Project title	Reducing disease losses in carrots and parsnip crops through appropriate seed health standards
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Project leader:	Dr J E Thomas, NIAB
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Project coordinator:	Mr Robin Wood, Elsoms
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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

Headline

- The health status of 26 commercial carrot seed lots tested in 2007 was found to be very high, with the majority having no pathogenic fungi detected
- Where pathogenic *Alternaria dauci* was found, levels of 3% on seed did not produce any detectable infection on juvenile plants in field plots.
- Disease-like symptoms appeared on many plant parts, but no pathogens were found

Background and expected deliverables

Carrot and parsnip seed may be infected with a number of seed-borne pathogens which have the potential to cause disease early in the life of the crop, and contribute significantly to later epidemic progress. Carrot and parsnip producers have been concerned that seed supplies carry significant disease and that this is responsible for subsequent problems. This project is aimed at examining samples of seed used by producers and identifying any health problems, and then investigating the relationship between seed health status and disease developing in the early stages of the growing crop. The results will deliver the basis for a voluntary seed health assurance by identifying infection levels which are likely to give rise to disease in the field, and those which are not.

Summary of the project and main conclusions

Carrot seed samples were obtained during the first year of the project, but only one parsnip seed sample was received, and further work on parsnips will be carried out in a project extension. Nearly all the carrot samples were completely free from disease using standard testing techniques, and would be unlikely to be the cause of field problems. Samples with up to 3% *Alternaria dauci* did not give rise to detectable disease in field plots and, so far, this would therefore appear to be an acceptable level in seed.

Financial benefits

The seed samples (26) were obtained from seven seed houses, and represented most major interest varieties and newer ones. Growers can therefore be assured that the health status of the majority of carrot seed surveyed is high, and unlikely to initiate extensive field disease development.

Action points for growers

- Ask for seed health test results
- Disease like symptoms may appear on juvenile plants, but if seed was healthy, the symptoms are
  unlikely to be caused by seed-borne disease
- Monitor any disease-like symptoms carefully for further spread

Science Section

Introduction

Carrot and parsnip seed may be infected with a number of seed-borne pathogens which have the potential to cause disease early in the life of the crop, and contribute significantly to later epidemic progress. Furthermore, seed-borne disease may introduce problems into relatively "clean" areas and create a reservoir of inoculum. Organic seed is particularly vulnerable to the effects of seed-borne disease, and in conventional seed, available seed treatment products may not always offer complete control of a range of diseases. A recent small survey (see FV 261) on parsnip seed confirmed the presence of various diseases in seed tests, but did not relate these to disease in the field. Carrot growers have frequently suspected that seed carries significant disease, but there has been no attempt to relate this experimentally to subsequent disease development. Relating disease outbreaks to seed-borne origins is usually difficult, since many growing areas have a high intensity of crops or crop debris which perpetuate diseases. Nevertheless, it is vital that both growers and suppliers of seed have information on seed health, and an indication of whether certain levels of disease may contribute significantly to disease development or not. This project aims to test seed lots sold in the UK and investigate the relationship between test result and disease developing during the early stages of crop growth. The results obtained could then be used to provide the basis for a voluntary assurance of health test results.

Materials and methods

Requests for carrot and parsnip seed samples used by growers were made through the BCGA group, and through the project coordinator. In addition, commercial samples used to drill the BCGA carrot demonstration trial in 2007 were included, together with some samples of organic carrot seed obtained by NIAB. Carrot samples were drilled on 20th July 2007, but unfortunately only one parsnip sample was obtained and included in the trial. Plots were 2 rows x 9 m long, with three replications per variety. Plots were irrigated to promote establishment, and to provide a favourable environment for disease development (25 mm per week over two 1 h periods). Juvenile plants were sampled on 19th September 2007, taking 30 plants per plot in 6 groups, each of 5 plants, and assessing for any apparent disease symptoms. Samples of the material were then surface sterilised and plated on potato dextrose agar to identify causal organisms.

Sub samples of the seed supplied were retained for testing in the laboratory. 200 seeds of each were plated on PDA, and assessed for the presence of known pathogenic agents, and any other organisms present. For known pathogens, standard identification methods available in ISTA/ISHI protocols were used. Treated seeds were plated without removing treatment.

A short literature survey was carried out to determine current knowledge on the range of seed-borne diseases of carrot and parsnip, and any published information on relationships between levels of disease on seed and field expression of symptoms.

Results

Samples from various parts of juvenile plants were classified as abnormal as follows:

Cotyledons – browning or blackening in discrete areas
Petioles – brown or reddish brown and black streaking, larger areas of discolouration
Crowns – distorted or browned
Roots – black or orange areas of discolouration or streaks on the upper root
Leaf tips – brown areas, yellow halo

There were no significant differences in the incidence of abnormal symptoms between any of the varieties, though a few had much higher levels of cotyledon discolouration (Table 1). Total numbers of fungal or bacterial colonies arising from abnormal tissue were relatively low, and consisted of non-pathogenic Alternaria types, Phoma types, Fusarium and unidentified bacterial colonies (Table 2). Plating of seed used to drill plots showed that most seed was healthy, with only two samples having infection with *Alternaria dauci* (Table 3), though one sample had high levels of non-pathogenic fungi. There was insufficient seed to allow tests for *Xanthomonas hortorum* f.sp. *carotae*. *Itersonilia* species were not found in the parsnip sample.

Table 1 Mean % of plants out of 30 with abnormal cotyledons, petioles, crown, upper root and leaf tip tissue

	Abnormal cotyledons	Abnormal Petioles	Abnormal crown	Abnormal root	Abnormal leaf tip
Newark	57.8	23.3	18.9	11.1	8.9
Adonis	64.7	10.0	12.2	4.4	6.7
Nairobi	46.7	14.4	16.7	4.4	5.6
Karotan	82.4	10.0	16.7	2.2	5.6
Riga	42.1	7.8	6.7	12.2	7.8
Miami	51.4	23.3	23.3	16.7	3.3
Starship	46.0	26.7	18.9	20.0	14.4
Bastia	40.9	17.8	11.1	8.9	10.0
Miami (organic)	44.2	15.6	14.4	12.2	6.7
Negovia (organic)	56.9	11.1	13.3	6.7	0.0
Nairobi (organic)	62.7	15.6	20.0	14.4	17.8
Volcano	53.0	10.0	11.1	25.6	20.0
Maestro	47.0	8.9	8.9	14.4	3.3
Coreo	25.0	20.0	20.0	12.2	10.0
Ca 4031	57.1	14.4	20.0	7.8	5.6
Torro	55.4	18.9	13.3	17.8	14.4
Elegance	36.7	14.4	15.6	8.9	6.7
Harvey	43.3	12.2	23.3	4.4	4.4
Nerac	53.0	10.0	20.0	11.1	5.6
Norwich	48.6	13.3	14.4	10.0	12.2
Nigel	44.1	16.7	15.6	12.2	8.9
Nottingham	46.4	16.7	14.4	18.9	16.7
Nipomo	57.5	14.4	24.4	23.3	14.4
Trevor	44.2	21.1	15.6	10.0	4.4
Ulysses	49.1	12.2	18.9	10.0	3.3
Artemis	50.0	21.1	33.3	12.2	6.7
Javelin (parsnip)	36.5	10.0	6.7	20.0	12.2

Table 2 Total numbers of colonies arising from plated tissues of all abnormal types

	Alternaria Colonies	Phoma colonies	Fusarium colonies	Bacterial colonies
Newark	16.3	1.7	6.3	2.7
Adonis	13.7	0.7	5.0	0.3
Nairobi	12.0	2.0	3.7	1.3
Karotan	14.7	0.7	4.0	1.7
Riga	13.7	0.3	5.0	1.0
Miami	13.0	0.0	4.0	1.3
Starship	9.0	0.3	3.3	7.0
Bastia	12.3	0.7	3.3	1.0
Miami (organic)	12.7	0.3	3.0	2.3
Negovia (organic)	10.3	1.3	3.3	2.3
Nairobi (organic)	25.7	2.3	3.3	1.3
Volcano	13.3	1.7	2.7	1.3
Maestro	11.7	0.0	2.7	2.7
Coreo	7.7	0.3	4.7	3.3
Ca 4031	21.3	2.3	4.7	0.3
Torro	16.7	0.3	2.7	1.7
Elegance	11.3	0.0	1.0	3.0
Harvey	8.7	0.3	2.0	1.0
Nerac	17.0	0.3	3.7	3.7
Norwich	11.3	0.3	4.3	1.7
Nigel	18.0	0.7	2.7	1.7
Nottingham	19.0	1.0	3.7	1.7
Nipomo	21.7	1.0	2.0	3.3
Trevor	13.0	0.0	5.3	1.7
Ulysses	11.7	0.7	4.0	3.3
Artemis	11.3	0.3	5.0	1.7
Javelin (parsnip)	14.0	0.7	0.7	3.7

Table 3 Number of colonies of different fungal species arising from plated seed

	Pathogeni	Non-	Phoma	*Cercospor*	Fusariu

	c Alternaria	pathogenic Alternaria	species	*a carotae*	*Stemphyllium botryosum*	m
Newark	0	0	0	0	0	1
Adonis	0	0	0	0	0	0
Nairobi	0	0	0	0	0	0
Karotan	0	76	0	0	40	3
Riga	0	0	0	0	0	0
Miami	0	6	1	0	2	0
Starship	0	0	0	0	0	0
Bastia	0	0	0	0	0	0
Miami (organic)	6	0	0	0	0	0
Negovia (organic)	3	0	0	0	0	0
Nairobi (organic)	0	0	0	0	0	0
Volcano	0	0	0	0	0	0
Maestro	0	0	0	0	0	0
Coreo	0	0	0	0	0	0
Ca 4031	0	0	0	0	0	0
Torro	0	0	0	0	0	0
Elegance	0	0	0	0	0	0
Harvey	0	0	0	0	0	0
Nerac	0	0	0	0	0	0
Norwich	0	0	0	0	0	0
Nigel	0	3	0	0	0	1
Nottingham	0	0	0	0	0	0
Nipomo	0	0	1	0	0	0
Trevor	0	0	0	0	0	0
Ulysses	0	0	0	0	0	0
Artemis	0	0	0	0	0	0
Javelin (parsnip)	0	1	0	0	0	0

Discussion

Only two seed samples, both organic, gave rise to pathogenic *Alternaria dauci* in the plate test of seed. No *A. radicina* was observed. The levels found did not lead to any detectable infection with either species in the field plots. Weather conditions during the trial period were very favourable for *Alternaria* blight development (warm and with frequent rainfall in addition to irrigation), but no disease was seen in the plots two months after drilling. A further visual inspection of foliage only on 7th December 2007, with check plating of ten leaf segments from throughout the trial, did not confirm any *Alternaria* infection on the organic samples or any other material.

The majority of seed samples received for carrots had a very high health status. No colonies of the pathogen *Cercospora carotae* were observed. There were very high numbers of

Stemphyllium botryosum on the seed sample of Karotan, which also had a high level of infection with *Alternaria alternata*. This seed was supplied untreated. Both these species are non-pathogenic on carrots, though the field sample of Karotan had a high number of abnormal cotyledons, suggesting that the very high levels of non-pathogenic fungi from the seed had colonised tissue and created some browning and necrosis. None of the other plant parts of Karotan were adversely affected compared to other varieties. The organic sample of Nairobi showed a relatively high level of brown patches on cotyledons, and a relatively high recovery of non-pathogenic Alternaria from these and other plant parts. However, there was no non-pathogenic Alternaria in the seed sample tested.

All of the Alternaria colonies recovered from plant parts with abnormal appearance in any variety were non-pathogenic types, and no *A. dauci* or *radicina* were recovered. A small number of plant parts, across all varieties, gave rise to Phoma – like colonies (pycnidia with whitish or pinkish-orange ooze). There was no relation between the incidence of these colonies and the incidence of Phoma like colonies found on seed, which was restricted to Miami and Nipomo. The identity of the Phoma species recovered from plant parts could not be confirmed. Colony type was not typical of the common non-pathogenic *Phoma herbarum*. It is possible that they were pathogenic *Phoma apiicola*, which is reported to infect celery, carrot and parsnip, and can be seed or debris-borne.

Several bacterial colonies grew from abnormal plant parts, but there was no evidence of *Xanthomonas hortorum* f.sp. *carotae* symptoms on leaves, and bacterial infection from the plated tissue is likely to be secondary.

The range of pathogens which are seed-borne in carrots and parsnips was confirmed using The Compendium of Umbelliferous Crop Diseases (American Phytopathological Society). In Europe, including UK, *Alternarai dauci*, *Alternaria radicina* and *Cercospora carotae* are all confirmed as fungal seed-borne diseases. *Phoma apiicola* is also seed borne, but of minor importance. *Xanthomonas hortorum* f.sp. *carotae* is the major bacterial seed-borne disease. Downy mildew (*Plasmopara umbelliferarum*) is reported as being seed-borne in Europe, though the disease is not known as a common foliar problem in the UK. On parsnip, *Itersonilia pastinacae* and *Itersonilia perplexans* are both common seed-borne fungi and cause cankers. *I. pastinacae* is regarded as the predominant UK pathogen, though there is still debate about the separation of this species from *I. perplexans*, and both would be assessed in standard seed tests. *Phoma complanata* is also found on parsnip seed, and may cause cankers. *Phloeospora heraclei*, a recently described leaf spot on parsnip has not been shown to be seed-borne. *Ramularia pastinacae* may be found on seed, though is generally thought not to cause extensive damage to parsnip foliage in the UK. *A. radicina* is seed-borne in parsnip as well as carrot.

Thresholds for this range of pathogens are not well established. Most literature refers to use of "disease free" seed being best practice, or using seed with infection below the inoculum potential required to generate disease in the field, but specific safe levels of infection are usually not reported (eg Pryor and Gilbertson, 2001 in relation to *A. radicina*). Farrar *et al*. (2004), suggested that planting seed with little or no *A. dauci* was an important factor in disease management. Seed treatments such as thiram and iprodione could reduce but not eliminate infection. An example of reduction with fungicides to 0.01% and 0.43% infection was cited, but at a range of commercial seed rates this could produce a potential 50 to 300 inoculum sources per hectare. The difference between potential inoculum sources and actual transmission to emerging plants is critical, and there does not appear to be any definitive threshold for Alternaria diseases below which seed can be planted without risk to the crop. In the case of bacterial blight of carrots, under low rainfall and humidity conditions, a relatively high number (10^4 to 10^5 colony forming units of bacteria per g of seed could be tolerated without significant disease appearing in the field (Umesh et al., 1998). No information relating specifically to Europe could be found, but it is likely that thresholds would be much lower. In parsnip, Channon (1963) found that when a seed sample with 77% infection with *I. pastinacae* was sown in the field, 6.5% of seedlings were affected by Itersonilia lesions,and deduced that a 1% infection in seed could potentially give rise to 73 infected plants/acre. As a result, it was suggested that only disease free seed should be used.

Conclusions

Carrot seed samples were supplied direct from producers (3 samples) or seed houses (23). One parsnip sample was provided by a producer. Seven seed houses were represented, and seven of the samples were untreated.

The health status of all the samples apart from two was very high, with nil disease recorded in a 200 seed test. From this evidence, it can be concluded that the 2007 seed would have been unlikely to be the cause of introduction of disease into carrot crops. This was confirmed by field sampling of juvenile plants.

Where some pathogenic Alternaria species were detected in seed (3% and 1.5%), there was no evidence of infection on sampled field plots after weather conditions which would be highly favourable for Alternaria development.

Juvenile plant parts (cotyledons, petioles, root, leaf tissues) frequently appeared to have disease-like lesions, but only non-pathogenic fungi were recovered, and there was no further development of disease symptoms.

Technology transfer

- Outcome of first year experiments summarised and reported to BCGA

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