DF to 3.6p/pot for the four-component control treatment (one Bavistin and two Octave drenches; bark and crab shell amendments) (Table 11).

Table 11. Cost of treatments for control of fusarium wilt.

	Treatment	Cost (p/pot)
1.	Peat	-
2.	Peat + Bavistin	0.13
3.	Peat + Bavistin + Octave (x 2)	1.51
4.	Peat + Bavistin + Bark	1.03
5.	Peat + Bavistin + Chitin	1.13
6.	Peat + Bavistin + Octave (x 2) + Bark	2.50
7.	Peat + Bavistin + Bark + Chitin	2.03
8.	Peat + Bavistin + Octave (x 2) + Chitin	2.51
9.	Peat + Bavistin + Octave (x 2) + Bark + Chitin	3.59

Prices used for costing:

Bavistin DF	£13/Kg
Octave	£69/Kg
Bark	£45/m^3
Ocean Supermix (chitin)	£6.25/5Kg

Costs exclude cost of application.

DISCUSSION

In previous experiments on control of cyclamen fusarium wilt (PC50 and 50a) drenching plants with Bavistin or Benlate appeared to reduce occurrence of the disease although differences were not always significant. The lack of control with Bavistin in the experiments reported here may have been because only one drench was applied, rather than multiple drenches at monthly intervals.

Plants drenched once with Bavistin and twice with Octave at 1 g/l had a significantly lower incidence of fusarium wilt than untreated plants (44% vs 75%) 7 weeks after inoculation but there was little difference after 15 weeks. In 1992, plants drenched once with Bavistin and three times with Octave (1 g/l) still had a significantly lower incidence of fusarium wilt than untreated plants (46% vs 95%) 28 weeks after inoculation. Three drenches of Octave at monthly intervals appear to be necessary to prolong disease control under conditions of high disease pressure.

Amendment of peat with bark gave no control of fusarium wilt, contrary to results obtained in 1991 and 1992; the bark used this year was the same grade as one of the treatments used in 1992 when it gave good control. Possibly different batches of the same bark have different fusarium-suppressive capacities. Alternatively, possibly the fusarium-suppressive effect of bark is not expressed when plants are grown with ebb-flood irrigation. In a previous experiment (PC50a) the suppression of fusarium with bark was greater when plants were grown on an open bench and hand-watered than when grown on capillary matting and watered by trickle-irrigation. The water content of a growing medium may affect the suppression of cyclamen fusarium wilt by bark.

Amendment of peat with 1% chitin in the form of crushed crab shells gave good control of wilt in Experiment 1 confirming the result obtained in 1992 (PC50a) using technical grade chitin. At the termination of the experiments growing media amended with chitin appeared to have greater populations of actinomycete bacteria than unamended media; the effect was most evident in Experiment 2. Further work is required to investigate the mechanism of cyclamen fusarium wilt suppression using chitin amendment, and to optimise its effect.

Chitin has previously been shown to reduce the severity of fusarium wilt of peas (Khalifa, 1965). Disease control was associated with a large increase in the number of actinomycete fungi and bacteria in the rhizosphere and a decrease in the population of *Fusarium oxysporum* f. sp. *pisi*. It was concluded that chitin diminished wilt by stimulating micro-organisms that antagonised and/or lysed the pathogen.

Reduction of fusarium wilt of tomato in light-coloured sphagnum peats is reported to be associated with species of the actinomycete *Streptomyces* (Tahvonen, 1993). Suppression of fungal growth by *Streptomyces* species on agar was associated with production of a polyene antibiotic.

Although bark alone gave no control of fusarium wilt in Experiment 1, the effect of Bavistin + Octave + chitin was improved by addition of bark to the growing medium. Hoitink *et al.*, (1991) reported that little was known about the mechanism of suppression of fusarium wilt in amended growing media. Elucidation of the mechanisms of disease suppression using bark and chitin may help to explain the interaction of these disease control factors. If the mechanism is biological, the effect of fungicides on disease suppresion merits further study.

The cost of treatments for control of wilt are low compared with the losses which can occur when fusarium wilt is widespread in a crop. Plants affected by fusarium wilt are usually unmarketable.

Growing medium amendments are preferable to fungicide drenches for control of wilt for three reasons:

1. There is minimal extra labour cost
2. Some protection against fusarium wilt is present from soon after potting
3. Use of amendments may result in a reduction in fungicide use.

However, growing medium amendments such as bark and chitin are likely to be most effective at low disease pressure and may provide less effective disease control when disease pressure is high. The results of the experiments reported here indicate that an integrated strategy, including fungicides, offers the most effective control when disease pressure is high, as in inoculated experiments.

CONCLUSIONS

1. A single drench of Bavistin soon after potting and before inoculation with *F. oxysporum* f. sp. *cyclaminis* gave no control of fusarium wilt.

2. Amendment of the growing medium with crushed crab shells, or drenching plants with Octave or Mycostop reduced the occurrence of fusarium wilt. Mycostop alone applied at 3-week intervals gave disease control equal to the four-component control treatment.

3. In these experiments, bark alone gave no control of fusarium wilt, contrary to the results of previous experiments (PC50 and 50a).

4. Amendment of peat with bark improved the control of fusarium wilt given by crab shell amendment and Octave drenches.

5. Increasing the number of disease control components increased the level of control.

6. The cost of treatments for control of fusarium wilt ranged from less than 1p/plant (1 Bavistin drench) to 3.6p/plant (1 Bavistin and 2 Octave drenches; bark and crab shell amendments).

7. Amending the growing medium with 40% bark and 1% crushed crab shells, and drenching plants once with Bavistin (1 g/l) and twice with Octave (1 g/l) did not adversely affect final plant quality.

8. Disease spread from inoculated plants to healthy plants on an ebb-flood bench with the irrigation water run-to-waste took at least 13 weeks from the time of inoculation (9 weeks from the time inoculated plants showed symptoms).

9. Disease spread from infector plants to adjacent healthy plants on capillary matting took at least 11 weeks from the time of introduction of wilt-affected plants.

10. Drenching plants with Octave slightly reduced root extent but did not affect plant height, spread, quality or shelf-life.

11. Plants affected by fusarium wilt appeared to flower slightly earlier than unaffected plants.

12. *Botrytis cinerea* and *Cylindrocarpon destructans*, as well as *F. oxysporum* f. sp. *cyclaminis*, may cause vascular discolouration within cyclamen corms.

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ACKNOWLEDGEMENTS

Funding of this work by the Horticultural Development Council is gratefully acknowledged. The work was carried out jointly by staff of ADAS Cambridge (Crop Science Team) and HRI Efford. Harry Kitchener and Selwyn Richardson (ADAS Huntingdon) and Lyndon Mason (ADAS Kings Lynn) provided valuable assistance. The cyclamen plants were kindly donated by Colegraves Seeds Ltd and Royal Sluis Ltd. Samples of Mycostop, bark and Ocean Supermix were provided by Kemira Oy (Finland), Melcourt Industries Ltd and Ocean Organics Ltd respectively, and all are gratefully thanked.

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

1. TITLE OF PROJECT **Contract No: PC/50b**
Contract date: 13.8.93

CYCLAMEN: EVALUATION OF INTEGRATED CONTROL SYSTEMS FOR THE CONTROL OF FUSARIUM WILT

2. BACKGROUND AND COMMERCIAL OBJECTIVE

As for PC50a.

3. POTENTIAL FINANCIAL BENEFIT TO THE INDUSTRY

As for PC50a.

4. SCIENTIFIC/TECHNICAL TARGET OF THE WORK

As for PC50a.

5. CLOSELY RELATED WORK - COMPLETED OR IN PROGRESS

See Project Reports for PC50 and PC50a.

6. DESCRIPTION OF THE WORK

Treatment

1. Peat	Control
2. Peat + Bavistin (x 1)	Standard treatment
3. Peat + Bavistin + Octave (x 2)	)
4. Peat + Bavistin + Bark (40%)	) 1 extra control factor
5. Peat + Bavistin + Chitin (10g/litre)	)
6. Peat + Bavistin + Octave (x 2) + Bark	)
7. Peat + Bavistin + Bark + Chitin	) 2 extra control factors
8. Peat + Bavistin + Octave + Chitin	)
9. Peat + Bavistin + Octave (x 2) + Bark + Chitin	) 3 extra control factors

Cropping Details

	HRI Efford	Commercial Nursery, Norfolk
Variety:	Sierra White with Eye	Zodiac
Irrigation:	Capillary matting	Sub-irrigation to waste
Infection method:	Infector plants (natural disease spread)	Spore drench
Plot size	12 + 1	16
Replication:	8 (trt 1) & 7 (trts 2-9)	4
Total Plant No:	768 + 64, infectors	640
Run time:	July - December	July - December
Design:	Reduced Latin square (8 x 8)	Randomised blocks

Contract No: PC/50B

TERMS AND CONDITIONS

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

Signed for the Contractor(s)

Signature.....J. Ashdown.....

Position.Head of Hosting Corp. Development Centre

Date.....25/8/93.....

Signed for the Contractor(s)

Signature.....

Position.....

Date.....

Signed for the Council

Signature.....

Position.....CHIEF EXECUTIVE

Date.....13.8.93.