

Project title:	Parsnip: An Improved understanding of root blemishes and their prevention
Project number:	FV 366
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Report:	Annual report, Year 1
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Date project commenced:	1 st January 2010
Date project completed (or expected completion date):	1 April 2013

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The results and conclusions in this report are based on an investigation conducted over a one-year period. The conditions under which the experiments were carried out and 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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CONTENTS

Grower Summary	1
Headline.....	1
Background.....	1
Summary	2
Financial Benefits	6
Action Points.....	6
 Science Section	 7
Introduction	7
 Materials and methods	 7
<i>Collection of samples</i>	7
<i>Isolation of pathogens from samples</i>	10
<i>Pathogenicity tests</i>	10
<i>Disease Nursery site</i>	5
<i>Seedling bait tests</i>	11
 Results.....	 14
<i>Spring samples 2010 – overwintered crops</i>	14
<i>Crop monitoring – Autumn 2010 to Spring 2011</i>	18
<i>Pathogenicity tests</i>	20
<i>Seedling bait tests on growers soils</i>	28
 Discussion	 30
Conclusions	31
References	25
Appendices	27

GROWER SUMMARY

Headlines

- A wide range of skin blemish symptoms were observed on root samples and not all were associated with the major fungal pathogens of parsnip.
- A range of brown spotting and skin symptoms were linked to various *Fusarium* species.

Background and expected deliverables

Various root blemishes continue to downgrade the quality of parsnip crops and cause economic damage in some seasons. Up to 80% crop losses were reported in some crops in the 2009/2010 season. The main cause or causes of some of these root blemishes are not known but it is considered that fungal or other root pathogens maybe involved.

There are several potential pathogens capable of causing various blemishes, rots & cankers on roots that have been identified in previous studies but their relative importance in specific situations is not clear and has not been fully investigated.

The range of pathogens encountered can vary between cultivars on the same site (Gladders, 1997) and this increases the problem. Large roots are often more severely affected than small roots and could be because the crown is more exposed and larger roots can have growth cracking.

Black cankers are generally thought to be a result of infection by *Itersonila pastinaceae* or possibly *Mycocentrospora acerina* (Davis & Raid, 2002). *Phoma complanata* has been associated with brown cankers previously though *Cylindrocarpon destructans*, a relatively common soil-inhabiting fungus, may also be involved in some situations.

The orange-brown cankers which have been reported more recently have not been fully investigated and the main cause has not been found. Also, the 'cavity spot'-like symptoms which occur in this crop, unlike in carrots, have not been formally confirmed to be caused by *Pythium* spp. or other specific pathogens (Gladders,1998).

The identification of the various root blemish symptoms in the field is not entirely reliable, especially using visual inspection alone. Detailed laboratory examination is therefore required to help identify and elucidate primary causal organisms or other factors involved. Hopefully it will be possible to produce a factsheet to help growers and their advisors quickly identifiable the primary cause of root blemish in this crop and hence instigate an early and preventative control programme.

Summary of the results and main conclusions

A large number of samples were collected from different parsnip crops and received by both STC and ADAS during 2010. A wide variety of skin blemish problems were catalogued and tests were carried out to help identify the causal organisms and link them to specific blemish types.

Typical symptoms found:



Crown canker



Black crown/small black crown



Corky crown



Black shoulder lesion



Narrow black bands



Ginger blotch



Cavity spot - like



Dry scars and deep dry scars



Deep soft rot



Pink/brown superficial lesions (watery)



Young red lesions near crown



Carrot fly mines

Figure 1: Lesions identified during sampling

Some skin blemish symptoms increased over the season e.g. cavity spot like lesions and the orange speckling.

Testing and monitoring was carried out on a selection of cultivars and no clear correlation between cultivar and lesion type was observed at this stage. This may suggest that the incidence of skin blemish is linked more closely to the presence of soil-borne inoculum rather than to differential susceptibility of specific parsnip varieties.

Tests to confirm pathogenicity of the collected fungal organisms were carried out. *Fusarium* isolates, *Cylindrocarpus destructans*, *Phoma* sp. and *Botrytis cinerea* had confirmed pathogenicity. Interestingly, although *Itersonilia* spp. were detected regularly in association

with the large shoulder and crown lesions, either STC or ADAS was able to re-create the symptom in pathogenicity tests. More investigations are needed.

Collected soil samples from all 12 monitored sites were used to set up a range of seedling bait tests to check for damping-off, possible development of cavity spot lesions, and also for longer term tests with a particular variety where an interesting banding symptom had developed. Some of these tests are still on-going.



Figure 2. Pathogenicity testing



Figure 3. Seedling bait tests

Work will be carried out in year 2 of the study will focus on trialling a range of chemical and biological control products for control of the primary organisms detected in small-scale *in-vitro* and *in-vivo* studies.

Promising candidates from this list will be taken forward into larger scale field trials at STC (in an existing disease nursery developed for this work) and ADAS (in a commercial crop) in year 3 where it is hoped they will result in a reduction in skin blemish problems.

Financial benefits

Additional work will be carried out in years 2 and 3 of this project may identify products which could be applied to parsnip crops to control some of the more consistently observed fungi causing blemishes from year 1.

Action points for growers

- Monitor crops regularly and submit samples with unusual skin blemish problems for testing to help identify the primary organisms responsible.

SCIENCE SECTION

Introduction

Approximately 4000ha of parsnips are grown annually in the UK. In 2009/10 the parsnip industry (growers & pack-houses) reported very high wastage figures with average losses in the region of 20% of the crop, but in some cases this has been reported to be much higher. At present, growers are unable to take effective targeted action to minimize crop losses due to root blemish and are therefore in the unenviable position of having to invest heavily to maintain production capacity yet with the possibility that in some years, or in some crops, this effort is wasted due to the late occurrence of blemishes on the washed parsnip roots. If the primary cause(s) of root blemish can be determined it should provide valuable information to guide selection of varieties and to investigate and develop well-targeted cultural, chemical and bio-control measures to help minimize infection and hence reduce wastage in crops in the future.

Materials and methods

Collection of samples

Initial samples of blemished parsnips were obtained by consultation with growers in spring 2010. A letter was drafted inviting growers and pack-houses to submit samples to ADAS Boxworth or Stockbridge Technology Centre (STC) and distributed via industry contacts, BCGA, seed companies and technical literature such as HDC Veg Notes. From East Anglia (ADAS area) 6 samples were received from pack-houses from 5 different crop sites and 2 growers. These were supplemented by field sampling from 3 further sites and another grower (Table 1). The STC Plant Clinic received 17 samples directly from growers or consultants. All samples were logged and descriptions/photographs of the lesion types were made. Isolations were carried out on the lesions and details of organisms collected and the results of any pathogenicity testing carried out were recorded.

Table 1. Details of sites and sampling dates, spring 2010 (ADAS)

Site	Grower	Date sampled received	Date 1 st sample collected	Date 2 nd sample collected
1	A	-	27 April 10	20 May 10
2	A	-	27 April 10	20 May 10
3	A	-	-	20 May 10
4	B	25 April 10	-	-
5	B	28 April 10 and 30 April 10	-	-
6	B	29 April 10	-	-
7	C	26 April 10	-	-
8	C	27 May 10	-	-

Both STC and ADAS teams also contacted local growers to identify parsnip crops for regular monitoring. Crop monitoring was carried out throughout autumn/winter 2010/2011 by both ADAS and STC. Initial sampling was completed at a total of 22 sites (STC – 9 and ADAS - 13 sites) between August and October 2010. Based on the incidence and severity of blemish symptoms, the number of sites for follow-on sampling was reduced to 12 (STC – 5 and ADAS -7). These crops were sampled twice more and monitored between September and November 2010. The sites were selected by liaison with local growers across East Anglia, the Midlands and Yorkshire based on a history of parsnip blemish problems. At 4 of the ADAS sites a later sample was taken pre-harvest from over-wintered crops in February/March 2011. Details of the monitored crops are shown in Tables 2 and 3. During each crop-monitoring visit approximately 100 roots were collected in a 'W' across the field. Soil samples were also collected at each site for nutrient analysis (Appendix 1) and further testing e.g. seedling bait tests.

Table 2. Details of sites and sampling dates, Autumn/Winter 2010/11 (STC)

Site	Grower	Variety	Date of sampling		
			Visit 1	Visit 2	Visit 3
1	A	Javelin	9 Sept 10	-	-
2	A	Javelin	9 Sept 10	-	-
3	A	Javelin	9 Sept 10	-	-
4	A	Javelin	9 Sept 10	-	-
5	A	Javelin	9 Sept 10	20 Oct 09	18 Nov 09
6	A	Javelin	9 Sept 10	20 Oct 09	18 Nov 09
7	A	Countess	16 Sept 10	20 Oct 09	18 Nov 09
8	B	Panache	16 Sept 10	20 Oct 09	18 Nov 09
9	B	Picador	16 Sept 10	20 Oct 09	18 Nov 09

Table 3. Details of sites and sampling dates, Autumn/Winter 2010/11 (ADAS)

Site	Grower	Variety	Visit 1	Visit 2	Visit 3	Visit 4 (spring 2011)
1	A	Palace	18 Aug 10	-	-	-
2	A	Javelin	18 Aug 10	20 Sept 10	10 Nov 10	21 Feb 11
3	A	Palace	18 Aug 10	20 Sept 10	10 Nov 10	-
4	A	Javelin	18 Aug 10	-	-	-
5	A	Palace	18 Aug 10	-	-	-
6	A	Javelin	18 Aug 10	-	-	-
7	A	Pinnacle	18 Aug 10	20 Sept 10	10 Nov 10	21 Feb 11
8	B	Javelin	23 Aug 10	20 Sept 10	10 Nov 10	-
9	B	Javelin	23 Aug 10	-	-	-
10	B	Palace	23 Aug 10	20 Sept 10	10 Nov 10*	-
11	B	Javelin	23 Aug 10	20 Sept 10	10 Nov 10	21 Feb 11
12	C	Javelin	5 Oct 10	-	10 Nov 10	21 Feb 11
13	C	Javelin	5 Oct 10	-	-	-

* Roots collected from surface as crop had been lifted

Isolations from samples

In the laboratory all roots were washed and those with blemish symptoms were grouped according to symptom type. Representative samples of roots were examined microscopically and grouped by known pest, pathogen, physical/mechanical injury and symptoms of unknown cause. Using the samples of known pathogen and unknown cause, laboratory isolations were conducted and potential pathogens recovered using the appropriate standardised diagnostic methodologies as detailed below:

- Direct plating onto range of non-selective and selective agars
- Suspended bait test for basidiomycetes e.g. *Itersonilia* sp.
- Incubation in humid chamber
- Aqueous float.

Any organism isolated consistently from blemishes in parsnip roots was secured in pure culture through repeated isolation on agar to ensure purity. Validated isolates were stored on agar slopes in sterile Universal Containers in the refrigerator at 2-3°C. Isolates stored will be retained by both STC & ADAS for future identification and inoculation purposes

Pathogenicity tests

Where any organisms were recovered consistently, artificial inoculation tests were carried out to determine if they were primary pathogens or merely secondary opportunists or saprophytic species. This was achieved by using washed healthy parsnip roots cv. Javelin free of blemish, onto which 5mm diameter disks cut from the leading edge of the active growing colony of the appropriate test fungus were placed. Each treatment consisted of two sections of parsnip root, one piece with and one piece without wounding inoculated at three positions on each piece. Untreated controls were included and consisted of four sections of parsnip root, two pieces with and two pieces without wounding inoculating at three positions on each piece with either Potato Dextrose Agar + Streptomycin Sulphate (PDA+S) or Waksman's agar. If lesions similar to those originally observed are produced and fresh isolations recover the same organism we can state that Koch's Postulates have been demonstrated and hence pathogenicity confirmed. ADAS tested 48 isolates whilst STC tested 38, all gained from a wide range of symptoms. Pathogenicity testing is an important part of the project to allow us to distinguish between true pathogenic species and saprophytic or opportunist organisms, and therefore identify the primary causal pathogens, as once they are known then appropriate treatments can be evaluated for control of these targets.



Figure 1. Example of pathogenicity testing on parsnip

Disease Nursery site

During June 2010 STC staff made 2 visits to a commercial pack-house in Lancashire to collect large quantities of 'waste' parsnips. These roots were discarded from the picking lines due to damage, fanging or a range of skin blemish problems. The roots were brought back to STC and roughly chopped into large pieces which were distributed across a chosen site in a field at STC. The ground was then cultivated and sown with seed of susceptible varieties – a mix of TPS 83, TPS 123, TPS 167.1, TPS169.9, TPS175.13 along with New White Skin, Yatesnip, Henderson Strong and PSL. All seed for the disease bed area was kindly supplied by Elsoms Seeds Ltd. It is anticipated that the germinating and developing seedlings in the disease bed will be infected by the pathogens present on the waste roots and this in turn will bulk-up inoculum of the blemish-causing pathogens in the soil in preparation for trials later in the project.

Seedling bait tests

Soil samples were obtained in November 2010 from the sites previously sampled for roots (5 STC and 6 ADAS). The purpose of these pot tests were to detect and identify any pathogens which cause early symptoms in parsnips such as damping off, collapse or imperfections which might develop into blemishes at a later date. This followed identification of root scarring on young roots from which it was difficult to identify the causal pathogen. Pathogens which cause these early symptoms may not be present when the later disease symptoms are established, and are therefore better recovered by 'baiting' using seedlings in test soils.

At STC the test soils were used to fill 3 replicate 1L which were densely sown with Palace and New White Skin varieties of parsnip seed and 3 replicate 5L pots of more finely sown Pinnacle seed (Fig 2). Seedlings in the 1L pots were monitored for signs of damping-off or collapse. The seedlings in the 5L pots have been retained for longer term tests to allow root development. This variety was chosen for this component of the study as unusual root scarring symptoms (Fig 3) had been seen only on this variety of parsnip.



Figure 2. Seedling bait test at STC

At STC additional samples of the collected soils from each site were collected and were subjected to a nutritional analysis for macro and micro-nutrients.



Figure 3. Narrow dark bands seen on sampled parsnip var. Pinnacle

At ADAS the test site soil samples were sown with 3 different varieties of parsnip as detailed in Table 4. A fully randomised block design was used with 3 untreated controls and three-fold replication. A plot was a 1L pot sown with 30 seeds. If any seedlings showed symptoms of damping off or collapse, the causal pathogen was investigated by incubation under high humidity conditions in a 'damp chamber' and direct plating onto both non-selective agar and the *Pythium* selective agar P5ARP. Seedlings were monitored after emergence and assessments were completed for date of emergence, % emergence and % damping off/collapse. A harvest of 10 seedlings per pot was taken at 8 weeks post planting and the organisms obtained are currently being assessed.

Table 4. Treatment list for seedling bait test, November - February 2010/11 (ADAS).

Treatment	Site	Grower	Seed variety
1	Untreated	-	Henderson Strong
2	Untreated	-	New White Skin
3	Untreated	-	Palace
4	7	A	Henderson Strong
5	7	A	New White Skin
6	7	A	Palace
7	3	A	Henderson Strong
8	3	A	New White Skin
9	3	A	Palace
10	2	A	Henderson Strong
11	2	A	New White Skin
12	2	A	Palace
13	10	B	Henderson Strong
14	10	B	New White Skin
15	10	B	Palace
16	8	B	Henderson Strong
17	8	B	New White Skin
18	8	B	Palace
19	11	B	Henderson Strong
20	11	B	New White Skin
21	11	B	Palace

Results

Spring samples 2010 ADAS

Two crops from Norfolk were sampled by ADAS on 27 April 2010 from grower A. The same fields were re-sampled on 20 May 2010, along with an additional field in Suffolk. Further samples were received from 2 growers from five different crops giving a total of eight crops sampled across Norfolk and Suffolk. Approximately 500 diseased roots were examined in total. Parsnips were received and sampled from a range of varieties including the commercial varieties, Palace and Javelin. A variety of symptoms were observed ranging from penetrating black crown cankers where the crown of the parsnip had been significantly rotted and blackened, to more superficial small red spots around the lenticels of the parsnip (Table 5). An unusual blemish seen in 2010 was 'Ginger Blotch' where large areas of the root were covered in irregular orange/ginger coloured patches. This particular blemish resulted in losses of 60% to some crops during 2010. Examples of the blemishes seen in the 2009/10 crops are illustrated in Figure 4.

Table 5. Symptoms seen at Eastern sites, April – May 2010 (ADAS).

Grower	Field ref/ name	Cultivar	Healthy	Fangs	Dry scars	Narrow black bands	Small spots	Ginger blotch	Severe Crown canker	Inner crown brown	Small crown canker	Corky crown	Deep soft rot	Red/brown speckly lesions on lenticels	Pink/brown superficial lesions (watery)	Cavity spot- like	Carrot fly mines
Field samples			% roots affected														
A	1	Palace	78	2	2	0	14	0	2	0	0	0	2	0	0	0	0
A	1	Palace	44	3	6	0	28	0	6	0	0	0	0	0	0	0	13
A	2	Palace	25	1	27	15	26	0	0	1	2	1	1	0	0	1	0
A	2	Palace	16	9	5	0	29	0	17	0	15	0	9	0	0	0	0
A	3	Not known	73	4	0	0	0	0	0	0	0	0	0	23	0	0	0
Totals (%)			236	19	40	15	97	0	25	1	17	1	12	23	0	1	13
Pack-house samples*			Numbers of roots														
B	4	Duchess (36 roots)	0	0	0	9	0	0	10	0	5	0	0	2	10	0	0
B	5	Countess (18 roots)	0	0	0	0	0	18	0	0	0	0	0	0	0	0	0
B	6	Countess (25 roots)	1	0	0	7	0	1	2	0	0	0	8	0	0	0	6
C	7	Javelin (29 roots)	0	0	5	15	0	7	0	0	0	0	0	0	0	2	0
C	7	Javelin (49 roots)	0	3	6	21	0	12	3	2	0	0	0	0	0	2	0
C	8	Javelin (82 roots)	0	0	0	0	0	0	48	0	0	0	0	0	0	0	34

* Pack-house samples were sent to ADAS directly and as such the samples tended to be biased towards blemishes.



a) Crown canker



b) Black crown/small black crown



c) Corky crown



d) Black shoulder lesion



e) Narrow black bands



f) Ginger blotch

Figure 4. Symptoms seen at Eastern sites, Apr – May 2010 (ADAS).



g) Cavity spot - like



h) Dry scars and deep dry scars



i) Deep soft rot



j) Pink/brown superficial lesions (watery)



k) Young red lesions near crown



l) Carrot fly mines

Figure 4 continued. Symptoms seen at Eastern sites, Apr – May 2010 (ADAS)

Grower samples received by STC Feb – Nov 2010

Approximately 17 samples were received following requests to the industry by STC during spring 2010. Samples were logged into the STC Plant Clinic and identified using PC numbers (Table 6).

Table 6. Details of samples received by STC during 2010

Sample ID	Variety	Symptoms	Organisms detected
PC5484	Palace	Black shoulder lesions	<i>Itersonilia</i> sp.
PC5507	Picador	Fine black cracks around crown*	None. Virus tests negative
PC5518	-	1. Orange slightly raised lesions	None
		2. Scattered orange/brown/black lesions/cavities	None
PC5522	-	1. Shoulder canker	<i>Itersonilia</i> sp.
		2. Orange spots	<i>Fusarium</i> sp.
		3. Orange/brown bruise like lesion	None
		4. Small dark brown/black lesions	<i>Itersonilia</i> sp.
PC5527	Javelin	Ginger blotch lesion on lower part of root.	<i>Cylindrocarpon</i> sp. ®
PC5536	Pinnacle	Canker on crown	<i>Itersonilia</i> sp.
PC5596	Javelin	Brown zig-zag longitudinal lesion	None
PC5607	-	Ginger blotch	<i>Cylindrocarpon</i> sp. ®
PC5614	Javelin	Ginger blotch	<i>Cylindrocarpon</i> sp. ®
PC5620	Javelin	Brown zig-zag longitudinal lesion*	None
PC5622	Javelin	Small orange/brown speckles	<i>Cylindrocarpon</i> & <i>Fusarium</i> ®
Ditto	Countess	Canker	<i>Itersonilia</i> sp.
		Small brown shoulder lesions	<i>Cylindrocarpon</i> sp. ®
PC5691	-	Orange canker type lesions	<i>Fusarium</i> sp. ®
PC5756	Gladiator	A range of orange/ginger lesions	<i>Fusarium</i> ® & <i>Cylindrocarpon</i> sp.
PC5770	-	Brown lesions around lenticels	None
PC5775	-	1. Bruise-like lesions	Yeast
		2. Black shoulder lesions	None - contaminated
		3. Orange discolouration of lenticels	None
PC5799	-	Canker type lesions on sides of root	<i>Itersonilia</i> sp.

* See Fig 5

® - Pathogenicity confirmed



Figure 5. Fine black/brown zig-zag symptom

Three organisms were consistently isolated from the various lesion types, *Fusarium* sp., *Cylindrocarpon destructans* and *Itersonilia* sp. Pathogenicity testing was carried out with all organisms, which were cleanly isolated, using the damaged and undamaged root methodology described in the methods section above. None of the pathogenicity tests with *Itersonilia* sp. resulted in the development of characteristic lesions or the re-isolation of the same organism and therefore Koch's postulates could not be confirmed. All isolates of *Fusarium* and *Cylindrocarpon* that were tested were found to be pathogenic, producing similar lesions, resulting in re-isolation of the same organism. The brown zig-zag lesions (Fig. 5) were reported by growers after the severe frosts in December 2010 and may be due to a frost effect as the brown lines were present symmetrically on both sides of the root.

Crop monitoring – Autumn 2010 - STC

Nine commercial parsnip crops were selected by two growers in Yorkshire for crop monitoring during autumn 2010. These sites had been identified as fields with a history of high wastage figures due to skin blemish in previous seasons. Following initial sampling in all 9 crops, the 5 crops which had the highest incidence of skin blemish were identified. Two additional monitoring and sampling visits were carried out during the development of the crop.



Figure 6. Fine orange speckling often associated with lenticels.

The most common symptom seen were the small orange/red speckles which were seen consistently on vars. Panache, Picador and Javelin. Only a few of the Countess variety displayed this symptom (Fig 6).

The orange/brown penetrating lesions on the shoulders of the roots were also commonly seen.

All crop samples were washed and scored under categories of type of damage seen. The data collected (Table 7) suggests that some skin blemish symptoms e.g. cavity spot and the fine speckling symptom shown in Fig 6. increased during the development of the crop at sites 7, 8 and 9. The Javelin crops (sites 5 and 6) seemed less affected by cavity spot and the small speckle symptom diminished in these crops as they matured. Crown canker-like symptoms were observed primarily on the roots harvested from sites 5 and 9. Ginger-blotch symptoms were observed almost exclusively on the Picador crop at site 9. With the exception of site 6, the number of marketable roots reduced during the monitoring period.

Table 7. Observations of skin blemish symptoms in regularly monitored crops in Yorkshire during Autumn 2010

Blemish symptoms	% roots affected														
	Site 5 Javelin			Site 6 Javelin			Site 7 Countess			Site 8 Panache			Site 9 Picador		
	Visit 1	Visit 2	Visit 3	Visit 1	Visit 2	Visit 3	Visit 1	Visit 2	Visit 3	Visit 1	Visit 2	Visit 3	Visit 1	Visit 2	Visit 3
Marketable roots (scurfing not included)	74	42	23	44	36	78	75	60	53	36	0	10	60	16	0
Dry Scars	0	0	0	0	0	0	0	0	2	0	0	1	0	0	0
Dark narrow scars	0	0	2	0	0	0	0	0	0	0	0	2	0	0	1
Dark black/brown canker lesion - crown	6	8	13	0	3	3	2	0	4	0	0	7	11	12	5
Ginger blotch	0	0	0	0	0	3	0	0	0	0	1	0	4	0	20
Small red speckles	30	14	4	50	43	8	3	0	10	26	66	26	15	54	54
Young orange/red skin lesions -shoulder	0	0	0	0	0	0	5	0	0	21	0	0	0	0	0
Orange penetrating lesion - shoulder	12	10	3	0	18	8	0	30	8	0	29	16	0	18	16
Deep soft rot	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0
'Cavity spot' – like lesion	0	32	42	0	0	0	1	5	18	4	2	19	2	0	5
Orange/brown/black raised scab like lesions	1	0	0	6	0	0	0	5	0	12	13	2	0	0	1
Red root/lenticel scars	0	0	0	0	0	0	15	0	0	0	0	0	8	0	0
Small root splits	0	0	7	0	0	0	0	0	2	0	0	15	0	0	1
Carrot fly mines	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
zig-zag lesions	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Slug damage	0	2	0	0	0	0	0	0	1	0	3	2	0	0	0
Superficial skin scurfing	0	60%	0	0	80%	0	0	0	60%	0	0	40%	0	80%	0

Crop monitoring – Autumn 2010 to Spring 2011 – ADAS

In East Anglia (ADAS) three growers participated and identified crops for regular monitoring. Approximately 100 roots were sampled at random from each crop per visit. Thirteen crops due for harvest in 2011 were sampled in total across Norfolk and Suffolk. Six crops from Grower A and B were sampled three times and two crops from Grower C were assessed twice. Four of these crops remained overwinter and were sampled and assessed again in Feb/Mar 2011. Any foliar disease was noted at each visit and 2 of the 7 crops sampled showed symptoms of Parsnip Yellow Fleck Virus (PYFV) and *Phloeospora* leaf spot but only at an incidence of < 0.05% per crop. Powdery mildew showed a very low incidence of <0.05% during September and early October but none was seen following a spell of wet weather in November.

At Grower A, initially seven crops were sampled in August and then reduced to three crops which were subsequently re-sampled in September and November (Table 8). Palace, Javelin and Pinnacle varieties were represented at all visits. Root symptoms seen varied at each visit but key trends to note are the increase in the small red spots and stripes which frequently occurred in conjunction with the lenticels on the parsnip root, and cavity-spot like symptoms (Table 8). There were no large black cankers seen at any of the sites in 2010, but the small lesions described above caused significant reduction to the marketable quality of the crops. Indeed, the number of marketable roots decreased at all sites between the first and third visits. An interesting blemish was narrow bands of black scarring seen chiefly on the variety Pinnacle and this was recorded at more than 70% incidence in the first two sample assessments. (Fig 3). These narrow bands appeared in the crop at an early stage and in some cases girdled the whole root. The incidence of this skin defect decreased as the crop matured but was still high at 32% roots affected in the November assessment. It is not clear at this stage whether the blemish is due to variety or field conditions, as few fungi were isolated from the lesions and further work is needed to determine cause (Table 8).

Table 8. Symptoms seen throughout 2010 – 2011 season at Grower A. (ADAS).

Blemish symptoms	% roots affected								
	Site 2 Javelin			Site 3 Palace			Site 7 Pinnacle		
	Visit 1	Visit 2	Visit 3	Visit 1	Visit 2	Visit 3	Visit 1	Visit 2	Visit 3
Marketable	89	61	20	80	50.5	25	13	16	25
Fangs	3	1	2.5	0	0	6.5	0	6	1
Dry Scars	8	4	2.5	0	0	0	0	0	10
Dark narrow scars	0	0	0	1	11	4	87	70	32
Dark brown lesion – shoulder	0	0	1.5	19	0	0	0	0	1
Ginger blotch	0	15	0	0	0	0	0	0	0
Small red spots/stripes	0	0	7.5	0	34.5	55	0	4	12
Young red skin lesions -shoulder	0	0	17	0	3	0	0	0	0
Young red skin lesions -midroot	0	3	0	0	0	0	0	0	0
Deep soft rot	0	2	6.5	0	0	0	0	1.5	1
‘Cavity spot’ - like	0	6	28	0	0	4.5	0	0	12
Red brown mid root canker	0	0	12	0	1	0	0	0	3
Red root scars	0	7	1	0	0	4	0	0	0
Small root splits	0	1	0	0	0	1	0	2.5	0
Carrot fly mines	0	0	1.5	0	0	0	0	0	3

At Grower B, four crops were sampled in August. Three of these crops were subsequently re-sampled in September and November (Table 9). Palace and Javelin varieties were sampled as indicated in Table 9. Small red dots or speckles form the greatest percentage of blemishes observed but vary in incidence between samplings, although the overall trend in marketable roots shows a decline at two sites, there was little change at the third site due to a combination of blemish problems. Fanging increased in incidence very slightly across all sites as the roots increase in size. Site 10 had a very poor marketable percentage from the first visit and was lifted early therefore the figures from visit 3 are not truly comparable.

Table 9. Symptoms seen throughout 2010 – 2011 season at Grower B. (ADAS).

Disease symptoms	% roots affected								
	Site 8 Javelin			Site 10 Palace			Site 11 Javelin		
	Visit 1	Visit 2	Visit 3	Visit 1	Visit 2	Visit 3*	Visit 1	Visit 2	Visit 3
Marketable	63	37	38	26	31	33	63.5	68	57.5
Fangs	3	3	6.5	5	5.5	8.5	2	5	5
Dry Scars	1	1	1	0	4.5	15.5	3.5	0	3
Dark narrow scars	0	0	5	1	4	6	0	0	0
Small red spots	14	29	22.5	43	35.5	23.5	20	20	30.5
Black crown	0	0	0	0	0	1.5	0	4	1
Dark red/brown Lesion - crown	10	0	8	2	1	0	0	0	0
Watery red skin lesions - crown/shoulder	6	19	0	22	13	1.5	3.5	0	0
Black dry raised lesion - crown	0	0	1	0	0	4.5	5.5	1	0
Red brown mid-root canker	0	3	1.5	0	0	1.5	0	0	0
Deep soft rot	2	0	10	1	2	0	2	0	2
Cavity spot - like	1	8	6.5	0	0	4.5	0	2	0
Small splits	0	0	0	0	3.5	0	0	0	1

*Crop had been harvested 2 weeks previously, roots collected from tops of beds were rather large, and showed a red discolouration at collection

Site 12 (Grower C) was sampled a little later than the other crops and only in October and November (Table 10). It and was sown with the variety Javelin. There were a higher percentage of marketable roots at this site but again fanging and small red spots or flecks often associated with the lenticels of the roots were increasing at the second sample date (Table 10).

Table 10. Symptoms seen throughout 2010 – 2011 season at Grower C. (ADAS).

No roots affected %		
Site 12		
Disease symptoms	Visit 1	Visit 2
Marketable	95	82.5
Fangs	0.8	6
Dry Scars	0.8	3
Dark narrow scars	0.8	1.6
Small red spots/flecks	0	3.5
Dark red/brown Lesion - crown	0.8	0
Small watery red skin lesions – shoulder/crown	0.8	1
Black dry raised lesion - crown	0	0
Red roots/root scars	0	0
Carrot fly mines	1	2.4

Pathogenicity testing of organisms collected during crop monitoring

A wide range of fungi were recovered from the roots sampled throughout 2010 by both ADAS and STC. The organisms cultured from different lesion types are summarised below (Table 11). *Fusarium* sp. and *Cylindrocarpon destructans* proved to be the most abundantly recovered, but at this point it wasn't clear which were pathogenic and which were simply secondary saprophytic species.

Table 11. Symptoms seen and pathogens recovered by ADAS & STC

Symptom	Pathogens recovered
Crown canker	<i>Botrytis cinerea</i> , <i>Fusarium</i> sp.
Black crown	<i>Cylindrocarpon destructans</i> , <i>Fusarium</i> sp., <i>Itersonilia</i> sp., <i>Verticillium</i> sp.
Black shoulder lesion	<i>Cylindrocarpon destructans</i>
'Young' red crown lesion (watery)	<i>Cylindrocarpon destructans</i> , <i>Fusarium</i> sp.
'Young' red shoulder lesion (watery)	<i>Botrytis cinerea</i> , <i>Fusarium</i> sp.
Red/brown mid-root canker	<i>Cylindrocarpon destructans</i>
Deep soft rot	<i>Cylindrocarpon destructans</i> , <i>Fusarium</i> sp.
Dry scars	<i>Botrytis cinerea</i> , <i>Cylindrocarpon destructans</i> , <i>Fusarium</i> sp., <i>Phoma</i> sp.
Dark narrow scars	<i>Cylindrocarpon destructans</i> , <i>Fusarium</i> sp.
Ginger blotch	<i>Botrytis cinerea</i> , <i>Cylindrocarpon destructans</i> , <i>Fusarium</i> sp., <i>Phoma</i> sp.
Red spots/speckles and stripes	<i>Cylindrocarpon destructans</i> , <i>Fusarium</i> sp., <i>Phoma</i> sp.
Cavity spot - like	<i>Botrytis cinerea</i> , <i>Fusarium</i> sp., <i>Cylindrocarpon</i> sp.
Red-root scars	<i>Cylindrocarpon destructans</i> , <i>Phoma</i> sp.
Black spots/scars	<i>Fusarium</i> sp.

During pathogenicity testing carried out by ADAS three different *Fusarium* sp. proved to be the possible cause of brown or black lesions on parsnip roots, as they resulted in the formation of similar lesions on the test roots and were successfully re-isolated in all cases. *Botrytis cinerea* originally isolated from cavity spot-like symptoms and ginger blotch

symptoms was also successfully re-isolated in all cases. One *Phoma* sp. originally isolated from ginger blotch symptoms also proved to be pathogenic. Four other *Fusarium* sp. and *Cylindrocarpon destructans* were isolated from four different symptoms and the symptoms were reproduced when the fungi were introduced to a clean root but the same pathogen was not 100% re-isolated in these cases.

Notably absent from Table 11 are *Itersonilia pastinaceae*, *Mycocentrospora acerina* and *Pythium* spp. An *Itersonilia* sp. was isolated from the roots but this did not prove to be pathogenic in the East Anglian or Yorkshire samples. Further culturing is in progress to establish that the *Itersonilia* species isolated was *I. perplexans* rather than *I. pastinacae*. *Pythium* spp. have been ‘baited’ out using a seedling test (see following section) but have yet to be tested for pathogenicity.

Table 12. Pathogenicity test results, Dec 2010. (ADAS)

Pathogen	Original symptom	% successful re-isolation
<i>Fusarium</i>	Black crown	100.0
<i>Fusarium</i>	Black crown	100.0
<i>Fusarium</i>	Black crown	100.0
<i>Botrytis</i>	Cavity Spot – like	100.0
<i>Botrytis</i>	Ginger Blotch	100.0
<i>Phoma</i>	Ginger Blotch	100.0
<i>Fusarium</i>	Deep Soft Rot	66.7
<i>Fusarium</i>	Black Dot	50.0
<i>Fusarium</i>	Dry Scars	50.0
<i>Cylindrocarpon</i>	Black Shoulder Lesion	16.7
<i>Fusarium</i>	Ginger Blotch	16.7

Pathogenicity testing at STC confirmed some of the findings from the ADAS tests. For example isolates of *Fusarium* sp. and *C. destructans* from a range of symptoms also proved pathogenic in STC tests as did the *Cylindrocarpon* isolated from cavity-spot lesions. Pathogenicity testing with *Itersonilia* sp. isolated from canker symptoms on roots at STC also failed to result in lesion development.

Seedling bait tests on growers soils

Seedling bait tests were set-up with soil collected from several of the regularly monitored crops.

At ADAS each soil was sown with 3 different varieties of parsnip seed; Henderson Strong is an older open pollinated variety, New White Skin is a non-hybrid variety and Palace is a new F1 hybrid variety. Henderson Strong showed poor emergence, while New White Skin proved the most susceptible to damping off. Site 10 showed a marked reduction in emergence and a fairly high percentage of damping off, and this was the site that was lifted early due to a rapid increase in blemishes in November. There was a large variability in damping off with respect to soil source, ranging from 0 - 22% seedlings affected. There were significant differences between varieties and sites for emergence and damping off, but there was no significant variety x soil source interaction (Table 13).

Table 13. Emergence and damping off from seedling bait tests, Dec 2010. (ADAS)

Factor	Treatment	% emergence 32 days after sowing	% damping off/collapse 32 days after sowing
Variety	Henderson Strong	36.3	7.5
	New White Skin	69.2	14
	Palace F1	63.8	5.2
Soil source	Site 2	64.1	16.9
	Site 3	64.4	4.4
	Site 7	54.8	10.8
	Site 8	61.1	8.5
	Site 10	33.7	13.3
	Site 11	61.9	4.2
	Untreated (compost)	55.2	4.6
LSD variety (40 df)		6.5***	5.68*
LSD soil source (40 df)		9.94***	8.68**
LSD variety x soil source (40 df)		NS	NS

The effect of soil source on damping off was investigated further by comparison with marketable percentage of crop at the November 2010 sampling. There was a good correlation between the percentage marketability of the crop compared with the percentage damping off/collapse if the data from all the varieties are averaged, apart from Site 3 which diverges below the main trend. The variable germination and emergence of Henderson Strong could have affected this figure, and any differences at the site also need to be investigated further.

The situation appears less clear initially if the varieties are separated but Palace and New White Skin still show a fairly good relationship between the marketability in the field crops and the damping off in the pot tests. Palace shows the best resistance to the pathogens that have caused the damping off. The data for Henderson strong is very variable but this could be due to the poor and varied germination of the seed. The relationship between damping off and diseased roots looks interesting and will be investigated further.

At STC the seedling bait tests were set up using soil collected from each of the 5 regularly monitored sites described earlier (5, 6, 7, 8 and 9). The soils were sown with parsnip seed cvs. Palace, New White Skin (in 1L pots for short term studies) and with cv Pinnacle (5L pots for longer term study).

The seedlings in the 1L pots were monitored for signs of damping off. None was observed in any of the STC soil samples. The pots were discarded 8 weeks after germination. The seedlings in the 5L pots have been retained to allow root development so that the roots can be examined for the presence of the unusual girdling lesions seen during earlier sampling of this cultivar.

Nutritional analysis was also carried out on samples of soil from each site. The results of these tests are included in Appendix 1. No obvious correlation between the skin blemish symptoms and the nutrient status of the sites can be observed at this stage; however the data may form part of a bigger picture following further testing at other sites.

Discussion

The crop sampling carried out by both STC and ADAS during year 1 of this investigation has produced some valuable information and data on the types of blemish being seen and has in many instances identified the potential causal organism. Further work is still required to establish the pathogenicity of these fungi in soil. Many of the blemishes and blotches are distinct from the larger cankers traditionally regarded as the important problems on parsnips. This already begins to fill a large gap in our knowledge regarding the causes of wastage in the UK parsnip industry. Organisms such as *Fusarium* and *Cylindrocarpon* have previously been thought of as being relatively harmless in parsnip crops, playing only a saprophytic role in damaged roots. However the work carried out in 2010 has demonstrated, using Koch's postulates, that these organisms are pathogenic on parsnip, capable of causing lesions on even undamaged roots. The relatively high incidence of both of these organisms during sampling at a number of sites suggests that they may well be having a significant impact on crop quality in the industry. The changing status of diseases and blemishes in parsnips may reflect changes in the cultivars that are grown and the selection for disease resistance being made by parsnip breeders. This will be examined later in the project in more detailed testing of varieties.

Among the commonest symptoms observed was the fine orange speckling, from which *Cylindrocarpon* was isolated consistently and the large ginger-blotch symptoms which seemed to be generally caused by a mixture of *Cylindrocarpon* and *Fusarium* sp. Cavity-spot like lesions were observed on 2-3 of the regularly monitored crops. This symptom, commonly seen on carrots has been demonstrated in carrot to be caused primarily by *Pythium violae* and *P. sulcatum*. However, isolation of the causal organism from the mature roots with the symptom can prove very difficult, if not impossible, and this was certainly the case with similar symptoms seen on parsnip. Both teams were unable to detect any *Pythium* spp. associated with the cavity-spot like symptoms, finding only *Botrytis cinerea* and *Cylindrocarpon*. It is generally accepted that the initial damage/lesions on carrot crops form when the roots are still immature and that the early lesion later becomes colonized by other secondary organisms. It would appear that the same scenario may also apply in parsnip.

We did observe some variability between the repeated visits to sites in terms of organisms detected, with only the cavity-spot and speckling symptoms showing any clear increasing pattern over the autumn period in some crops. The reasons for this are unclear, but may be

associated with small 'pockets' of inoculum in crops where skin blemish symptoms were formed rather than a complete 'blanket' inoculum scenario where infective material was generally at a similar level across a field. As the repeat samples were taken randomly in a 'W' across sites it would be unlikely that samples were collected from the same vicinity on each visit. However, general cultivation of the soil in fields where higher than normal levels of skin blemish problems have been observed is likely to result in spread of inoculum of soil-borne pathogens around the sites.

Itersonilia sp. was isolated from a high percentage of the roots with large black/brown shoulder lesions, as would be expected. However, in all of the pathogenicity tests conducted we were unable to demonstrate that this organism was the primary cause of this lesion type and this is rather intriguing. Possible causes for our inability to reproduce symptoms with the isolated fungus may be; a loss of pathogenicity of the isolates collected during repeated culturing, incorrect environmental conditions e.g. temperature, light or humidity to permit the *Itersonilia* to infect and produce a lesion, the 'healthy' test material may have been resistant to infection e.g. have contained resistance genes, although the use of a commonly-sampled 'susceptible' variety (Javelin) for these tests makes this unlikely. An alternative possibility still being investigated is that the isolate collected was *Itersonilia perplexans* and this may never have been the primary cause of this type of lesion but is purely present in a secondary, saprophytic capacity. Further work with the recovered cultures, on Waksman's Agar may be required for species differentiation.

We also observed a great deal of variability in the amount and type of skin blemish within varieties e.g. Javelin appeared to show fewer skin blemish problems at the sites monitored by STC than at some of the sites monitored by ADAS. This suggests that the development of symptoms is linked to the site rather than to any inherent susceptibility to skin blemish issues within varieties.

Conclusions

Work carried out during the first year of this investigation has provided some clear indications of the type, incidence and severity of skin blemish problems that the UK parsnip industry are experiencing. Examination of large numbers of roots from provided samples and visits to pack-houses enabled us to identify the lesion types and carry out isolations to help identify the probable causal organisms, although in many cases we found more than

one organism associated with the symptoms. Follow-on pathogenicity testing with these cultured organisms identified several organisms as potential pathogens. These include several *Fusarium* spp., *Cylindrocarpon destructans*, *Botrytis cinerea* and *Phoma* sp.

There were several notably absent organisms in our findings e.g. *Pythium* sp. *Itersonilia* (isolated but not proven to be pathogenic), *Mycocentrospora acerina* (liquorice rot).

Initial sampling at 22 sites in September 2010 was reduced to 12 crops where there was the highest incidence of skin blemish issues and these were monitored during the 2010/11 season by ADAS & STC. Very similar symptoms were observed at both locations despite the geographical separation and the range of different cultivars examined. We observed a wide variety of symptoms from large shoulder and crown cankers, to a relatively new 'ginger-blotch' symptom along with a fine orange 'speckling' and cavity-spot lesions. The latter two symptoms were seen most frequently and were generally found to increase in the monitored crops over the season.

We did observe some level of inconsistency of symptoms in crops between visits and also between crops of the same cultivar. This would suggest that the skin blemish problems are more closely linked to 'inoculum pockets' of potentially soil-borne pathogens in the field and also that the blemish issues are more linked to incidence of the organisms than to the variety. This also supports grower anecdotal evidence of 'high wastage fields' where in particular seasons they expect to lose a percentage of the crop to blemish. However, the possibility of seed-borne infections creating foci for infection and leading to a build-up of inoculum in the soil cannot be discounted at this stage.

The work will continue in year 2 when both ADAS and STC will carry out laboratory screening (*in vitro* and *in vivo*) of potential control options including soil amendments, chemical and biological control treatments. We will aim to produce a short-list of possible control options to be taken forward into a large-scale field evaluation in year 3 using the disease bed set-up at STC and a commercial site identified by ADAS.

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APPENDIX 1. Soil nutrient analysis – STC

Site No.	pH	Index			mg/L available		
		P	K	Mg	P	K	Mg
5	7.4	4	1	2	61.6	116	81
6	6.6	3	1	2	44.2	108	85
7	7.1	4	3	2	48.6	268	79
8	7.6	4	2-	2	58.4	121	78
9	6.8	3	2-	2	44.8	176	91

Micro nutrients

Determinand	Site 5 result + (comment)	Site 6 result + (comment)	Site 7 result + (comment)	Site 8 result + (comment)	Site 9 result + (comment)
Organic matter (%)	5.7 (Normal/high)	2.8 (Risk)	9.5 (High)	10.4 (High)	8.8 (High)
Copper (mg/L)	1.2 (Risk)	1.0 (Risk)	1.1 (Risk)	2.1 (High)	2.0 (Normal/High)
Boron (mg/L)	6.1 (Normal)	7.1 (High)	22.7 (High)	19.3 (High)	5.2 (Normal)
Zinc (mg/L)	93.8 (Normal)	77.5 (Normal)	33.5 (Normal)	167.4 (High)	53.8 (Normal)
Iron (mg/L)	2.0 (Risk)	1.5 (Low)	1.6 (Risk)	2.2 (Risk)	4.3 (Normal)
Sulphate (mg/L)	131.8 (High)	75.3 (High)	33.8 (Risk)	29.0 (Risk)	148.9 (High)
Manganese (mg/L)	2.2 (V. low)	4.0 (V. Low)	7.8 (Low)	8.2 (Low)	1.0 (V. Low)