AGRICULTURAL DEVELOPMENT AND ADVISORY SERVICE

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FV36A

Investigation of Cause of Foliar Die-back and Crown Rotting in Over-wintered Carrots 1989-92

Undertaken for HDC

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AUTHENTICATION

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

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CARROTS - INVESTIGATION OF CAUSE OF FOLIAR DIE-BACK AND CROWN ROTTING IN OVERWINTERED CROPS, 1989-92

Summary

Following a major problem with foliage death and subsequent crown rotting in Lancashire carrot crops in 1987, laboratory tests and field work were initiated in order to identify the cause.

Numerous isolations using various techniques were performed from 1989 to 1992 but no consistent primary fungal or bacterial pathogens were associated with affected leaves or roots. Fusarium dry rot (F. avenaceum) was fairly common on affected roots but was not invariably present. This fungus is described as a weak pathogen of carrot roots, requiring wounds, damage or infection to invade. In laboratory tests, F. avenaceum caused similar rotting of cut root tissue but could not penetrate intact crowns.

Three field trials were conducted to investigate the effect of a range of fungicides on incidence and severity of crown rot. The results were inconclusive as there was little correlation between the fungicides' effects, their known target organisms and the fungi encountered in this work. However, in Trial 1, straw covering alone reduced crown rot in untreated plots from 83 per cent to 29 per cent and the latter was further reduced by Fubol, Octave and Bravo. A reduction in crown rot due to Fubol was noted in other trials; however no fungal pathogens controlled by Fubol were found during this study. Contrastingly, work in 1991 and 1992 indicated control of crown rot by Corbel (which controls higher fungi such as powdery

mildews and rusts) and thiabendazole products. This could be due to an effect on F. avenaceum, as indicated by laboratory work in Holland.

It was observed that the disorder was aggravated by wet conditions prior to, and during, the winter; prolonged overwintering of some unsuitable Nantes and Berlicum varieties; early drilling; poor or late winter protection and overmaturity of the carrots.

The conclusion drawn was that foliar die-back due to adverse weather conditions (or, potentially, fungal disease) can lead to crown damage and infection by Fusarium dry rot and other soil fungi and bacteria. F. avenaceum can then cause further internal rotting. Damage is most likely in crops in fields with high F. avenaceum populations, in wet autumn/winter weather and with pre-disposing agronomic factors.

Further work should be performed on the foliar phase of the disorder, allied to control of fungal pathogens such as Alternaria spp, and powdery mildews. The role of calcium and boron levels in pre-disposing carrots to crown rot should also be considered. Further work on fungicidal control would have to be accompanied by the generation of residue data.

Meanwhile, carrot growers are advised to avoid prolonged field storage of less hardy Nantes and Berlicum varieties and other pre-disposing factors in high risk situations. The demands of marketing and retail outlets for certain types of carrots should be tempered with an appreciation of such inherent problems.

Introduction

In August 1987, many carrot crops in south-west Lancashire exhibited extensive leaf browning and subsequent die-back. Laboratory tests showed that the symptoms were not due to Alternaria blight (A. dauci) or other pathogens but were probably the result of adverse weather conditions. The first signs of foliar damage occurred after a prolonged period of high rainfall, low temperatures (minimum $\leq$ 5°C) and high humidity in July/August. By autumn, much of the foliage in many crops had died. Wet conditions in the winter then rendered the straw cover on overwintered crops extremely damp and extensive rotting of crown and upper root areas was prevalent by January 1988. The problem appeared to be less severe in crops overwintered under plastic covers. Laboratory tests on the affected crown and root tissue revealed no primary fungal or bacterial pathogens; only saprophytic species were present.

Over the drier winters of 1988-89, 1990-91 and 1991-92, progressively less crown rot has been observed, presumably due to a lack of foliar die-back and dry, relatively mild weather. However, some crops with symptoms of internal pitting and discolouration around the upper core area were always found, particularly in unprotected or poorly protected situations. Numerous tests at various laboratories again showed no primary pathogens to be consistently associated with the symptoms, although Fusarium spp. were fairly common.

Clarkson (1989) conducted a survey of overwintered carrot crops in Lancashire in spring 1989 and concluded that crown rot was more prevalent in Nantes (particularly hybrids) and Berlicum varieties than in the hardier Autumn King types. Symptoms were found to be most severe where susceptible varieties were early sown and/or received no, inadequate or late (after first frosts) overwinter protection. It was postulated that crown rotting was a non-pathogenic disorder in which crown tissue of some susceptible varieties became vulnerable to breakdown following wet and/or cold weather and was subsequently invaded by soil fungi and bacteria. These may have progressed the rotting process further. Incidence of crown rot was unaffected by the standard Fubol fungicide treatment for cavity spot control. There was no obvious correlation with Boron or Calcium deficiency in a limited rumber of tests.

In order to investigate a possible pathological cause of the disorder, two approaches were adopted:

1. Laboratory tests to isolate any resulting fungal and bacterial pathogens from affected foliage and roots and subsequent tests of their pathogenicity.

2. Field trials to assess the effects of various representative fungicides on the incidence and severity of foliar die-back and crown rot.

Materials and Methods

Laboratory tests

Standard laboratory procedures were employed in order to isolate fungi from carrot foliage with browning or die-back and from roots with external or internal crown rot. These involved incubation of affected tissue in damp chambers and culturing on to Potato Dextrose or Sucrose Agars plus antibiotics (streptomycin, erythromycin). Further subculturing was performed as necessary and fungi were identified initially by microscopic examination and confirmed by the Commonwealth Mycological Institute at Kew.

Testing for bacterial pathogens in crown rotted tissue was carried out at the Microbiology Department, ADAS Cambridge, using standard microbiological tests.

In addition, samples of crown rot were sent to Dr J G White, Horticulture Research International, Wellesbourne for specific tests for Pythium using a selective medium (White, 1988) and for Pythium and Fusarium using antibody probes.

Pathogenicity testing of resultant fungal isolates was performed by placing cubes of agar cultures on to discs of fresh carrot tissue in damp chambers. These were incubated for 5-10 days and the degree of rotting was assessed subjectively as Absent, Slight, Moderate or Severe on a 0-3 scale.

Field trials

Sites

Three trials were conducted in the autumn/winter period of 1989-90, 1990-91 and 1991-92. All were located on the same farm, T R Travis & Son, New House Farm, Burscough, Ormskirk, Lancashire. Site details are given in Appendix I.

Design

All three trials were of a randomised block design with four replicate blocks. The plot size was approximately 4.5 m^2 (3 m x 1 bed width). In the 1989-90 and 1990-91 trials, plots were half covered with straw overwinter, the other half remaining unprotected. In the 1991-92 trial, the whole trial area was straw covered as in normal farm practice. Untreated control treatments were included in all three trials.

Fungicides

Table 1. **Fungicides, active ingredients (ai) and dose rates**

Fungicide	ai	Amount ai in product	Dose rate product/ha
Benlate	benomyl	50% w/w	1.1 kg
Fisons Octave	prochloraz-Mn	50% w/w	0.5 kg
Rovral Flo	iprodione	250 g/l	2.0 l
Bravo 500	chlorothalonil	500 g/l	3.0 l
Fubol 58WP	metalaxyl + mancozeb	10:48 w/w	12.0 kg
Fisons Basilex	tolclofos-methyl	50% w/w	10.0 kg
Topas 100EC	penconazole	100 g/l	0.5 l
Dithane 945	mancozeb	80% w/w	1.7 kg
Fongarid 25WP	furalaxyl	25% w/w	4.0 kg
Chiltern Kocide 101	copper hydroxide	77% w/w	2.8 kg
Corbel	fenpropimorph	750 g/l	1.0 l*
Bayfidan	triadimenol	250 g/l	0.5 l
Fungaflor	imazalil	200 g/l	0.5 l
Storite Clear	thiabendazole	260 g/l	2.0 l*

* Half and double rates also used in 1991-92 trial (see Table 2)

Treatments

Table 2. Treatments and timing of fungicides, 3 trials

Treatment	1989-90		1990-91		1991-92	
	x 3	x 1	x 4	x 1	x 4	x 1
Benlate	/	/				
Octave	/		/	/		
Rovral Flo	/	/				
Bravo 500	/				/	
Fubol 58WP	/		/	/		/
Basilex	/					
Topas 100EC	/					
Dithane 945			/	/		
Fongarid			/	/		
Kocide 101			/	/		
Corbel - full rate					/	/
" - half rate					/	/
" - double rate						/
Bayfidan					/	
Fungaflor					/	
Storite - full rate						/
" - half rate						/
" - double rate						/
Water			/			
Untreated	/		/		/	

x 3 or x 4 = 3 or 4 applications between August and November
x 1 = 1 application pre-strawing down (final spray only)

Table 3. Actual application dates

Trial	First spray	Second spray	Third spray	Fourth spray
1989-90	22.8.89	21.9.89	31.10.89	-
1990-91	7.8.90	5.9.90	1.10.90	5.11.90
1991-92	2.8.91	3.9.91	30.9.91	11.11.91

Fungicide application

In all three trials, fungicides were applied as an high volume drenching spray to run-off in 2000 litres of water per hectare. The sprayer used was an OPS CO_2 powered with F80 06 nozzles at a pressure of 200 kPa. The fungicides were applied as a programme of three (1989-90) or four (1990-91, 1991-92) sprays and/or as single pre-strawing down treatments on the final spray date only (see Tables 2 and 3). An equivalent volume of water was applied on the four spray occasions to one treatment in the 1990-91 trial only. An untreated control treatment was included in all three trials.

Harvest and assessment

All three trials were overwintered and samples taken for crown rot assessment in the spring. This was performed by sampling 50 carrots from the covered and 50 from the uncovered area of each plot in the 1989-90 trial (17 April 1990) and 1990-91 trial (15 April 1991). In the 1991-92 trial, 100 plants per plot were sampled at random (3 June 1992), as the whole trial area had been straw covered.

For assessment purposes, plants were transported back to the laboratory at Wolverhampton. Roots were assessed for crown rot by cutting off the top 1 cm below the crown and assessing the degree of rotting on the transverse surface according to the following key:-

0 = No crown rotting present

1 = Slight crown rot (up to half of circumference around core with brown discolouration or pitting)

2 = Moderate crown rot (over half of circumference around core with brown discolouration or pitting)

3 = Severe crown rot (total circumference around core girdled with brown discolouration or pitting and/or more general rotting present)

Crown rot incidence and severity (Disease Index) were computed for each treatment.

Yields, in terms of weight of roots, were not considered to be appropriate in this work.

Statistical analysis

The assessment data were subjected to an analysis of variance. Treatment means were separated using Duncan's Multiple Range Test if significant differences were found.

Results

Laboratory tests

There was little consistency in the results of isolations from foliage with die-back symptoms and from roots with internal or external crown rot. Numerous laboratory tests showed a lack of any organism universally associated with foliar or root symptoms. In many cases, no fungi or bacteria were recovered from affected roots. The most common fungi isolated from roots were species of Fusarium, particularly F. avenaceum, and Cylindrocarpon. However, even these were not consistently found and levels of Fusarium detected in specific antibody tests at Wellesbourne indicated secondary rather than primary infection. Specific tests for Pythium and Phytophthora species at Wolverhampton and Wellesbourne proved negative.

Pathogenicity tests on carrot discs in the laboratory indicated that Fusarium avenaceum and F. compactum were able to cause internal rotting similar to the symptoms encountered in the field (Table 4). Further small-scale tests indicated that they could not penetrate carrot crowns, when inoculated from above, unless the tissue was mechanically wounded but that they could infect carrot foliage at 100% relative humidity. Fusarium equiseti (L) and Cylindrocarpon sp. (F) caused slight to moderate rotting but most other species were non-pathogenic, including those isolated from foliage rather than roots.

Table 4. Ability of fungal isolates to rot carrot tissue *in vitro*

Isolate	Identification	Degree of rotting *
A	*Fusarium compactum*	3.0
B	*Fusarium compactum*	3.0
C	*Fusarium flocciferum*	0
D	*Fusarium avenaceum*	2.5
E	*Fusarium culmorum*	0.5
F	*Cylindrocarpon sp.*	1.5
G	*Rhizoctonia sp.*	0
H	*Sclerotinia sclerotiorum*	0
J	*Fusarium flocciferum*	0.5
K	*Phoma eupyrena*	0
L	*Fusarium equiseti*	1.5
M	*Rhizoctonia sp.*	0.5
N	*Fusarium sp.*	2.5
O	*Fusarium oxysporum/avenaceum*	2.5
P	*Fusarium avenaceum*	2.5
Q	*Acremonium sp.*	0
R	*Fusarium avenaceum*	3.0
S	*Fusarium sp.*	-
T	*Fusarium avenaceum*	2.5
U	*Alternaria sp.* (ex foliage)	0
V	*Sclerotinia sclerotiorum* (ex foliage)	0
W	*Fusarium avenaceum*	2.5
X	*Alternaria sp.* (ex petiole)	0
Y	*Cladosporium* sp. (ex petiole)	0
Z	*Stemphylium* sp. (ex petiole)	0.5

* 0-3 scale of severity (see text)

\- Not tested

Field trials

Trial 1, 1989-90

No phytotoxicity or foliar die-back occurred during the winter and internal crown rot only became apparent in unprotected areas from February onwards. By April 1990, a high percentage (83%) of roots was affected by the disorder in uncovered control plots (Table 5). This level was not reduced significantly by any of the fungicide treatments. In contrast, only 29% of roots were affected in the straw-covered areas of the control treatment. This level was significantly reduced by the Fubol, Octave and Bravo treatments, Fubol performing particularly well. In view of this unexpected result, a late assessment of crown rot was performed in the adjacent cavity spot trial (Table 6). These results showed a reduction in crown rot incidence and severity from a single pre-strawing down treatment of Fubol but no effect of the standard post-drilling treatment.

These results suggested that a fungal pathogen, such as Pythium or Phytophthora, could be involved in this disorder. However, no such pathogens have been isolated from foliage or crown rot symptoms (see above).

Table 5. Incidence and severity of internal crown rot in covered and uncovered areas of plots, Trial 1, Burscough, Lancs, April 1990

		COVERED		UNCOVERED	
	Treatment	% Roots affected	Disease Index	% Roots affected	Disease Index
1.	CONTROL	29.2 c	15.5 bcd	83.0 a	45.3 a
2.	Benlate x 3	24.0 bc	12.3 bcd	86.0 a	45.5 a
3.	Octave x 3	11.1 ab	5.1 ab	89.5 a	47.8 a
4.	Rovral Flo x 3	36.0 c	27.3 d	75.5 a	40.3 a
5.	Bravo x 3	11.5 ab	5.3 ab	84.5 a	46.2 a
6.	Fubol 58 x 3	4.5 a	1.8 a	87.0 a	42.1 a
7.	Basilex x 3	37.0 c	20.7 cd	88.0 a	48.7 a
8.	Topas 100 x 3	21.0 bc	9.7 abc	86.5 a	46.0 a
9.	Benlate x 1	22.0 bc	11.9 bcd	89.0 a	45.7 a
10.	Rovral Flo x 1	25.5 bc	14.0 bcd	85.5 a	47.8 a
	SED (27 d f)	7.42	4.87	5.42	4.76
	CV (%)	47.3	36.0	11.2	14.8

Means followed by the same letter in a column do not differ significantly (P = 0.05)

Table 6. Incidence and severity of internal crown rot in selected treatments from Cavity Spot trial, Burscough, Lancs, May 1990

	Treatment	% Roots affected	Disease Index
1.	CONTROL	33.0	19.0
2.	Fubol 58 at drilling	36.0	24.3
3.	Fubol 58 pre-strawing-down	20.0	9.3
4.	Fubol 58 at drilling and pre-strawing-down	26.0	13.1

No statistical analysis performed

Trial 2, 1990-91

Observations through the winter indicated that crown rot was present from February 1991 onwards and had become fairly severe in control plots by harvest in April. No obvious phytotoxicity was observed from any of the treatments. A high level of general bacterial soft rotting was present, possibly confusing the results.

Incidence and severity of crown rot were similar in both uncovered and covered areas of plots (Table 7). This was in contrast to the previous year's results, in which covering greatly reduced crown rot incidence. In uncovered plots, crown rot incidence and severity were significantly reduced by Treatment 11 (Kocide x 4). Severity alone was significantly reduced by Treatments 2 (Water x 4), 3 (Fubol x 4) and 12 (Kocide x 1). Note that application of water was expected to increase crown rot levels! In covered plots, incidence and severity were significantly reduced by Treatments 3 (Fubol x 4), 5 (Dithane x 4) and 9 (Octave x 4). Incidence alone was significantly reduced by Treatments 2 (Water) and 11 (Kocide x 4). The reduction of crown rot levels was not great, with the exception of Treatment 3 (Fubol x 4) in covered plots. This result was in agreement with that of the previous year's trial.

Adjacent to this trial were unreplicated plots of carrots treated with a range of fungicides by the grower. Of 8 fungicides applied, only thiabendazole (as Storite Clear and Hymush) and fenpropimorph (as Mistral) reduced crown rot markedly when the plots were observed in mid-April. Ronilan, Bravo, Sportak, Trustan and Recoil did not reduce crown rot levels.

Table 7. Incidence and severity of carrot crown rot in uncovered and covered plots, Trial 2, Lathom, Lancs, April 1991

Treatment	UNCOVERED		COVERED	
	% Roots affected	Disease Index	% Roots affected	Disease Index
1. Untreated	82.0 bc	68.4 c	90.0 d	73.6 d
2. Water x 4	67.5 ab	47.3 ab	71.0 bc	58.4 bcd
3. Fubol x 4	66.0 ab	40.5 a	34.5 a	23.5 a
4. Fubol x 1	80.5 abc	58.8 abc	82.0 cd	67.1 cd
5. Dithane x 4	76.5 abc	55.6 abc	64.0 b	51.1 bc
6. Dithane x 1	72.0 abc	57.1 abc	84.0 cd	73.9 d
7. Fongarid x 4	76.5 abc	63.3 bc	81.5 cd	68.6 cd
8. Fongarid x 1	76.5 abc	57.4 abc	82.0 cd	71.1 cd
9. Octave x 4	81.0 abc	56.3 abc	62.0 b	45.0 b
10. Octave x 1	87.5 c	66.6 bc	77.0 bcd	65.1 cd
11. Kocide x 4	64.0 a	39.8 a	73.5 bc	57.4 bcd
12. Kocide x 1	69.0 ab	47.6 ab	81.5 cd	70.3 cd
SED	7.18	8.62	6.90	8.52
df	33	33	33	33
CV (%)	13.5	22.2	13.3	19.9

In the same column, means followed by the same letter are not significantly different (P = 0.05)

Trial 3, 1991-92

Levels of crown rot in 1991-92 were the lowest since the problem began in 1987. Very little crown rot was encountered in crops in Lancashire and foliage health was particularly good prior to, and after, overwintering. The final assessment was delayed as long as possible to allow crown rot to develop but levels were still very low by June. The results are given in Table 8.

Table 8. Incidence and Severity of Crown Rot. Trial 3, Burscough, Lancs, June 1992

	Treatment		% Roots Affected	Disease Index
1.	Control		4.0	3.33
2.	Corbel (1 l)	x 4	0	0
3.	Corbel (0.5 l)	x 4	2.5	1.83
4.	Bayfidan	x 4	2.25	1.83
5.	Fungaflor	x 4	3.0	1.75
6.	Bravo 500	x 4	3.5	2.58
7.	Corbel (1 l)	x 1	1.75	1.17
8.	Corbel (0.5 l)	x 1	1.0	0.83
9.	Corbel (2 l)	x 1	1.25	1.08
10.	Storite CL (2 l)	x 1	1.75	1.17
11.	Storite CL (1 l)	x 1	3.0	2.58
12.	Storite CL (4 l)	x 1	2.0	1.42
13.	Fubol 58WP	x 1	2.5	2.17
	LSD (5%)		NS	NS
	CV (%)		60.5	65.8

NS = Values in column are not significantly different (P = 0.05)

Only 4% of roots were affected by crown rotting in the untreated plots and the severity, expressed as Disease Index (%), was also very low. All fungicide treatments appeared to reduce incidence and severity but the results were not statistically significant. However, there was a definite trend towards reduction of crown rot by Corbel applied as a programme at 1 litre per hectare (Treatment 2) and as a single pre-strawing drench (Treatments 7, 8 and 9). Storite Clear, which should control Fusarium fungi, was disappointing and did not perform as expected. This low level of crown rot did not test the efficacy of the fungicides adequately.

Discussion

The results of laboratory tests to isolate a causal organism of crown rot were inconsistent; no primary fungal or bacterial pathogens were found. Typically, approximately 20 per cent of isolations yielded Fusarium spp., some Cylindrocarpon sp. and secondary bacterial soft rotting. In many cases, no fungi or bacteria were present. No phycomycete fungi, ie Pythium spp., Phytophthora spp. or downy mildews, were associated with foliar or root symptoms. Of the Fusarium spp. isolated, F. avenaceum was the most common. This weak pathogen is associated with Fusarium dry rot of carrots but is regarded as a secondary or wound invader requiring damage, previous pest or disease attack etc for infection (Ramsey and Wiant, 1941; Chupp and Sherf, 1960; Baker, 1972; Snowdon, 1991). Similar root symptoms to those encountered in this study were found in Norway and attributed to an unidentified fungus with sterile mycelium (Arsvoll, 1969). Fungi isolated from foliar die-back included the black rot pathogen, Alternaria radicina, Fusarium spp., Itersonilia sp. and saprophytes, but no consistency was found.

Small scale laboratory pathogenicity tests showed that F. avenaceum (and F. compactum) was able to re-produce rotting of internal carrot root tissue but could not penetrate the crowns. During a visit to Holland (see Appendix II), pathogenicity testing involving dipping roots in F. avenaceum spore suspension was observed to cause general root rotting dissimilar to the symptoms described in this work. Also, all varieties and types of carrot were equally affected, unlike the field situation in Lancashire (Clarkson, 1989).

Field trials, in which fungicides were used to attempt to control crown rot, also gave variable results. Perhaps the most significant result was the great reduction in crown rot levels by straw covering alone in Trial 1. Only in covered plots did fungicides (Fubol, Octave, Bravo) produce further reductions. A programme of Fubol drenches appeared to control crown rot well and some reduction was also noted from a single pre-strawing down drench in an adjacent cavity spot trial. However, it should be noted that no phycomycete fungi, which would be controlled by Fubol, were found in this work. Trial 2 in 1990-91 also showed an effect of Fubol on crown rot but otherwise gave ambiguous results, possibly due to a high incidence of general soft rotting. Adjacent farmer's plots showed an effect on foliar re-growth and crown rot by thiabendazole (Storite Clear, Hymush) and fenpropimorph (Corbel/Mistral) and these fungicides were thus included in Trial 3.

Unfortunately, crown rot levels in 1991-92 were the lowest since the major problem began in 1987. Only 4 per cent incidence was recorded in untreated plots in Trial 3 and no fungicide treatments significantly reduced this figure. However, there was a trend towards reduction by single and multiple Corbel treatments. It is noteworthy that foliage was very healthy before and after the winter period.

It is difficult to interpret the various results of the fungicide trials in terms of control of potential pathogens of crown rot. Fubol controls the lower (phycomycete) fungi, of which none were encountered in this work, while Corbel/Mistral attacks higher fungi, such as powdery mildews and rusts, again not associated with the problem. The results with Octave, Bravo, thiabendazole and, to a lesser extent, Corbel/Mistral

could possibly be related to control of Fusarium but were rather inconclusive. Laboratory tests in Holland showed control of F. avenaceum on agar plates by MBC fungicides (benomyl, thiabendazole) as expected and to a limited extent by fenpropimorph (Dr B Schrijver, personal communication). These results must be considered together with the lack of any consistent pathogens isolated from foliar-die-back and crown rot symptoms.

Conclusions

In the absence of any consistently isolated pathogen from foliar die-back and crown rot symptoms, it can only be concluded that the problem is not caused by a primary pathogen. This view tends to be supported by the variety of results obtained in fungicide trials.

However, at least some of the symptoms encountered on/in the upper root tissues are those of Fusarium dry rot (F. avenaceum). This is considered to be a secondary invader of wounded or damaged tissue but has the ability to cause further internal rotting. The precursor of such invasion could be damage to the roots themselves but is more likely to be foliar die-back giving rise to susceptible crown tissue. Foliar die-back, in this case, appeared to be caused generally by adverse weather conditions but can also be caused by primary pathogens such as Alternaria dauci and A. radicina. The latter was occasionally encountered on both foliage and roots during this study.

The occurrence of crown rot was encouraged by certain agronomic factors such as overwintering of some unsuitable varieties of Nantes and Berlicum types, early drilling, poor or late overwinter covering and over-maturity. In soils with high populations of Fusarium avenaceum and in wet, cold conditions, foliar die-back and crown rot could result in "high risk" crops.

Recommendations

1. Growers should be made aware of the potential risks from crown rot and avoid prolonged overwintering of unsuitable varieties in high risk situations.

2. Marketing organisations, supermarkets etc, should be informed of the inherent problems of over-wintering carrot varieties selected by them on grounds of shape and size only.

3. Further work should be performed on the effects of foliar diseases of carrots on root health, yield and marketability. Control by fungicides, eg Spinnaker, should be investigated.

4. Further work on crown rot should include elucidation of the role of calcium and boron in susceptibility to the disorder.

5. Further fungicidal work on crown rot alone would be speculative. The effects of thiabendazole and fenpropimorph could be investigated further but efficacy data would need to be supported by residue data in the event of an application for Off-Label Approval.

Acknowledgements

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The Horticultural Development Council is thanked for supporting a visit to Bejo Seeds, Warmenhuizen, Holland to discuss mutual work on this subject.

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Storage of Data

The raw data will be stored by the author at ADAS Wolverhampton, Woodthorne, Wolverhampton WV6 8TQ for a period of ten years. HDC will be consulted before disposal.

APPENDIX I Details of Trial Sites

1989-90 Trial 1

Soil texture:	Black sand	
Soil analysis:	P Index	4
	K Index	1
	Mg Index	1
	pH	5.9
Cultivar:	Narman	
Drilling date:	19 May 1989	
Fungicides:	Fubol, 19 May 1989	
Insecticides:	Standard farm practice	
Herbicides:	Standard farm practice	
Straw covering:	Applied late-October 1989	
Harvest	17 April 1990	

1990-1991 Trial 2

Soil texture:	Black sand	
Soil analysis:	P Index	4
	K Index	1
	Mg Index	1
	pH	6.0
Cultivar:	Narman	
Drilling date:	4 April 1990	
Fungicides:	Fubol, 7 April 1990	
Insecticides:	Standard farm practice	
Herbicides:	Standard farm practice	
Straw covering:	Applied mid-November 1990	
Harvest:	15 April 1991	

1991-92 Trial 3

Soil texture:	Black sand
Soil analysis:	P Index 5 K Index 2 Mg Index 2 pH 5.3
Cultivar:	Narman
Drilling date:	25 May 1991
Fungicides:	Fubol, 25 May 1991
Insecticides:	Standard farm practice
Herbicides:	Standard farm practice
Straw covering:	Applied late-October 1991
Harvest:	3 June 1992

APPENDIX II - VISIT TO HOLLAND, 15-17 NOVEMBER 1990

The author was invited to visit a Dutch seed company (Bejo Seeds, Warmenhuizen, North Holland) in November 1990 to discuss mutual work on the carrot crown rot disorder, with particular reference to laboratory testing procedures. The visit was authorised and financed by HDC.

Detailed discussions were held with the chief plant pathologist and his staff on the history of the problem, test methods and the role of agronomic factors. The Dutch workers have also isolated Fusarium spp. (notably F. avenaceum) from crown rot symptoms fairly consistently and currently consider this to be the cause. A test method had been developed to screen varieties for their susceptibility to Fusarium infection. This involves dipping topped field-grown carrots into a Fusarium spore suspension and subsequently incubating them in a tray of sand covered with black polythene in a controlled environment for about 2 weeks. Using this method, most roots exhibited rotting, mainly from the outer side tissues inwards, and no differences in varietal susceptibility were found. This is in contrast to UK field experience where Nantes and Berlicum types have been found to exhibit more severe crown rotting than the hardier Autumn Kings. It is possible that the test method conditions are highly favourable for fungal infection and may not reflect the situation in the field. Overmaturity was considered to render the plants more prone to crown rot.

Some fungicide plate tests have been conducted to ascertain the chemicals with most activity against F. avenaceum. Thiabendazole, prochloraz and imazalil inhibited fungal growth in vitro. Quintozene gave partial control but mancozeb was ineffective.

The opportunity was also taken to observe other aspects of the company's work on plant diseases and plant breeding. Of interest was resistance breeding work on pinkroot of onions and downy mildew, yellows and Turnip Mosaic Virus of brassicas. A mutual problem with Fusarium on red beet was also discussed. The most modern tissue culture techniques employed in breeding of brassica, carrot and chicory varieties were observed in the laboratories and controlled environment rooms. Brief visits were also made to the glasshouses, seed production and treatment plants and to the administrative headquarters.

The visit was extremely valuable in gaining further information on carrot crown rot, in particular the laboratory test procedures.