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The results and conclusions in this report are based on an investigation conducted over a one-year period. The results have been reported in detail and with accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.

AUTHENTICATION

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

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Grower summary

Headline

Choisya root rots, mainly caused by species of *Phytophthora* and *Thielaviopsis basicola*, are linked to plant stress caused by high temperatures or poor drainage.

Background and expected deliverables

Choisya are prone to root rots resulting in a loss of crop vigour and marketability. Root rot can result in up to 60% crop losses. Losses in recent years may equate to tens of thousands of pounds in lost sales. There have been reports that *Choisya ternata* cv. Sundance is the worst affected variety on most UK nurseries. *Choisya* species naturally grow on rocky slopes in the USA and Mexico where their rooting environment is extremely free draining. It is possible that some growing conditions on nurseries may favour the development of root rots. Recognising contributory factors to losses, including the identification of potential pathogens, is essential to enable the correct decisions to be made for control.

The project was undertaken to collate information on pathogens affecting *Choisya.* Growers of the crop were also surveyed to record current husbandry and best practice. The aim was:

1. To determine whether there are consistent husbandry factors in the production stages of *Choisya* that affect the incidence of root rotting.
2. To collate information on fungal pathogens most consistently associated with root rot in *Choisya.*

Summary of the project and main conclusions

Information from *Choisya* samples received by four British plant clinics and 21 UK *Choisya* growers showed root rotting to be widespread, and attributable across the samples to several fungal species. *Phytophthora* spp. *Thielaviopsis basicola, Pythium* spp., *Fusarium* spp. and *Rhizoctonia* sp. were all recorded, with *Phytophthora* spp., and *T. basicola* both dominating the pathogen species isolated by the Food and Environment Research Agency (Fera) plant clinic. *Armillaria* spp. were also important in samples received by the Royal Horticultural Society (RHS), but were not reported from commercial nurseries. Only the RHS plant clinic identified the *Phytophthora* species isolated, with *P. citricola, P. cryptogea, P. cinnamomi, P. nicotianae and P. citrophthora* recovered. The RHS also identified some *Pythium* species, including the pathogenic *P. ultimum.* At ADAS it was shown that more than one pathogen can occur in a single plant, with combinations of *Phytophthora* sp. plus *Pythium* spp., *Rhizoctonia* sp. plus *Pythium* spp., and *Fusarium* sp. plus *Pythium* spp.

In both France and Italy, *Phytophthora* spp. was isolated from *Choisya* together with *Fusarium* spp. In the USA, *Phytophthora* spp. and *Rhizoctonia* sp. were recorded. In southern France *Fusarium* spp. and *Pythium* spp. supplanted earlier root infection by *Phytophthora* spp., contributing to plant death. French research showed that water stress increased *Choisya* susceptibility to infection, with greater plant survival on capillary beds compared with overhead irrigation, particularly if shaded. In the hot conditions of the south of France, plants potted with more peat than wood-fibre had less disease, probably because the roots retained more moisture and so had less heat stress.

The symptoms and epidemiology of the root rots identified on *Choisya* were reviewed. The growth of *Pythium* spp. was favoured at the lowest temperatures of 10-15°C, growth of *T. basicola* between 17-23°C, and *Phytophthora* spp. (in particular *P. cinnamomi*) were favoured by higher temperatures of 20-30°C. *Pythium* spp. and *Phytophthora* spp. zoospore spread is favoured by wet conditions.

Seventy-five percent of the nurseries surveyed had experienced some *Choisya* loss to root rot. The proportion of pots lost to root rot ranged from less than 5% to 50%, with liner losses reported from across this range. At the final pot size most growers lost 5% or less of their stock. There were higher incidences of root rot in *C. ternata*, *C. ternata* cv. Sundance and *C. x derwitteana* cv. Aztec Pearl compared with *C. x derwitteana* cultivars Goldfinger and White Dazzler. Growers reported the diagnosis of *Phytophthora* root rot on *Choisya* more frequently than that of other pathogens, but black root rot (*T. basicola*) and *Pythium* root rot were also confirmed on a number of samples in the last five years. Fungicides and bio-stimulants were applied to *Choisya* to reduce root rotting.

Root rots or reduction in vigour became apparent to a number of growers between May and August. Where growers were potting early in the season, from late February to early April, most reported a reduction in losses. It was important to get plants well established before the onset of hot weather and to achieve fast establishment by not over-potting. Most crops were grown under protection, and there was less root rotting where a range of measures was used to reduce heat stress, including shading and ventilation. Potting *Choisya* into a well-drained mix (containing 15 – 50% bark / wood fibre) also aided establishment resulting in a reduction in losses. Grading plants prior to potting reduced root rotting as smaller plants were kept apart from more strongly growing material and so not over-watered. Most growers watered plants overhead, and principally used either mains water or water from boreholes.

Financial benefits

The findings of this research report will enable growers to reduce the unacceptable losses experienced in recent years. Production planning can be improved so that potting can be scheduled to a time of year when losses should be minimal. This combined with other cultural techniques should reduce losses and thereby increase profitability. Staff costs relating to *Choisya* production are also likely to reduce with less time spent removing affected plants. Recognition that several fungal species can cause *Choisya* root rot should ensure that diagnosis is sought and the appropriate fungicides are then selected. It is estimated that the information contained within this report will enable growers to save £500 for every 1000 finals produced, due to reductions in wastage. Changes in production scheduling will not result in additional capital expenditure on most nurseries.

Action points for growers

- Pot *Choisya* liners and stock for summer sales by April.

The following points could also help to minimise losses, particularly where stock is potted later than April:

- thorough plant grading prior to potting;
- a high % of bark / wood fibre in the growing medium (air-filled porosity Index 2);
- careful grading to prevent smaller plants sitting wet;
- good irrigation management with a well-drained growing medium;
- good bed drainage (e.g. Mypex over sand rather than soil);
- blanket shading from May / June to September or production under milky polythene;
- good ventilation to prevent excessive temperatures within protected structures;
- regular applications of potassium phosphite (e.g. fortnightly);
- select appropriate fungicide drench products according to the diseases present.

Science Section

1. Introduction

The *Choisya* species *C. dumosa and C. ternata* (Mexican Oranges) in the family *Rutaceae*, grow naturally on rocky slopes in the USA and Mexico. Container-grown nursery stock plants of these species can be prone to root rots, resulting in a loss of crop vigour and marketability. High losses can occur in hot summers when plants are likely to suffer from water stress, but losses also occur in poorly drained pots in cooler weather. It is not clear how growing conditions affect root rotting, and whether diseases play a primary or secondary role.

Diagnosis of growing problems with *Choisya* is often done on site by consultants and growers, but both nurseries and gardeners also send material to plant clinics for diagnosis. *C. ternata* cv. Sundance and the hybrid *C. x dewitteana* Aztec Pearl are common cultivars on UK nurseries. There is an impression in the industry that cv. Sundance tends to be the more frequently affected by growing problems, but it is not clear whether inherent differences in cultivar susceptibility do exist. Information on the identity of any pathogenic micro-organisms or physiological causes of poor growth from specific samples, supplemented by a literature review, will help in the understanding of the ongoing problem of *Choisya* root rot.

The aims of this project are to determine the situations in which root rotting of *Choisya* has occurred, and the pathogens or other factors involved in losses. This will enable control options to be formulated for testing in future work. The work will be carried out using the following objectives:

<u>Objective 1</u>
To carry out a preliminary literature review, and devise a questionnaire for use in a grower survey on production methods and root rot in *Choisya*. To use the questionnaire supplemented by telephone contact and nursery visits to key producers.

<u>Objective 2</u>
To gather information from plant clinics on the diagnoses made on *Choisya* samples submitted with root rots. To review the scientific literature on potential pathogens and pests that may cause *Choisya* root rot.

Objective 3

To report the information collected in Objectives 1 & 2. To propose areas of work that would help in the control of *Choisya* root.

2. Sources of information

Internet sites were searched (worldwide, and UK-only) for information on *Choisya, Choisya* root rots, and *Choisya* plus each fungal species identified in the grower survey or clinic records. Further searches were carried out for individual pathogens. Search engines (e.g. Google Scholar, Science Direct) were used and relevant websites (e.g. extension / advisory services and scientific publishers) were searched directly for relevant information. Compendiums of plant disease were examined for references to *Choisya.*

3. Survey of *Choisya* growers

Twenty-one UK nurseries producing *Choisya* were surveyed as part of nursery visits or via telephone using a standard set of questions (Appendix 1) in order to determine whether particular husbandry procedures such as growing medium, timing of potting-on and irrigation method, might have had an influence on the establishment, vigour and health of the plants grown over the last 5 years (2004 – 2009). Differences were likely to exist in growing systems, crop management and microclimates between nurseries. Growers were asked to quantify their losses to root rot at production stages from cutting to final container, and to name any disease that had been diagnosed. Several growers volunteered further information on practices that they believed enabled them to produce a high quality crop. Data from the survey was analysed by C. Dyer, ADAS Biometrician.

3.1 Results of questionnaire

The majority of replies from growers on their crop husbandry are tabulated in Appendix 2. Key results are discussed below.

3.1.1 Plant losses to root rot

Seventy-five percent of the nurseries surveyed had experienced some plant loss to root rot.

There was a higher incidence of root rot in some *Choisya* cultivars than others. Percentage losses were averaged for each of the following *Choisya* species / cultivars; *C. ternata* cv.

Sundance 13%, *C. ternata* 12%, and the *arizonica* x *ternata* hybrid, *C. x derwitteana,* cultivars Aztec Pearl 15%, Goldfinger 5% and White Dazzler 4%.

Many growers (43%) noted root rot or loss of vigour between May and August, with only 19% reporting these problems in the 7 months between September and April (Table 3.1). However, 38% could not identify a particular month when loss became apparent (a statistically similar proportion to those citing May to August). Most growers (75%) thought that losses varied between years.

Table 3.1: Key months that root loss or a reduction in vigour becomes apparent in the life of container-grown *Choisya* in the UK

Period in which losses were seen	Number of growers seeing plant losses
No particular month	8 (38%)
January – April	2 (9.5%)
May – August	9 (43%)
September – December	2 (9.5%)

Liner losses reported by growers were equally divided between 5% or less, 6-15% and 16-50% of plants. Growers most commonly reported 5% or less lost at the final pot size, statistically significantly more than in any other loss category (Table 3.2). There were no clear regional differences in the incidence of plant losses.

Table 3.2: Losses of *Choisya* in liner and final pot size, categorized by percentage on different nurseries

Proportion of pots lost to root rot	Number of growers reporting losses in liner production	Number of growers reporting losses in final pot size
5% or less	3	9
6-15%	3	2
16-30%	1	1
31-50%	2	1
> 50%	0	0

Most growers (75%) had sought to identify the cause of root rotting (Table 3.3). This would previously have required samples to be sent to a plant clinic, but with the availability of Lateral Flow Devices (www.pocketdiagnostic.com), it has been possible to detect the presence of either *Pythium* or *Phytophthora* species in plant tissue while on site. The survey confirmed that species of *Phytophthora, Thielaviopsis, Fusarium, Rhizoctonia* and *Pythium* have all been found in commercial crops of *Choisya* within the last 5 years.

Table 3.3: Identity and frequency of pathogens confirmed on *Choisya* on commercial nurseries in the last 5 years

Fungal genus	Number of cases
Phytophthora	8
Pythium	4
Thielaviopsis	3
Rhizoctonia	1
Fusarium	1

3.1.2 Crop husbandry and effect on root rotting

Choisya was mainly grown under protection (both polythene and glass), with only four growers having outdoor crops.

A third of growers produced their own cuttings for liner production. Grade-outs because of variable growth at this stage were not included in the losses attributed to root rot. Bought-in liners would be potted-on soon after delivery. Many (43%) of growers both bought in and produced their own liners, and no differences in plant health were reported between sources.

Of the 16 growers who took some or all of their own cuttings, 15 took cuttings between May and August, and eight between August and November, some therefore taking material at both times of year. Fewer cuttings were lost to root rot by growers who struck before August. The use of either pre-formed plugs or own-filled trays was equally divided, and there was no additional reporting of root rotting from growers who favoured either one method.

Half of growers pot their liners between the end of February and April. Around 40% pot liners between May and June and 10% between September and October. A lower incidence of rotting was reported by growers that potted liners either early (before April) or late (in September). All of the liner producers surveyed potted on rooted cuttings between February and April. The survey highlighted the fact that final potting dates are related to sales periods. Stock potted in the spring (February to April / May) being destined for summer sales and stock potted in summer / early autumn (May to September) for early spring sales. Where liners are bought in, potting dates are often dictated by delivery dates.

More than twice as many growers potted by machine as potted by hand. Root rot was recorded regardless of the method of potting.

Some growers produced only young plants, but of those producing mature plants the most common final pot size was 3 L, requiring on average a 24-month production period. A number of growers pot either two or three litre plants into 5 or 10 L pots in order to produce specimen plants. During production differences were reported between growers in their husbandry techniques.

Most growers (80%) used between 15 – 50% bark / wood fibre in their growing media mixes. Liner producers use between 30 and 50% bark or a free draining mix containing bark and coir. The three growers using the highest percentage of bark (30 and 33%) or wood fibre (30%) in the final potting mix, reported average losses of less than 5% which is statistically significantly lower than some other growers.

Most nurseries had more than one source of water, with the majority using mains and / or water abstracted from boreholes. These water sources were supplemented with river water, roof water, collected and recycled water and other sources. Application to crops was mostly overhead via spray lines / gantry systems.

The majority of crops were produced under shading, statistically significantly more than without. Shading may minimise losses in hot summers. Some growers said that shading was essential whilst others grew good crops without shading. The majority of those surveyed applied shade-paint to glass from April / June through to the early September. Other means of summer shading included: growing under milky polythene throughout the production period, using automated shading, partially shading the glass with shade paint and with automatic shading or suspending white fleece over wires. The use of shading was not related to the location of the nurseries within the UK, as many growers in the north used it as in the southern counties.

Growers used a range of fungicides, microbial products, bio-stimulants and other products (Table 3.4), however programme details such as the frequency of application were not recorded as part of the survey. Products were being used that would control Oomycetes such as species of *Phytophthora* and *Pythium,* and also products that would control *Thielaviopsis basicola.* It was not recorded whether these were applied as preventative measures (i.e. before disease was seen in any plants in the batch), or used to halt the spread from infected plants. Most nurseries monitored sciarid flies and implement controls where necessary. Given the revocation for use of key active substances and plant protection products (pesticides) under Annex 1 of 91/414 and other legislation, growers have shown increased use of bio-stimulants.

Growing medium incorporation of products containing *Trichoderma* species, such as DCM Bio-Fungus Instant and Trianum (carried out by the growing media supplier), were reported to have reduced losses post-potting. Compost tea was the most widely used bio-stimulant, with use as a foliar spray rather than through the irrigation supply during the winter when the root ball was sufficiently wet. Potassium phosphite foliar fertiliser was used by some growers. A few growers were evaluating the benefits of Worm cast tea.

Table 3.4: Fungicides and bio-stimulants used in crop production by surveyed commercial growers of *Choisya*

Fungicide product	Number of growers using specific fungicides	Bio-stimulant	Number of growers using specific bio-stimulants
Subdue	11	Compost tea	8
Aliette 80 WG	10	Trianum	5
Octave	10	Potassium phosphite	4
Repulse	2	Agrilan Revive	3
		Worm cast tea	2

3.2 Additional information from growers

Growers reported poor establishment, root rot and die-back of *Choisya*. Losses were reported to vary between years on most nurseries and seem to be greater in the majority of cases in hot summers. Several growers mentioned a number of key practices that were believed to influence the production of a successful crop:

1. Pot early in the year (in late February or early March) just as plants start to grow, so that they establish before hot weather.
2. Ensure that liners are even and well-rooted and graded so that smaller liners are not sat too wet. Timing the production of liners for the planned potting date is important. Quality of liners, particularly the roots, is of great importance.
3. Pre-potting treatments (fungicide drenches), where necessary, can be beneficial.

The following factors were believed to contribute to losses:

1. Potting on uneven liners or liners that are not fully rooted out.
2. Hot summers seem to stress crops, particularly if plants are not well established.
3. Late potting in hot years (after April): temperatures over 30ºC can cause extensive problems.
4. High temperatures can cause flash releases of fertiliser that may contribute to plant stress and root damage.

5. Poor weather and excessive rainfall that causes crops to sit too wet outdoors. Plants in leaking glasshouses or under gutters were also liable to sit too wet.
6. Poor drainage from pots.

In addition to shading, other factors mentioned by growers that were thought to be beneficial to crop growth and seemed to minimise losses were:

1. Growing the crop outside.
2. Uncovering polythene tunnels in summer.
3. Potting in late February / early March and growing on a dry regime.
4. Growing in tunnels where side vents can be opened up to the roof.
5. Potting early in the season into growing media containing Trianum G (*Trichoderma,* microbial growth stimulant).
6. Drenching with Aliette 80 WG (fosetyl aluminium) if temperatures exceeded 30 ºC. If there was more than a month of hot weather, potassium phosphite was also applied.
7. Drenching plants with Subdue (metalaxyl-M) prior to potting, with potting done early in the season to establish crops when it is cool.
8. Ensuring that liners had sufficient nutrients prior to potting.
9. Monitoring moisture levels to avoid over watering, especially on late-potted batches.
10. Maintaining water levels at the bare minimum over winter.

Fungicides were considered important in order to maintain root health, although cultural conditions such as good drainage can reduce the need for fungicide applications. Aliette 80WG, Subdue and Octave were the most widely used fungicides by the growers surveyed. Fungicides that are currently approved for use on ornamental crops are shown in Table 3.5.

Table 3.5: Fungicides with full approval / specific off-label approval (SOLA) for use in ornamental plant production

Product name	Active ingredient	Examples of fungal species controlled	Approval status
Invader	dimethomorph + mancozeb	*Phytophthora*	Off-label use at growers' own risk under the Revised Long Term Arrangements for Extension of Use (2002) as a SOLA is currently being sought.
Aliette 80 WG	fosetyl-aluminium	*Phytophthora, Pythium*	On-label approval for this use.
Standon Fullstop	fosetyl-aluminium	*Phytophthora, Pythium*	On-label approval for this use.
Previcur Energy	fosetyl-aluminium + propamocarb hydroxide	*Phytophthora, Pythium*	SOLA 2667/2008 for use on this crop.
Rovral WG	iprodione	*Rhizoctonia*	On-label approval for this use.
Subdue	metalaxyl-M	*Phytophthora, Pythium*	On-label approval for this use.
Scotts Octave	prochloraz	*Fusarium, Thielaviopsis*	On-label approval for this use.
Filex	propamocarb hydroxide	*Phytophthora, Pythium*	On-label approval for this use.
Pan PCH	propamocarb hydroxide	*Phytophthora, Pythium*	On-label approval for this use.
Proplant	propamocarb hydroxide	*Phytophthora, Pythium*	On-label approval for this use.
Cercobin WG	thiophanate-methyl	*Fusarium, Thielaviopsis*	SOLA 1384/2008 for use on this crop

4. Survey of Plant Pathology Clinic Reports on *Choisya*

4.1 Direct contact with plant pathologists, and results of plant clinic diagnoses

Plant clinic sample information on *Choisya*, covering the period 1996 to 2008, contributed by (Fera) (Charles Lane and Anne Barnes, pers. comm., 2008) showed a range of diagnoses throughout the years (Table 4.1). Across the years, either species of *Phytophthora*, or *Chalara elegans / Thielaviopsis basicola* (synonymous) were recorded from a similar number of samples (six and eight samples, respectively). Samples with either disease were all received in between July and October. *T. basicola* was the only disease isolated in 2002. One sample originated in the Netherlands; otherwise they were from the UK. Information was not available on the cultivars submitted.

Foliar pests reported by Fera such as the carnation tortrix moth (*Cacoecimorpha pronuba*) and the cottony cushion scale (*Icerya purchase*) were unlikely to have caused die-back, but the leaf and bud nematode (*Aphelenchoides ritzemabosi*) can cause ornamentals to have stunted growth and discoloured leaves (Buczacki and Harris, 1989) and could be mistaken by growers for fungal die-back.

Bacteria were also occasionally recovered by Fera. *Pseudomonas syringae* causes a blight with blackening and wilting (Buczacki and Harris, 1989), and *Pectobacterium chrysanthemi* (syn. *Erwinia chrysanthemi*) causes stunting, yellowing and wilting on various plants (Bradbury, 1977). Both bacteria could thus be included in causes of die-back symptoms.

In the Fera survey, although seven samples were tested for virus infection, the tests were negative. In all but one of these cases, no other cause was determined.

Table 4.1: *Choisya* leaves and whole plant samples received by CSL (now Fera) Plant Clinic between 1996 and 2008. Dates each sample was received and diagnosis

Date received	Disease	Pest	Negative / Other
30-Oct-96	*Colletotrichum acutatum*		
03-Nov-97			No virus
02-Apr-98	*Glomerella cingulata*		
19-Aug-98			Negative
26-Aug-99		*Aphelenchoides ritzemabosi*	
23-Mar-00			Cultural
01-Dec-00	*Pseudomonas syringae*		
29-Jan-01	*Pseudomonas syringae*	*A. ritzemabosi*	

Table 4.1: continued

09-May-01			Cultural
20-Jun-01	*Phytophthora spp.*		
30-Jul-01			Chemical Damage
05-Sept-01			No pest. No virus
06-Sep-01			No pathogen
04-Oct-01	*Erwinia chrysanthemi* *Phytophthora spp.*		
17-Jan-02	*Chalara elegans*		
22-Mar-02		*Cacoecimorpha pronubana*	
16-Jul-02			Chemical Damage
08-Aug-02		*Icerya purchasi*	
11-Sep-02	*Chalara elegans*		
03-Oct-02	*Chalara elegans*		
15-Oct-02	*Chalara elegans*		
24-Oct-02			No pathogen. No virus
11-Nov-02		*I. purchasi*	
16-Jul-02	*Phytophthora spp.*		No pest
13-Aug-03			No pathogen
22-Aug-03	*Chalara elegans*		
02-Sept-03	*Chalara elegans* *Phytophthora spp.*		
10-Sep-03			No pathogen
18-Sep-03			No pathogen
29-Sep-03			Cultural
06-Oct-03			No virus
27-Nov-03			No virus
26-Feb-04			No pathogen
04-Aug-04		*Trialeurodes vaporariorum*	
01-Aug-05	*Phytophthora spp.*		
03-Aug-05		*T. vaporariorum*	
03-Oct-05			No pest. Physiological
29-Nov-05			No pathogen
25-Apr-06			No pathogen
26-Sep-06	*Phytophthora spp.*		
10-Oct-06	*Thielaviopsis spp.*		
19-Jan-07		*C. pronubana*	
24-Oct-07	*Thielaviopsis spp.*		Negative - No virus
05-Feb-08	*Phytophthora ramorum*		
22-Feb-08			No pathogen
06-Nov-08			No pathogen. No virus

Identification of *Phytophthora* to species level was not carried out at Fera, other than for the notifiable *Phytophthora ramorum* recorded from one sample of *Choisya* leaves and likely to have been causing a leaf blight or dieback.

The Royal Horticultural Society (RHS) plant clinic receives plants from RHS members (Table 4.2) (Béatrice Henricot, pers. comm., 2008). Samples are mainly from members of the public and likely to be from plants transplanted into gardens. The record contributed to this report covers samples received from1998 to 2008. During this period the majority of samples (22) had *Armillaria* spp. Ten samples were found to have a *Phytophthora* species. Plants with *Phytophthora* spp. infection were received between March and December, with the majority in September.

Table 4.2: *Choisya* samples received by the RHS Plant Pathology Clinic between 1998 and 2008. Date each sample was received and diagnosis

Date Received	Disease	Negative/Other
09-Apr-98		No diagnosis
23-Apr-98	*Phytophthora* spp.	
15-May-98	*Armillaria* spp.	
07-Jul-98	*Phytophthora* spp.	
20-Jul-98		Sooty mould
12-Aug-98		No diagnosis
28-Sep-98		Insufficient material
18-Jan-99		Insufficient material
23-Feb-99	*Armillaria* spp.	
23-Mar-99	*Armillaria* spp.	
05-May-99		Insufficient material
25-May-99		No diagnosis
23-Feb-00		Insufficient material
17-Mar-00	*Phytophthora* spp.	
03-Apr-00		Insufficient material
05-Apr-00		Insufficient material
05-May-00		Insufficient material
07-Jul-00		Insufficient material
05-Apr-01	*Armillaria* spp.	
25-Apr-01		Root stress
29-May-01		Insufficient material
22-Jun-01		No pest or disease
04-Jul-01	*Armillaria* spp.	
02-Oct-01	*Armillaria* spp.	
07-Nov-01		No diagnosis
18-Mar-02		Insufficient material
08-Apr-02		Insufficient material
12-Apr-02		Insufficient material
17-Apr-02		Insufficient info.
09-May-02		Insufficient material
19-Aug-02	*Armillaria* spp.	
07-Oct-02	*Armillaria* spp.	
28-Oct-02	*Armillaria* spp.	
28-Oct-02	*Armillaria* spp.	
26-Feb-03	*Armillaria* spp.	
12-Mar-03	Leaf spot	
13-Mar-03	*Armillaria* spp.	
15-Apr-03		Insufficient material
05-May-04		Stress
10-May-04		Saprophytic fungus
07-Jun-04		Insufficient material
01-Jul-04	Root rot	Identity unconfirmed
08-Sep-04		No diagnosis

Table 4.2: continued

12-Oct-04		Insufficient material
22-Oct-04	*Armillaria* spp.	
20-Dec-04	*Armillaria* spp.	
05-Jan-05		No diagnosis
30-Mar-05	*Armillaria* spp.	
26-Apr-05		Insufficient material
17-Jun-05	*Armillaria* spp.	
13-Jan-06	*Armillaria* spp.	
16-Feb-06	*Armillaria* spp.	
27-Mar-06		Physiological
18-Apr-06	*Phytophthora* spp.	
21-Apr-06	*Armillaria* spp.	
07-Jun-06		Frost
03-Aug-06	*Armillaria* spp.	
23-Aug-06	*Phytophthora citricola.* *Phytophthora citrophthora,* *Phytophthora cryptogea*	
14-Sep-06		Nutrient deficiency
25-Sep-06	Damping off	
21-Feb-07		Insufficient material
23-Feb-07		Insufficient material
18-Apr-07		Insufficient material
29-Jun-07	*Armillaria* spp.	
12-Jul-07		Insufficient material
03-Sep-07	*Phytophthora cryptogea*	
13-Sep-07		Insufficient material
24-Sep-07		Insufficient material
27-Sep-07	*Phytophthora cinnamomi.* *Phytophthora nicotianae* *Pythium* sp.	
27-Dec-07	*Phytophthora citricola*	
27-Dec-07	*Pythium* sp.	
18-Feb-08		Insufficient material
21-Apr-08	*Armillaria* spp.	
17-Jun-08		No diagnosis
08-Aug-08		Insufficient material
04-Sep-08		Insufficient material
22-Sep-08		Insufficient info.

Further information was available on *Pythium* and *Phytophthora* species as part of a research project at RHS using DNA sequencing (Geoff Denton, pers. comm., 2008). Samples were obtained for sequencing either directly from tissue samples, or by using apple baited with infested soil. *Pythium* species were recovered from soil, but were not identified as they were either new species or species for which DNA sequences are not available for comparison (Béatrice Henricot, pers. comm., 2008). *Choisya* was confirmed as a potential host for *Phytophthora cryptogea* (Denton, 2008). The particular *Phytophthora* species isolated varied depending on whether roots, soil or stem isolations were made (Table 4.3).

Table 4.3: Isolation sites and identity of *Phytophthora* species recovered from roots, soil and stems of some *Choisya* samples examined by the RHS

Root	Soil	Stem
P. citricola	*P. citricola*	*P. citrophthora*
P. cryptogea	*P. cryptogea*	
P. cinnamomi	*P. nicotianae*	

P. cryptogea was previously identified morphologically from *Choisya* received by the RHS (sample Wis9), from an isolate sent in 1995 to the Scottish Crop Research Institute by D. Whitehead (David Cooke, pers. comm*.,* 2009).

Phytophthora spp. was isolated in 2008 from plug plants of *Choisya* at Stockbridge Technology Centre (STC) (Cathryn Lambourne, pers. comm., 2008), and *Choisya* root rot in samples has generally been attributed to either one *Phytophthora* species alone or a number of species together (Martin McPherson, pers. comm., 2008).

In Guernsey, the government plant clinic rarely receives any *Choisya* samples and the records show very few specific problems. There are no nurseries producing *Choisya* on the island and so any samples come from garden centres or private gardens. The clinic has not received any *Choisya* with specific root rot symptoms, apart from some mortality caused by *Armillaria* in gardens (Terry Brokenshire, pers. comm., 2008)

In south-west France, the plant clinic at the Experimental Station for Plants and Flowers (GIE) found *Phytophthora* spp. to be the primary pathogen isolated from *Choisya* with root rot, with *P. nicotianae* the principle species identified. *Fusarium oxysporum* and *Pythium ultimum* were also commonly isolated (Jean-Marc Deogratias, pers. comm., 2008).

Three samples were received at ADAS in early July 2007. Liners of *Choisya* cultivars Aztec Pearl and Sundance Yellow were wilting. The roots were brown, and it was noted that there had been little growth of roots through the paper sleeve around the original rootball transplanted in to the large pot. A *Phytophthora* sp. with hyphal swellings, and at least three *Pythium* isolates of differing morphology, and thus probably different species, were obtained from the roots of cv. Aztec Pearl. Roots of cv. Sundance Yellow also contained *Pythium* spp. including one culture identified by Tim Pettit of the Eden Project as a *P. ultimum* / *Pythium sylvaticum* type, and also a *Rhizoctonia* sp. Another sample of Sundance Yellow from a different nursery had roots that were rotted and very brittle. Although the plants had rooted through to the outside of the 3L pots, the roots fell off easily leaving only 3 cm around the stem base. The root cortex sloughed off easily leaving a central strand (a symptom suggestive of *Pythium*). The stem base was corky with blackening below, but no vascular staining. *Pythium* was isolated from the roots and a range of *Fusarium* species from the roots and stem base, including possibly *Fusarium redolens.*

A summary of the plant clinic diagnoses made on *Choisya* material, and the numbers belonging to each category, is given in Table 4.4. All sample types are shown, not only root rots. A single diagnosis count for either *Phytophthora* or *Pythium* has been made where multiple species (or probable different species) of the same genus were recorded in the same specimen. Where more than one potential pathogen or pest was recorded from a sample, each has been counted so total records can be greater than the number of samples received.

From the individual UK plant clinic records (Tables 4.1, 4.2), most plant samples arrived between spring and the start of winter. This could indicate that infection and symptom expression both occurred in this warmer growing period, rather than during winter. It may be, however, that garden plants are less frequently checked over the winter. Infection could occur in the colder conditions over winter and not shown symptoms until later in the year, perhaps once temperatures are more favourable to pathogen growth. The latter could apply to *Pythium* infection as this develops in colder conditions than *Phytophthora* (Smith *et al.*, 1988). *Phytophthora* is known to infect hardy nursery stock in autumn, but not produce foliar symptoms until warmer conditions prevail (Evans, 1979).

Table 4.4: Summary of the incidence of each disease, pest or other diagnosis made on *Choisya* at each of six plant clinics

Plant Clinic source	Number of clinic records	*Pythium* spp.	*Phytophthora* spp.	*Thielaviopsis* / *Chalara basicola*	*Fusarium* spp.	*Rhizoctonia* sp.	*Armillaria* spp.	Bacteria	Other diseases	Damage / stress	Pests	Negative or not diagnosed
CSL, York	46	0	7	8	0	0	0	3	2	6	8	15
RHS, Wisley	78	2	8	0	0	0	22	0	4	5	0	38
ADAS, Cambs.	3	3	1	0	1	1	0	0	0	0	0	0
STC Ltd, Cawood	1	0	1	0	0	0	0	0	0	0	0	0
GAS, Guernsey	Few	0	0	0	0	0	Yes	0	0	0	0	0
GIE, France	?	Yes	Yes	0	Yes	0	0	0	0	0	0	0
Totals	120	5	17	8	1	1	22	3	6	11	8	53

4.2 Surveys published by Plant Clinics

At the Istituto Regionale per la Floricoltura in Italy, a new case of rot was reported in 2000. *Choisya* had collapsed and showed either stem base and root damage, or an extended browning of the vascular tissue. *Phytophthora* spp. was always isolated from the crown, and a *Fusarium* sp. from the inner tissues. The relationship between these two fungi is under investigation (Rapetti *et al.*, 2000).

Root and crown rot caused by *Phytophthora* spp. are responsible for serious damage to pot grown ornamental plants on nurseries in northern and southern Italy. Seven different *Phytophthora* species were isolated and identified by morphological, biochemical and molecular characters, including *Phytophthora nicotianae* from *Choisya ternata* (Pane *et al.*, 2005).

A study of *Phytophthora* spp. specifically on *Choisya* was started in 2002 by the CDHR Centre Loire Valley to address the problem with this disease on a French nursery (Website Ref. 1).

In Lorraine, France the high temperatures and humidity in 2005 favoured *Phytophthora* spp. on hardy nursery stock including *Choisya* sp. *P. nicotianae* was isolated from *Choisya ternata*, with other hosts being infected by *P. cactorum, P. nicotianae, P. citricola* and *P. syringae* (Larousse, 2005).

In Washington USA, the State University plant clinic has isolated *Phytophthora* sp. and *Rhizoctonia* sp. from *C. ternata* with root rot (Website Ref. 2).

4.3 Work on *Choisya* root rot in south-west France

Various methods of growing *Choisya* have been investigated at associated research stations in France (Anon, 2007) to determine whether *Choisya* root rot could be controlled. *Phytophthora* was the primary pathogen and cause of initial plant decline, with species of Fusarium and *Pythium* contributing to plant death. It was shown that in summer the plants suffered from water stress, particularly if they were watered either by overhead gantry or rotary sprinkler and grown in peat-free growing medium. Plants in growing media with peat, rather than wood fibre, were able to retain more water and had greater survival, probably because with less water stress they were less susceptible to infection by *Phytophthora* spp. Few plants died when grown with minimal water stress on capillary beds (flooded twice a day), under 50% shading. The greatest survival was where mycorrhiza had been added at potting. It was concluded that the lower light and increased humidity on shaded capillary beds favoured mycorrhizal survival and establishment. The mycorrhiza was then probably able to limit *Phytophthora* sp. development and so reduce plant mortality.

5. Literature surveys of pathogens and pests of *Choisya*, and conditions favouring their establishment

Authoritative compendia, including the European Handbook of Plant Diseases (Smith *et al.* 1988), Microfungi of Land Plants (Ellis and Ellis, 1985), Diseases and Pests of Ornamental Plants (Pirone, 1978) and *Phytophthora* Diseases Worldwide (Erwin and Ribeiro, 1996) do not list *Choisya ternata* as a host. Diseases of Trees and Shrubs (Sinclair *et al.*, 1987) notes *Nectria cinnabarina* on *Choisya ternata*. Fungi on Plants and Plant Products in the United States (Farr *et al.*, 1989) lists only spot anthracnose caused by *Sphaceloma choisyae*, on *Choisya mollis*.

Table 5.1 gives the total worldwide records for fungi on *Choisya* by the United States Department of Agriculture Research Service database (Website Ref. 3). Of these, only *Phytophthora* spp. would be likely to cause root rot and wilting. Twig die-back (originating from infection on stems) following infection either by *Eutypa* or *Nectria* spp. would be unlikely to be mistaken by growers for symptoms following root rotting unless fruiting bodies had not developed on the branches.

Table 5.1: Fungal pathogens recorded worldwide on *Choisya* by USDA, and symptoms

Fungal species	Record source	Probable disease symptoms
Phytophthora nicotianae	England	Root rot, foliar wilt/die-back
Phytophthora nicotianae var. *parasitica*	Australia	Root rot, foliar wilt/die-back
Eutypa lata	Europe	Twig die-back
Nectria cinnabarina	Canada	Twig die-back
Sphaceloma choisyae (on *C. mollis*)	USA	Scab or spots
Capnodium sp.	Australia	Sooty mould
Eutypella scoparia	Switzerland	Dieback
Meliola sp.	Australia	Sooty mould
Uredo clavo	Mexico	Rust

Across web-based literature sources, there was sparse reference to either *Choisya* or *Choisya* root rots. Neither UK nor other countries' plant sites, including a number of horticultural extension services and gardening information websites, highlighted any particular problem with root rotting in *Choisya*.

Host / pathogen listings give little information on epidemiology, and so further information on root rot pathogens was obtained from other hosts, including the International Mycological

Institute Descriptions of Pathogenic Fungi and Bacteria available from CABI Bioscience (Website Ref. 4).

5.1 Loss of plant vigour

Choisya is generally considered to be a low maintenance, disease-resistant shrub. The preferred growing conditions of *Choisya* are not demanding. They can be grown in full sun or partial shade, in a range of soil types and in either well-drained or heavy, acidic or alkaline situations. Only *C. ternata* is considered hardy in the UK (Morgan, 2008) (Website Ref. 5).

Plants may, however, show the poor vigour described by growers for some *Choisya* species by growers for a variety of reasons. These include nutrient imbalance, incorrect growing medium pH, lack or excess of water, either sun scorch or lack of light, and pests or diseases in the leaves. Pathogens in the growing medium can cause root loss, sometimes colonising tissues already weakened by physical or physiological means. Foliar wilting can follow loss of roots, or fungal infection leading to disruption of stem vascular tissue and reduced water uptake. Full wilting may be delayed until hot weather causes greater water demand, but plants will initially look unthrifty with the reduced uptake of water and nutrients.

In a trial of compost teas on *Choisya*, after an initial improvement in quality, treated plants finally had significantly poorer root and quality scores. This was not attributed to disease, but to excess water in the pots (Litterick, 2006). Pioneering growers have overcome this problem by applying compost tea as a spray rather than a drench when plants do not require additional water.

Some plant clinic samples of unthrifty *Choisya* received by Fera and the RHS had no pest or disease damage identified. The RHS diagnosed nutrient deficiency, physiological causes including possible root stress and frost in some cases.

5.2 Insects and nematodes

Pests common on nursery stock and causing wilting followed by plant death include vine weevils (*Otiorhynchus sulcatus*), and leaf and bud nematodes (*Aphelenchoides ritzemabosi*).

Vine weevil damage was not recorded by plant clinics on *Choisya.* If vine weevils were affecting *Choisya* it is likely that most growers would recognize the distinctive leaf notching by the adults, or the occurrence of white larvae around root feeding, and so samples were not submitted to clinics. Growers reported in the survey that adult weevils rarely feed on *Choisya*.

Leaf and bud nematodes (*A. ritzemabosi*) were found on two *Choisya* samples received at Fera. This pest is also known as the chrysanthemum eelworm, although it attacks many other ornamental species and uses weeds as alternate hosts. The nematodes move over the plant surface on water films (and so can cause particular problems in cool wet summers) and invade healthy leaves through stomata. They can also move internally in plant tissues. The host's leaves may become discoloured, with necrotic areas, then wilt and die. Growth can be stunted. Such symptoms could be attributed by growers to a root rot. Growers can check for this pest themselves by breaking affected leaves into water. After half an hour, released nematodes form a wriggling mass on the bottom of the container (Buczacki & Harris, 1989).

5.3 Micro-organisms

A number of fungi were recorded from *Choisya* by clinics (Table 4.4). Most were probably causing root rot, although a few would have caused foliar die-back without root rotting. Pathogenic bacteria were not commonly recorded.

5.3.1 *Phytophthora* spp.

Phytophthora spp. were widely identified by clinics on *Choisya* with root rot, although not always to species level. Individual plants may be infected by more than one species of *Phytophthora.*

Detailed information on *Phytophthora* species, including host range, distribution, biology, symptoms, and control is available from CAB International CPC PhytID Datasheets (Website Ref. 6).

Phytophthora spp. are Oomycetes and this group has traditionally been included taxonomically with the fungi. However, Oomycetes possess unique significant structural and biochemical features including the occurrence of cellulose rather than chitin in the cell walls. Structural analyses now group the Oomycetes with the chromophyte algae and other taxa that possess tubular flagellar hairs, in a taxon called the Stramenopiles, and this has been confirmed by molecular studies (Hardham, 2005).

Phytophthora spp. are soil-borne microorganisms which spread by motile spores (zoospores). These are flagellate and swim in soil water films and larger water volumes such as reservoirs. *Phytophthora* spp. also produce thick walled oospores and chlamydospores which survive sometimes for years. Infection of newly potted plants by any spore type may arise from infested soil or growing medium. Inadequately disinfected re-used pots or soil in the growing medium may introduce infection from resting spores.

Zoospores will spread in inadequately treated irrigation water, particularly if collected from standing areas and glasshouse roofs (Waterhouse and Waterston, 1964; Waterhouse and Waterston, 1966; Stamps, 1978; Hall, 1994). Infected cuttings can introduce the disease. Some genera and particular cultivars e.g. *Chamaecyparis lawsoniana*, and in particular cv. *Ellwoodii,* are more susceptible than others (Evans, 1979), but there are no similar literature records of either species or cultivar susceptibility in *Choisya.*

Phytophthora species (including a strain from *C. ternata*) have been shown to secrete small extracellular proteins termed "elicitins", which in some host families, at least, elicit a hypersensitive response (Kamoun *et al.*, 1994). This can mean that the host produces e.g. tissue necrosis around the pathogen, sometimes to some distance away from the infection, which blocks pathogen colonisation.

Root and basal stem (foot) rot of hardy ornamental nursery stock in the UK is often caused by *Phytophthora cinnamomi,* although *P. cryptogea, P. citricola, P. cactorum* and *P. cambivora* can also cause disease. *P. cinnamomi* is most active in the summer months at temperatures between 20ºC and 30ºC and makes little growth below 10ºC. As water is essential for infection, severe attacks are often associated with poorly drained soil or growing medium. Infection can occur in both acidic and alkaline soils. *P. cryptogea* is associated with poor root growth and death in container-grown *Chamaecyparis*, and is active at lower temperatures than *P. cinnamomi*. Roots infected by *Phytophthora* spp. become dark brown with no fine roots and the whole root system is reduced in size. The fungus eventually invades the stem base and a demarcation zone can be seen between the reddish brown discoloration and the white tissue above. Foliar wilting usually follows after stem base penetration, but if penetration has not occurred by autumn, symptoms may not be seen until the plants start to die in summer (Evans, 1979).

The species isolated from *Choisya* plant clinic samples differ in their known host range and principal symptom expression. *Phytophthora cryptogea* causes wilts, root rots and damping-off of many herbaceous and woody plants (Stamps, 1978). The RHS have registered a new host record for *P. cryptogea* on *Choisya* (Denton, 2008). *Phytophthora citrophthora* occurs on a number of plant families, including the *Rutaceae* (to which *Choisya* belongs). It causes different symptoms in the various hosts, including leaf and shoot blight, collar and root rot, and seedling damping-off (Waterhouse and Waterston, 1964). *Phytophthora nicotianae* (identified in French *Choisya* by Jean-Marc Deogratias (pers. comm., 2008)) causes root rot across a very large number of agricultural and ornamental crops (Hall, 1994). *Phytophthora* *cinnamomi* infects mainly woody hosts, causing wilts and root rots (Waterhouse and Waterston, 1966).

Choisya x dewitteana cv. Aztec Pearl has been recorded in the UK as a natural host of *Phytophthora ramorum* (non-indigenous sudden oak death) and with certain other ornamentals is to be included in holding notices around suspect infected plants (Website Ref. 7). *P. ramorum* attacks the bark of some hosts causing ramorum lethal canker, but only causes either ramorum leaf blight on the foliage, or ramorum dieback on the foliage and twigs. Foliar inoculation tests have shown *Choisya ternata* to be virtually immune (defra, 2005).

5.3.2 *Pythium* spp.

Pythium spp. were recorded by both the RHS and ADAS plant clinics. The RHS confirmed by molecular diagnostics that a number of species could be recovered from *Choisya* samples, but they were not identified to species level as there no DNA reference sequences exist for them. Some species e.g. *P. ultimum* are plant pathogens, but numerous *Pythium* species are principally saprophytic in soil, and may only very occasionally be found attacking plants (Smith *et al.,* 1988).

Pythium spp., like *Phytophthora* species, are Oomycetes, surviving by oospores. Oospores germinate to form sporangia, which may release zoospores (most species) or germinate by germ-tube (*ultimum* group). The *ultimum* group is favoured by cool conditions (10 - 15ºC) and high soil moisture, so in practice attacks are mainly seen in spring. Numerous *Pythium* species are principally saprophytic in soil and may very occasionally be found attacking plants. *Pythium* is most well documented as causing damping-off of seedlings; however it can cause root necrosis of plants. Necrosis develops rather slowly from root-tip backwards, with brown or black discolouration. The effect on the plant is general slowing of growth. Plants may be able to compensate under favourable conditions by developing new roots (Smith *et al.*, 1988).

Pythium and *Phytophthora* are generally controlled by the same fungicide products. These products are not usually effective against fungi that are not also Oomycetes (such as species of *Thielaviopsis, Rhizoctonia* and *Fusarium*). Products with label approval on container grown hardy nursery stock include Aliette 80 WG (fosetyl-aluminium), Standon Etridiazole 35 (thiadiazole) and Filex (propamocarb hydrochloride) (O'Neill and Ann, 2004). There are also products with Specific Off-label Approval including Previcur Energy (fosetyl-aluminium + propamocarb hydrochloride), SOLA 2667/08.

5.3.3 *Thielaviopsis basicola*

Thielaviopsis basicola (syn. *Chalara elegans*) was commonly recorded as *Phytophthora* spp. on *Choisya* at the Fera clinic. It was not recorded by the other plant clinics surveyed. *Thielaviopsis* would not be obtained by techniques directed at the isolation of *Phytophthora or Pythium* species (such as apple baiting or agars selective for *Phycomycetes*). *Thielaviopsis basicola* is the current name for black root rot, reverting in 2006 to this name after a period as *Chalara elegans* (Website Ref. 8).

T. basicola causes black root rot in many plants with 120 species in 15 families known to be susceptible. Important ornamental hosts include begonia, cyclamen, geranium, pansy and poinsettia (Raabe *et al.* 2005). It is mainly seen on herbaceous species, but has been reported on hardy nursery stock; e.g. in the USA containers of Japanese Holly (*Ilex crenata)* showed severe decline as a result of root death (Hansen, 2000).

The root symptoms on ornamentals range from black discolouration and extensive loss of root mass, through to grey and brownish discolouration and little obvious rotting. Above ground there is a reduction in growth and increasingly obvious foliage discolouration, followed by wilting and death (Trebilco *et al.*, 1999). Plants are stunted and below ground black, rough, longitudinal cracks can develop (Raabe *et al.*, 2005). The speed and severity of infection and symptoms depend on a wide range of factors including the susceptibility of the host species and cultivar and the strain of the fungus present (Trebilco *et al.*, 1999).

Black root rot has been identified as a major disease problem in Australian nurseries since 1993 where it has affected a wide range of crops, in particular bedding plants. The disease has very frequently been misdiagnosed as being due to fertiliser injury, underfeeding, heat and cold injury, over-watering, under-watering, infection by species of *Rhizoctonia, Pythium* or *Cylindrocladium,* fungus gnats and nematodes. Although symptoms can be seen within a week in pansies, in perennial crops, such as peach, citrus and rose, symptoms may take years to become obvious (Trebilco *et al.*, 1999).

In tobacco, the fungus invades the roots through ruptures in the cortex due to the emergence of secondary root primordia. Resistant tobacco cultivars have been developed (Subramanian, 1968). In pansy, infections usually start at root tips and through root hairs and the roots of infected plant plugs often fail to grow beyond the original plug after transplanting (Pscheidt & Copes, 2008).

T. basicola produces two types of conidia; brown macroconidia (chlamydospores) and non-pigmented microconidia (endoconidia). It is capable of prolonged saprophytic survival in soils. Disease development is favoured by soil temperature at 17-23ºC, soil pH about 5.7-5.9, a high soil moisture content and inadequate aeration (Subramanian, 1968). Disease can be reduced at growing medium moisture of 36% or lower (Trebilco *et al.*, 1999) and acidic conditions (with prevention at pH 4.8 and reduction at pH 5.5, subject to plant tolerance) (Raabe *et al.*, 2005).

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Chlamydospores of *T. basicola* are highly resistant to chemical sterilants and studies have been carried out in Australia (Trebilco *et al.*, 1999) and the UK (HNS 147) to enable selection of the most effective products for disinfecting re-used pots, trays and general nursery hygiene (O'Neill *et al.*, 2005).

Fungicide drenches against black root rot have been investigated on pansies, with Amistar (azoxystrobin), Octave (prochloraz), Plover (difenoconazole) and Stroby WG (kresoxim-methyl) all reducing the level of disease (Jackson and McPherson, 2002). However, of these products, only Octave (label approval) and Cercobin WG (thiophanate-methyl), SOLA 1384/2008, can be used as drench treatments

5.3.4 *Fusarium* spp.

Fusarium oxysporum has been identified only from French *Choisya* samples (in association with *Phytophthora* spp.) (Jean-Marc Deogratias, pers. comm., 2008). *F. oxysporum* infects via the roots (with or without wounds) and causes wilting in a number of hosts usually by a host-specific *formae speciales.* Symptoms vary between host and pathotype, but in general the older leaves first show light vein-clearing, and wilting. Necrotic streaks appear on stems and spread towards the plant apex, with browning visible internally in the vascular tissue (Smith, *et al.*, 1988).

Fusarium redolens is widespread in soil in temperate regions and has a wide host range of herbaceous and woody plants, causing wilt (or damping-off of seedlings) by infection through the roots (Booth and Waterson, 1998). This species was possibly the *Fusarium* species present in *Choisya* roots cultured by the ADAS clinic in 2007.

Fusarium solani was not specifically mentioned in any plant clinic surveys, but is a soil-borne facultative parasite associated with wounds and other localised infections on hosts weakened by unfavourable conditions or by injuries from nematodes or infection by viruses or other fungi such as species of *Phytophthora, Rhizoctonia* and *Fusarium.* It produces a lower stem base or root rot and has a very wide host range. Development is favoured by temperatures at 26-28ºC and a soil moisture level of 15%, with infection reduced by frequent and heavy irrigation (Booth and Waterston, 1964).

5.3.5 *Armillaria* spp.

Species of this fungus were very commonly recorded in *Choisya* samples sent to the RHS plant clinic. Plants in soil can be attacked by Armillaria root rot (a complex of *Armillaria* spp., including *Armillaria mellea*). Many mainly woody hosts are affected worldwide. *Armillaria* invades the bark and cambial region of roots and the root collar, killing roots and causing the death of trees of all sizes. Some species, or perhaps strains within species, are virulent parasites, but others are opportunists that act selectively on weakened or damaged plants (Sinclair *et al.,* 1987).

Leaves on trees and shrubs wither and the whole plant deteriorates or dies. The disease spreads in the soil by bootlace-like strands (rhizomorphs) from infected plants or by root contact (Anon., 1991). The disease progresses slowly and would be expected to take at least a year to kill plants transplanted into an infected area (Buczacki and Harris, 1989). However, rhododendrons can be killed within a week (Mikolajski, 2007). The toadstool stage of the fungus develops in autumn and its colour gives the fungus its common name of honey fungus.

5.3.6 *Rhizoctonia solani*

Rhizoctonia solani is commonly recognised in ornamental plants causing seedling damping-off, but on older plants, attack at the stem base or soil level results in a dry, light brown discolouration. *R. solani* together with *Pythium* spp. was recorded by ADAS in the roots of young *Choisya* plants cv. Sundance Yellow. In general, on more mature plants of various species, the fungus typically shows as discrete brown lesions along the root length with rotting of the cortical tissues. Some plants may develop cankers with longitudinal cracking of the stem base. *Rhizoctonia* root rot increases at growing medium temperatures of 17-26ºC and when growing medium is dry (O'Neill and Green, 2004).

5.3.7 Leaf and stem spots, leaf blights and die-back.

Fera Plant Clinic recorded single occurrences of *Glomerella cingulata* and *Colletotrichum acutatum* leaf spots on *Choisya*. Symptoms produced by both species are known as anthracnose.

Glomeralla cingulata is normally encountered in its conidial state, *Colletotrichum gloeosporioides,* characterised by subcuticular acervuli that develop in recently killed above ground tissue. A range of symptoms including anthracnoses (brown blotches on foliage) and stem diebacks are caused across a range of woody and non-woody hosts. *G. cingulata* enters intact or wounded tissues and can remain latent until the plant part becomes more susceptible. It is particularly aggressive towards plant parts weakened by environmental stress or improper nutrition (Sinclair *et al.,* 1987).

C. acutatum is a very variable species, it has been recorded on 20 genera, but is not easily distinguished by symptoms from damage caused by *Colletotrichum gleosporoides* (Smith *et al.*, 1988).

Nectria cinnabarina (coral spot) has been recorded on *Choisya* in Canada (Website Ref. 3). It is a saprophyte on many species, but it is also an opportunist pathogen that colonises the bark, cambium and sapwood of weakened or damaged stems. Transplanting, fall in air temperature in autumn and frost damage can predispose plants to infection.

Symptoms of coral spot canker or dieback include failure of twigs to produce leaves in spring or sudden wilting of shoots or entire plants soon after growth begins in spring. Young stems become discoloured, but the lesions may remain unnoticed until spore cushions (initially coral coloured) erupt (Sinclair, 1987).

Cylindrocladium spp. causes foliage blight and stem die-back (well known in *Buxus* spp.), but also causes root rot, stunting, wilting and death in many woody species. Root infections are characterised by multiple dark brown lesions on lateral and main roots. The fungus grows most rapidly at 24 to 28ºC (Sinclair *et al.,* 1987). Although the root symptoms resemble symptoms reported on *Choisya*, there is no record for this fungus on *Choisya.*

5.3.8 Bacteria

Pseudomonas syringae and *Erwinia chrysanthemi* were recorded by Fera on *Choisya*, and could have been causing stem die-back.

P. syringae has a wide host range, including many woody plants, and causes symptoms including canker and shoot die-back. Bacteria are spread in wind-driven rain and enter stomata or wounds (Hayward and Waterston, 1965). Systemic infection can occur, and infection may remain latent (Moore, 2003).

E. chrysanthemi causes various rotting, necrotic and systemic diseases of a wide range of crops, including protected ornamentals. There is evidence of host specificity and bacterial pathovars. For example, in *Dieffenbachia* it causes bacterial stem and leaf rot with more virulent strains spread in the vascular system and less virulent producing only local soft rot lesions (Smith *et al.*, 1988).

5.3.9 Viruses

An apical die-back of young *Choisya* shoots and plant stunting on a nursery in southern England in 2001 was attributed to a virus infection. Arabis mosaic virus (ArMV) was confirmed in the roots (although probably earlier present in the leaves), and is the first virus isolated from *Choisya* spp. (Mumford *et al.*, 2002). This virus is transmitted by free-living, soil-inhabiting nematodes, *Xiphinema* spp., which retain the virus for at least 31 days. ArMV occurs in a wide range of plants (Murant, 1970). Plant clinic samples received by Fera that are negative for fungi or bacteria are tested for virus if symptoms are suspect, but this virus has not been picked up in routine samples.

Discussion

The grower survey highlighted that *Phytophthora* spp. root rot was the most frequently identified disease on *Choisya* plants on commercial nurseries in the UK in the last 5 years. This may reflect the higher incidence of *Phytophthora* spp. (the species involved were not always identified), but easy diagnosis on-site using a Lateral Flow Device (LFD) could have caused bias in the results. The Fera clinic results of samples from commercial growers between 2001 and 2008 also commonly identified *Phytophthora* spp., however *Thielaviopsis basicola* was isolated from a similar number of samples.

T. basicola was recorded by growers with a similar frequency to *Pythium* spp. No on-site LFD test is currently available for *Thielaviopsis basicola* and so diagnosis was probably made by a plant clinic. *Pythium* spp. may have been identified by growers using an LFD. However, *Pythium* species are not all primary pathogens and were not recorded by Fera. *Fusarium* spp*.* identification was uncommon in the grower and UK clinic records, although it was identified as an important contributory factor in plant death in the south of France.

The plant clinic survey included the RHS, which reported the most commonly occurring pathogen to be species of *Armillaria.* The RHS samples were from gardens after planting out and so do not necessarily reflect the problem occurring on production nurseries.

Three cases of bacteria were confirmed on *Choisya* by Fera. These were likely to relate to bacterial losses in propagation, such as when immature cutting material is stuck during late summer.

Most of the growers surveyed (75%) reported that losses vary between years. The most obvious reason for annual differences in root rotting would appear to be differences in the weather. 2008 was generally cool, overcast and wet over the summer, except for a hot, dry period at the start. However, few *Choisya* crops were grown outdoors, and so rainfall is unlikely to have been a problem. Both over-watering, poor drainage and root drying can increase root susceptibility to fungal infection. Low light levels reduce plant vigour and may increase their susceptibility to infection. Infected plug plants may take several months to show disease symptoms, with the effect of a poor root volume manifesting itself when plants are put under water stress. This is likely to be why the majority of growers who had noted losses during a particular period reported it between May and August. Although sciarid flies can carry fungal pathogens and the larval damage to tissues can allow pathogen entry, they are unlikely to have been a major source factor in root rotting as most growers had control measures in place.

Clinic samples and some literature sources identified more than one fungus present in *Choisya* plants with root rot. The invasion of one fungus may be favoured over another depending on the environmental conditions present. Some fungal species only enter following damage by primary pathogens. If chemical control is used this needs to be effective against all the fungal species present.

Most growers used either mains or bore-hole water, which have a low probability of harbouring water-borne diseases such as species of *Phytophthora,* unless it is stored in a way that allows fungal contamination. River, roof or recycled water can contain pathogens, but there are various methods of cleaning it before use. The use of non-mains or borehole water was too infrequent in the survey to say whether they increased the probability of root rotting. The re-cycling of water is likely to become more common in the future and growers will need to treat recycled water. Growers using mains or borehole water may also have plants affected by root rots, hence the importance of good drainage to draw excess water away from the roots.

No difference was noted in root health between users of either pre-formed plugs or cell trays. This question was included in the survey because in plant clinic samples it had been noted that the roots of cuttings stuck in pre-formed plugs appeared to have been restricted by the mesh, fleece or paper wrappings. Stresses associated with poor root development might have been expected to aid disease attack.

A range of fungicides and bio-stimulants were used by growers, however application programmes were not examined in this study. Without conducting replicated trials, it is difficult to draw conclusions of their effectiveness. Bio-stimulants were used as protectants, to build up plant strength to resist disease. Bio-stimulants are IPM compatible, an important consideration on most nurseries, particularly as control by predators is often necessary against two-spotted spider mite on *Choisya*. Some growers report compost tea to benefit the crop as long as excessive water is not applied. It is best practice to apply compost tea via a sprayer during the winter, as irrigation requirement can be minimal.

It is known that composted barks and wood wastes are useful for suppressing some soil-borne diseases. In addition, composted barks and wood fibre generally increase air filled porosity (AFP) and drainage, presumably mimicking the well-drained, well-aerated rooting environment in which *Choisya* would grow in their natural environment

It is thought by some growers that flash releases of fertiliser caused by high temperatures may be part of the problem. Stock potted late in the season, that has not rooted around containers, is more likely to be affected than plants with a established root system that is able to take up nutrients. If this is the case, there may be some merit in lowering the rate of CRF (controlled release fertiliser) and supplementing with liquid feeds as required.

Conclusions

1. Root rotting in *Choisya* was recorded by 75% of growers, with losses up to 15 % not uncommon in both liner and final pot production.
2. *C. ternata* and cultivars Sundance and Aztec Pearl were more frequently reported by growers to have root rot than either cv. Goldfinger or cv. White Dazzler.
3. Root rotting or a reduction in vigour was reported by a number of growers to become apparent between May and August.
4. *Phytophthora* spp., *Thielaviopsis basicola* and *Pythium* spp. were the pathogens most frequently diagnosed. *Fusarium* spp. and *Rhizoctonia* sp. were also reported.
5. Plant stress from either overheating or poorly drained compost increased losses.
6. Potting in late February to early April was the key factor in improved root establishment and reduced plant losses, with further benefits gained by using shading and a well draining growing medium.
7. Potting inferior liners was likely to produce poor results, it was important to ensure that liners were well rooted and properly graded. If smaller liners were potted on it was important to grade them out from the larger liners and to irrigate the two batches independently in order to meet crop needs.
8. Good drainage of standing down beds was important.
9. Growers used fungicides and bio-stimulants, but their relative effectiveness was not evaluated.

Technology transfer

Articles

- *Choisya* conundrum. *HDC News* **148**, p 8.
- Dry routes for healthier *Choisya*. *HDC News* **155**, pp. 20-21.

Proposed future technology transfer

- To ensure that the results of this research are used by the industry there is scope for a two page factsheet summarising best practice relating to the production of *Choisya.*

Glossary

Bio-stimulant: a substance with properties that stimulate a plants natural defence system, helping to reduce susceptibility to disease e.g. Farm – Fos – 44 (potassium phosphite).

Lateral Flow Devices (LFD): Manufactured by Forsite Diagnostics Ltd, these can used on site for testing for certain pathogens e.g. *Phytophthora* spp. or *Pythium* spp.

Liner: Plant in 9 cm diameter (or similar sized) pot. Produced from a potted-on rooted cutting. This will be potted on to the final size for marketing e.g. 3 L.

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Appendix 1: Grower survey form

Business Name:					**Date:**			
Contact Name:								
Have you had any of the following diseases confirmed on Choisya in the last 5 years	***Pythium***	***Phytophthora***	***Rhizoctonia***	***Thielaviopsis***	***Fusarium***	**Other - please specify.**		
Which of the following Choisya cultivars/species do you produce	***C. x dewitteana* 'Aztec Pearl'**	***C. ternata* 'Goldfingers'**	***C. ternata***	***C. ternata* 'Sundance'**	***C.* 'White Dazzler'**			
What % of each cultivar/species do you frequently lose due to root rot	***C. x dewitteana* 'Aztec Pearl'**	***C. ternata* 'Goldfingers'**	***C. ternata***	***C. ternata* 'Sundance'**	***C.* 'White Dazzler'**			
Do losses vary between years, if so can you attribute this to any particular reason/s								
When does root rot or a loss of vigour usually become apparent in the life of the crop - any particular month?								
Components of Growing media	**% Peat in mix (and grade)**		**% Bark (and grade)**		**Other growing media constituents**		**Name (code no.) of proprietary mix & supplier**	
Please specify source (s) of irrigation water	**Please tick**	**Please give details of any water treatment (e.g. acid dosing, slow sand filtration, chlorination) carried out prior to irrigation**						
Bore hole								
River								

Roof water		
Mains		
Recycled - drainage from bed		
Other		

Method of irrigation	**Advantages**	**Disadvantages**
Overhead - by hand		
Overhead - spray line/gantry		
Capillary sand bed		
Ebb and flow		
Drip		
Other		
How do you ensure that the correct amount of water is applied		

Drainage of production beds	**Advantages**	**Disadvantages**
Drained Mypex over sand		
Drained Mypex over gravel		
Drained gravel		
Drained sand		
Lava		

Other		
Production Schedules		
Are liners produced on the nursery or bought in. Please specify supplier if bought in.		
When are cuttings normally taken month/week		
Are you striking cuttings into pre-formed paper plugs or into own filled trays		
What size of module do you use		
What percentage of losses do you generally experience at this stage		
When are rooted cuttings normally potted into liners	**Date or week of potting**	
	Why	
What percentage of losses do you generally experience in liner production		
When are liners normally potted into finals	**Date or week of potting**	
	Why	

What percentage of losses do you generally experience in final production		
Cropping	**Produced under glass**	
	Produced under plastic (details of how tunnel is ventilated)	
	Any part of production outside	
Size of final container	**Two litre**	
	Three litre	
	Other	
Potted by	**Machine**	
	Hand	
Shading used in summer	**During periods of hot weather**	
	Between which months	
	Other	
Other questions		

Are sciarid fly numbers routinely monitored								
Are control measures implemented if sciarid numbers rise to damaging levels - please specify.								
Plant protection products used during production	**Aliette 80WG**	**Filex / Proplant**	**Subdue**	**Octave**	**Other - specify**			
Please specify								
	Agrilan Revive	**Compost Tea**	**Trianum**	**Other - specify**				
Are any bio-stimulants used - please specify.								
Recommendations for successful production								
Most frequently occurring problems								

Appendix 2: Details of grower survey

Appendix 2.1: Potting dates for liners and the reasons given by growers for their selection

Potting within the period	Reason for potting during selected period
February to April	Gives the crop a good start, establishes liners when cool. Potting soon after the suppliers deliver plugs.
April/May	Fits production schedules.
May/June or September/October	One month after insertion into seed trays, potting on needed before cuttings get short of feed.
July, or March the following year	Overwintered plugs potted in March are stronger than those potted in July.
Early August	To maximise growth prior to winter.
September	To get plugs to root out and establish whilst day length is sufficiently long.

Appendix 2.2: Potting dates for final pot size and the reasons given by growers for their selection

Potting within the period	Reason for potting during selected period
February to April	To establish plants before periods of high temperatures (crucial to minimise losses). Pot in mid-March for maximum growth and establishment before summer heat builds up. Some growers pot on a 1 L plant to enable it to get stronger more quickly.
March to June	To match plant growth with sales.
April	To be ready for autumn sales.
May/June	Main potting season for shrubs. Liners are well rooted by then, it fits production and the available space.
March, July and September	To meet sales demand.
June	For spring sales, lack of space earlier in the season.
Early August	On delivery of liners.

Appendix 2.3: Propagation periods, types of tray used for cuttings and sources of liners

Months that cuttings are taken	Number of growers propagating between stated months	Cuttings inserted into	Number of growers using tray type	Source of liners	Number of growers buying in or producing liners
May – August	15	Own filled trays	10	Bought-in & home produced	9
August – November	8	Pre-formed plugs	8	Home produced	7
April	1			Bought-in	5

Appendix 2.4: The number of growers (out of 21) using shading in crop production and the protected structures being shaded.

Shading used	Number of growers without shading and shading usage
During summer	8
No	7
Yes	2
Milky polythene	2
Location of crop	**Number of growers with crops in each location**
Polythene tunnel	14
Glasshouse	13
Outdoors	4

Appendix 2.5: Method of irrigation and source of irrigation water

Method of water application to the crop	Number of growers applying water by specific methods	Source of irrigation water	Number of growers using water from each source
Overhead spray line / gantry	17	Mains	11
Overhead by hand	11	Bore hole	9
Drip	4	River	3
Capillary sand bed	4	Roof	3
Other	3	Recycled	3
Ebb and Flow	1	Other	3

More than one method on different parts of most nurseries, most also use more than one source of water.

Appendix 2.6: Monitoring and control of sciarids by growers

Monitoring carried out by growers	Number of growers
Monitor sciarids and implement controls	13
Monitor sciarids	4
No monitoring	4