

**Project title:** Carrots: Incidence of cavity spot in Commercial Crops

**Project number:** FV 373

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**Previous report:** None

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**Location of project:** England and Scotland

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**Date project completed  
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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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# GROWER SUMMARY

## Headline

This project identifies the relationship between cavity spot, water input and temperature: this will lead to a better understanding of the disease and ultimately better control.

## Background

Cavity spot is a serious and recurring disease of commercial carrots in the UK. Current control systems rely on the use of a single soil applied fungicide treatment which is only partially successful and growers need improved methods of control.

In 2008-09 the British Carrot Growers Association developed a specific R&D strategy for Cavity Spot. This strategy has now been finalised following active and robust discussion from members of the BCGA technical committee. Six target categories have been identified in the strategy with details of what is understood and not understood by the industry for each target. Targets include: Diagnostics, irrigation, fungicide efficacy, general agronomy, plant breeding and soil microbiota. This project is intended to cover a gap under general agronomy.

- General Agronomy - Recent review work by BCGA leads to the conclusion that the occurrence of cavity spot needs to be documented more clearly with regard to all appropriate agronomic details and most appropriate local weather records and site specific total water input, soil moisture and soil temperature. An identified gap therefore is a firm understanding of the relationship between confirmed Cavity Spot infection in commercial crops, soil environmental conditions and cultural practices. The BCGA therefore have decided to conduct a data collecting exercise to establish the relationships and draw on the dispersed knowledge of the industry.

### *What is understood:*

- Recent work at Warwick HRI (by Dr D J Barbara) has demonstrated that growers need to focus on disease risk control through a variety of approaches including soil and water management.

*What is not understood:*

- All commercial growers have experiences of disease in their crops and some growers have tried to relate the occurrence of the disease to their particular circumstances. However, little data has been collected across the industry on the incidence of disease in relation to rotations and agronomic conditions. Consequently much that is said about cavity spot is based on poor evidence and there is little certainty about how particular rotations or management practices have affected its occurrence and expression.

This study aims to document, as far as possible, the conditions relating to new outbreaks of cavity spot which together with site history and site conditions will add considerably to the knowledge bank and should help identify situations which should be avoided.

## **Summary of the project and main conclusions**

Thirty commercial carrot production sites provided by members of the BCGA were monitored for total water input (precipitation and irrigation), soil moisture and soil temperature. At each site the incidence and severity of cavity spot disease was established by sampling prior to harvest and relationships were sought between the recorded site conditions and the incidence of disease.

**Table 1:** Sites monitored in 2010

<b>ID</b>	<b>Name</b>	<b>Longitude</b>	<b>Latitude</b>
1	Sherwood Thoresby	-1.051829	53.233297
2	FG Caistor	-0.359861	53.50699
3	Sherwood Apley Head	-1.017921	53.28844
4	KPL Rameldry	-3.089274	56.245054
5	HF Norton	-0.769297	54.125680
6	Sherwood Carburton	-1.093142	53.258428
7	MF Plex Moss Lane	-2.992245	53.583655
8	FG Retford	-0.983141	53.337364
9	Taylor Hine Heath	-2.614129	52.81251
10	VCS Elveden	0.6190	52.3384
11	3M Greenwell	1.4673	52.0992
12	VCS TBG Sutton	1.3688	52.0604
13	VCS Raker	0.8352	52.5271
14	3M Westrope	1.3687	52.0287
15	AG Mayhew	1.2845	52.0137
16	MF Rennacres Lane	-2.951787	53.597494
17	Farley Collumpton	3.3977	50.8220
18	WP Cockley Cley	0.6718	52.5864
19	3M Wantisden	1.4500	52.1061
20	TBG Isleham	0.3790	52.3608
21	WP Drayton	1.2376	52.6903
22	TG Houghton	0.6327	52.8154
23	SL Torworth	-1.01802	53.368489
24	SL Tichwell	0.5956	52.9338
25	VCS TBG Westrope	1.3784	52.0396
26	HPF Thornton Grange	-0.862963	53.906796
27	KPL Edenwood	-3.043140	56.293134
28	KPL Raecruick	-3.206958	56.275221
29	SL Rainworth	-1.070114	53.118082
30	PSL W Pinchbeck	-0.2466665	52.837510

At each site an automatic soil moisture station was installed in a representative area of the field. This consisted of a Remote Transmission Unit (RTU) and SIM set up to use the GPRS network together with an automatic tipping bucket total water input sensor (resolution 0.2mm per tip) and soil moisture (SM) probe using an SDi12 interface. The SM probe

consisted of a sealed tube containing capacitance sensors at 100, 200 and 300mm depths and an integrated temperature sensor at the middle level.

The station recorded the total water input (precipitation plus irrigation), soil temperature (degrees C) and soil moisture (% soil moisture at 3 levels).



**Figure 1:** Monitoring station showing RTU and total water input sensor



**Figure 2:** Soil moisture sensor showing insertion into carrot bed alongside rows



**Figure 3:** Soil moisture sensor showing internal construction

Data was collected from all of the RTUs from the time of installation (normally shortly after seeding) to just prior to harvest of the crop or just prior to strawing down. The resultant data file was converted to hourly values and then to daily summaries for analysis.

Crops were sampled when mature and before harvesting or strawing. At each site samples were collected and washed to reveal any cavity spot lesions. Each sample was recorded for the incidence of disease lesions (% roots affected) and the severity of the disease (scale 1 to 5)

**Table 2:** Summary of Incidence % and Severity (1 to 5) of Cavity Spot disease in 2010

<b>Field</b>	<b>Incidence</b>	<b>Severity</b>
1	0	0
2	41	4
3	31	2
4	0	0
5	0	0
6	0	0
7	23	2
8	0	0
9	0	0
10	11	2
11	8	3
12	1	1
13	24	2
14	0	0
15	5	1
16	0	0
17	0	0
18	51	3
19	7	2
20	1	2
21	2	1
22	5	2
23	0	0
24	2	1
25	3	1
26	0	0
27	0	0
28	0	0
29	22	2
30	0	0
Mean	7.9	1.0

Cavity spot disease was recorded in 53% of sites.

For each of the recorded site conditions (total water input, soil temperature and soil moisture), multiple 7 day periods were used to calculate values (correlation coefficients) starting with week 23 (Jun 6<sup>th</sup>). So for 'total water input' values were calculated each week from week 23 for the following 8 weeks and this was repeated up to Week 38 (19<sup>th</sup> Sept). The calculation was then repeated for the other two site conditions – 'soil moisture' and 'soil temperature'. This allows us to see if there is any relationship between the presence of cavity spot and any of the site condition variables (total water input, soil temperature and soil moisture).

The range of correlations was examined and those that produced significant results ( $P < 0.05$ ) were noted and used in a regression analysis in order to determine those weather variables that gave an indication that there was a likelihood of diseases being present.

**Table 3:** Correlation between total water input and presence of disease.

	Week 28	Week 29	Week 30	Week 31	Week 32	Week 33	Week 34
1wk	-0.31	-0.12	0.43	0.25	0.39	-0.03	<b>0.55</b>
2wks	-0.26	0.19	0.42	0.48	0.28	<b>0.51</b>	0.38
3wks	-0.06	0.29	<b>0.53</b>	0.43	<b>0.54</b>	0.34	0.27
4wks	0.06	0.44	<b>0.53</b>	<b>0.58</b>	0.43	0.23	0.22
5wks	0.24	0.43	<b>0.61</b>	0.47	0.35	0.19	0.25
6wks	0.22	<b>0.59</b>	<b>0.53</b>	0.42	0.31	0.24	0.20
7weeks	<b>0.52</b>	0.45	0.50	0.36	0.35	0.18	0.26

Table 3 highlights those periods where there was a significant correlation between total water input and presence of the disease. It shows that the total water input around week 30 (25th July) gives the best correlations and the best correlation is obtained using the total

water input in the 5 weeks following week 30 and indicates that the likelihood of disease increases as the total water input increases.

A similar procedure was carried out for soil temperature and soil moisture but significant relationships were not obtained for these variables – see Science Section for more details.

## **Financial benefits**

In this study of commercial crops the average loss due to cavity spot was almost 8% representing a loss of c£20 million retail sales value (RSV). On completion of the project and implementation of improved management practices and controls this loss should be able to be reduced.

## **Action points for growers**

The results from year 1 lead to an indication that growers should ensure that total water input (precipitation plus irrigation) during August is minimised. Whilst it is not possible to influence precipitation, the management of irrigation is at the grower's command and it may be possible to reduce disease through less irrigation.

## SCIENCE SECTION

### *Introduction*

Cavity spot is an intractable disease problem and there has been a lot of effort in the last 20 years to try and understand it. The projects listed below were conducted largely by a team at HRI lead by Dr Geoff White during the 1990's:

FV 5: Investigation and control of carrot cavity spot disease

Fv 5a: Carrot detection of cavity spot pathogens in soil

FV 5b: carrots: an integrated approach to the control of cavity spot

FV 5c: Carrots: production of antibodies to *Pythium violae* and *Pythium sulcatum* in large volumes for diagnostic services

FV 5d: Carrots: screening fungicides for the control of the *Pythium* spp. which cause cavity spot

FV 5e: Carrots: a review of cavity spot disease

FV 5f: Carrot: the control and biology of cavity spot

Fv 5g Optimization and field evaluation of PCR assays to quantify cavity spot pathogens (*P.violae* and *P.sulcatum*) in soils and to rapidly identify them in carrot tissues

FV 249: Carrots: a cost-benefit study in the control of free-living nematodes, soil diseases and volunteer potatoes by comparing specific management systems before and during cropping.

Defra HH1746SFV: Detection methods for *Pythium* (cavity spot of carrots & ornamental pathogens).

Defra HH3230SFV: Factors Affecting the Inoculum potential of soil-borne plant pathogens

More recent projects have been conducted by Dr Dez Barbara at WHRI. Following the development of the Cavity Spot R&D strategy in 2009 the following project, FV 353, was commissioned to answer key gaps in that strategy whilst the PhD studentship CP 46 will answer some questions not covered by earlier work done in the 1990's.

FV 353: Carrot cavity spot: (i) using quantitative PCR to 'predict disease in strawed crops; (ii) controlling soil moisture for optimum disease management

CP 46: Carrot cavity spot – the effects of non-carrot crops on levels of relevant *Pythium* spp. in the soil (PhD)

The current cost of cavity spot outbreaks is minimised by growers through active salvage – the implementation of emergency harvesting and marketing operations. This has costs in terms of disruption to normal operations and through taking price discounts to move large volumes of distressed crops. If disease is well developed, whole crop loss is inevitable. Even with effective active salvage it is estimated that the incidence of cavity spot in carrots

in the UK in a typical season costs growers around £3 to 5 million in direct crop loss. Data from the first year of this study suggests this estimate agrees well with a loss in Retail Sales Value of around £20 million.

This report summarises the monitoring exercises and records obtained during the first year of this 3-year study.

## Materials and methods

Members of the BCGA were contacted in the spring of 2010 and asked to identify commercial production sites which could be studied during the growing season. Thirty sites were selected to represent the main growing areas and typical soil types of England and Scotland and which might be 'risky' in terms of cavity spot disease. Such sites would normally have grown carrots before but would have not been cropped with carrots or related crops during the preceding 5 or 6 seasons. A wide geographic spread of sites from Fife, Yorks & Lancs, the East Midlands and East Anglia was selected to ensure, as far as possible, that representative conditions were obtained together with a good chance of disease expression.

A consultant agronomist visited each site and installed the monitoring equipment in a representative area as soon after sowing as possible. All new equipment was used to ensure the instrumentation was reliable and consistent.



**Figure 1** Monitoring station showing RTU and total water input sensor

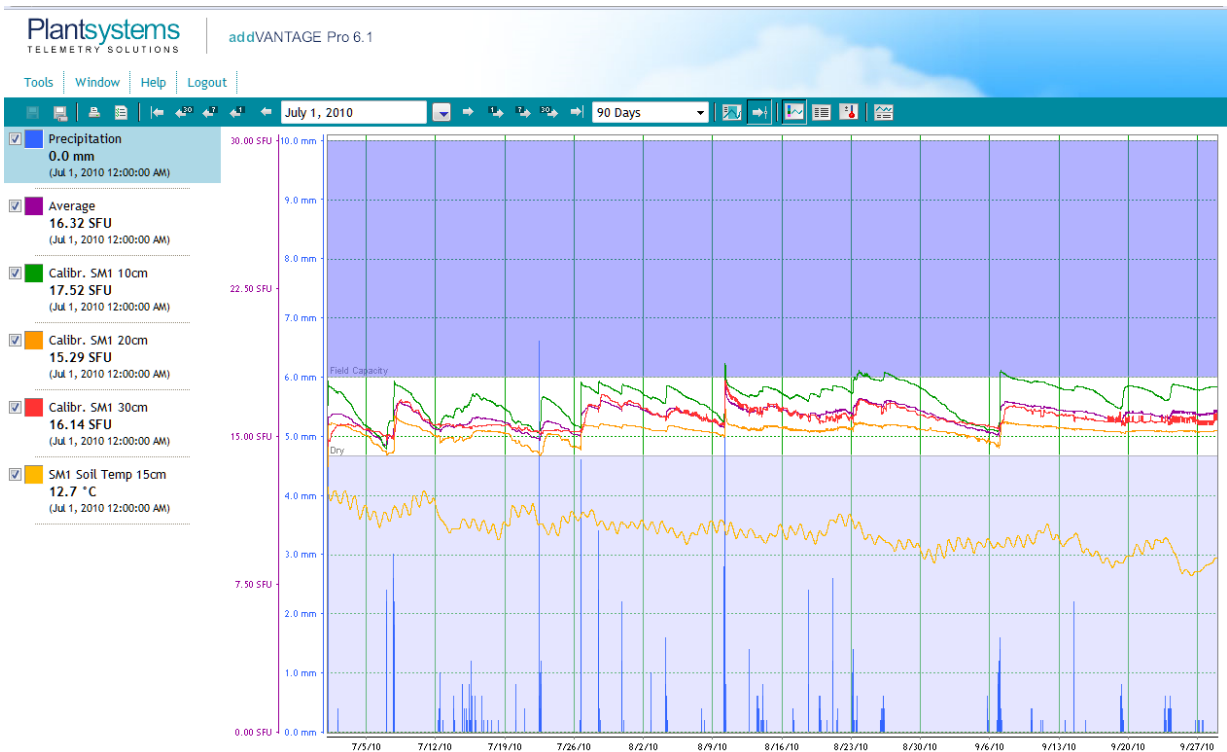


**Figure 2** Soil moisture sensor showing insertion into carrot bed alongside rows



**Figure 3** Soil moisture sensor showing internal construction

Data capture was initiated immediately and the quality of the data was verified. The data capture and visualisation software used in the work allowed for continual charting of the conditions in each site.



**Figure 4:** Typical chart of site variables July to September captured during the work

The data files were exported into MS Excel and summaries were developed using pivot tables.

As the crops approached maturity a site visit was made to inspect the crop for the presence of cavity spot disease. Three replicates each of 100 roots were taken from representative areas around the monitoring position, washed and assessed on the following basis.

1. Roots which were infected were separated and the incidence of cavity spot was recorded and expressed as a percentage of the total roots.
2. Infected roots were then inspected and an average score for disease severity was allocated according to the following system

<b>Typically small single lesions present</b>	<b>Typically more than one lesion present</b>	<b>Multiple mainly small lesions present</b>	<b>Multiple mainly medium lesions present</b>	<b>Many severe lesions present</b>
1	2	3	4	5

The site data summaries together with the information on disease incidence were statistically analysed to determine if there were any significant relationships between the presence of cavity spot and total water input, soil temperature and soil moisture.

For each of the recorded site conditions (total water input, soil temperature and soil moisture), multiple 7 day periods were used to calculate values (correlation coefficients) starting with week 23 (Jun 6<sup>th</sup>). So for 'total water input' values were calculated each week from week 23 for the following 8 weeks and this was repeated up to Week 38 (19<sup>th</sup> Sept). The calculation was then repeated for the other two site conditions – 'soil moisture' and 'soil temperature'. This allows us to see if there is any relationship between the presence of cavity spot and any of the site condition variables (total water input, soil temperature and soil moisture) and the results are presented in Tables 2 to 4.

## Results

**Table 1:** Assessments of cavity spot in monitored crops

Field	Date of assessment	Incidence %	Severity 1 to 5
1	19/10/2010	0	0
2	19/10/2010	41	4
3	19/10/2010	31	2
4	15/10/2010	0	0
5	15/10/2010	0	0
6	19/10/2010	0	0
7	19/10/2010	23	2
8	19/10/2010	0	0
9	21/08/2010	0	0
10	20/10/2010	11	2
11	19/10/2010	8	3
12	20/10/2010	1	1
13	22/07/2010	24	2
14	19/10/2010	0	0
15	20/10/2010	5	1
16	01/10/2010	0	0
17	27/09/2010	0	0
18	20/10/2010	51	3
19	19/10/2010	7	2
20	19/10/2010	1	2
21	20/10/2010	2	1
22	11/10/2010	5	2
23	19/10/2010	0	0
24	26/10/2010	2	1
25	20/10/2010	3	1
26	28/09/2010	0	0
27	15/10/2010	0	0
28	15/10/2010	0	0
29	02/11/2010	22	2
30	15/09/2010	0	0
Mean		7.9	1.0

Cavity spot disease was recorded in 53% of sites.

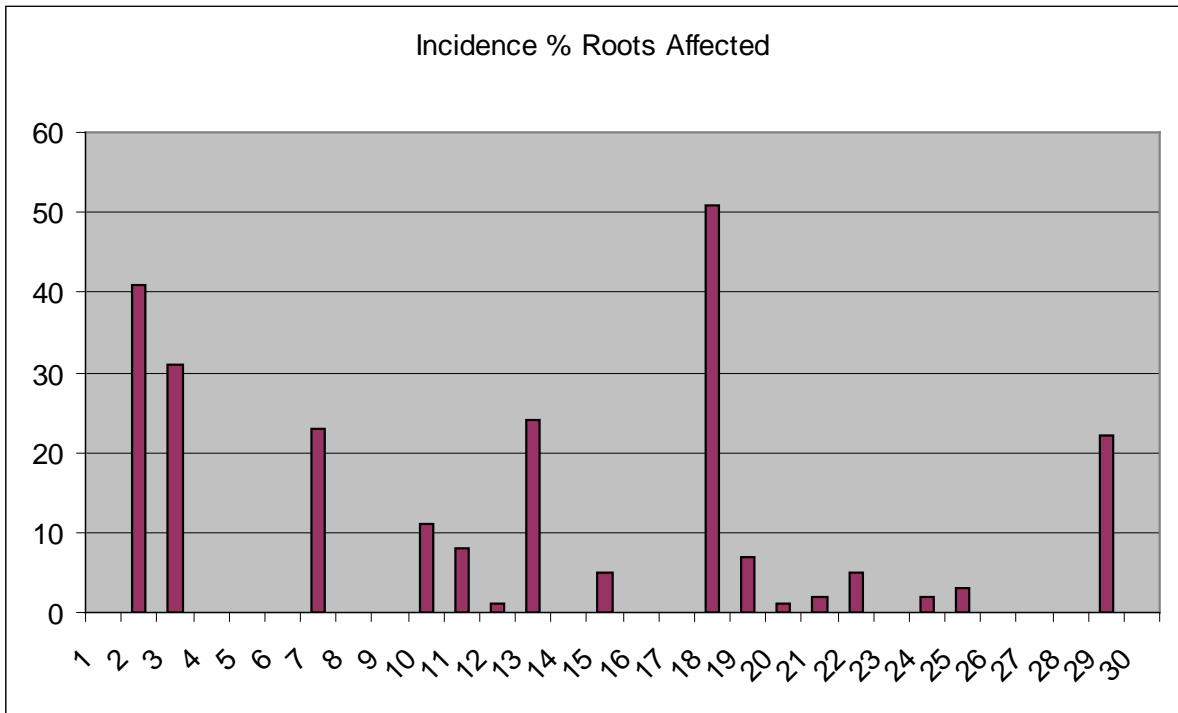


Figure 5: Summary of Incidence of cavity spot across all sites

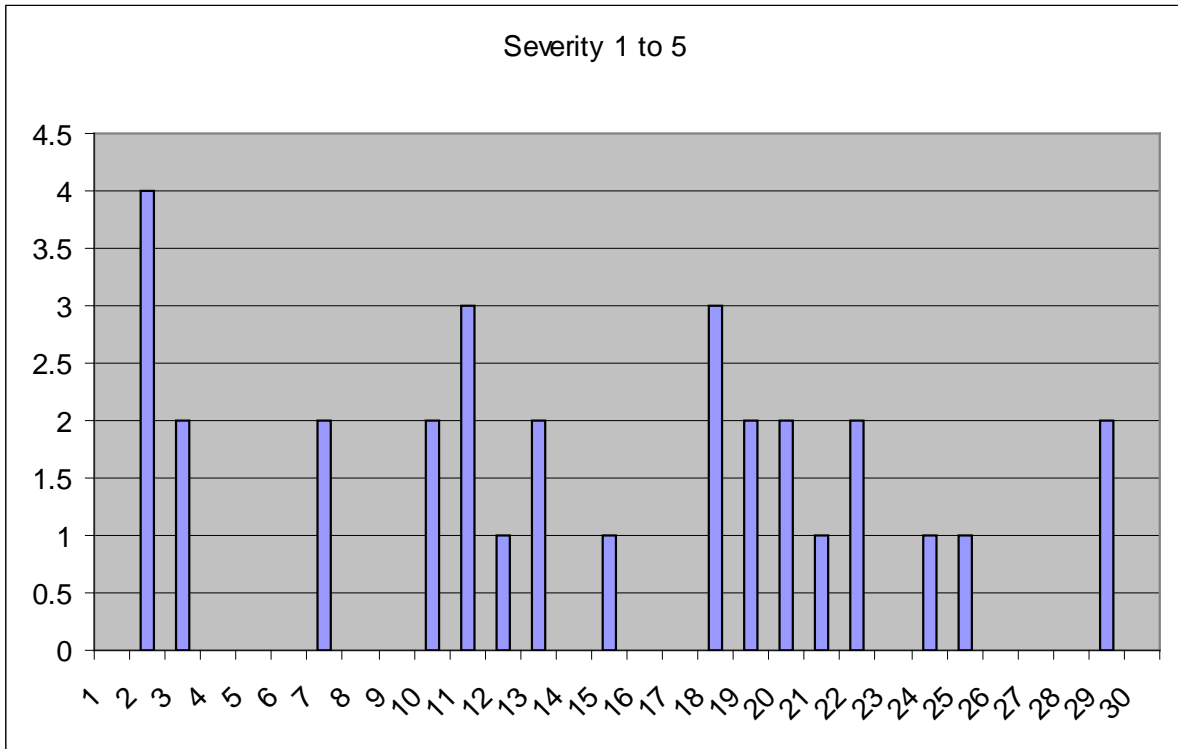


Figure 6: Summary of severity of cavity spot across all sites

Table 2 shows the correlation between 'total water input' and the presence of cavity spot, for a 7-week period following the beginning of each period from week 28 to week 34. Each of the values is a 'correlation coefficient' where a value of 1 indicates a perfect correlation between the two factors analysed ('total water input' and presence of cavity spot). The data therefore shows that at a probability of 5% ( $P < 0.05$ ) the values of 0.51 and above are a good correlation. The results indicate that 'total water input' gives the best correlation with presence of cavity spot in the 5 wks following week 30. Therefore the likelihood of disease increases as the 'total water input' increases at this time of year.

**Table 2:** Correlation between total water input and presence of disease ( $P < 0.05$ )\*

	Week 28	Week 29	Week 30	Week 31	Week 32	Week 33	Week 34
1wk	-0.31	-0.12	0.43	0.25	0.39	-0.03	<b>0.55</b>
2wks	-0.26	0.19	0.42	0.48	0.28	<b>0.51</b>	0.38
3wks	-0.06	0.29	<b>0.53</b>	0.43	<b>0.54</b>	0.34	0.27
4wks	0.06	0.44	<b>0.53</b>	<b>0.58</b>	0.43	0.23	0.22
5wks	0.24	0.43	<b>0.61</b>	0.47	0.35	0.19	0.25
6wks	0.22	<b>0.59</b>	<b>0.53</b>	0.42	0.31	0.24	0.20
7weeks	<b>0.52</b>	0.45	0.50	0.36	0.35	0.18	0.26

\*P=probability

**Table 3:** Correlation between soil temperature and presence of disease

	Week 23	Week 24	Week 25	Week 26	Week 27	Week 28
1wk	-0.05	-0.36	-0.02	0.38	<b>0.46</b>	<b>0.46</b>
2wks	-0.31	-0.28	0.27	<b>0.42</b>	<b>0.46</b>	0.44
3wks	-0.25	-0.01	0.34	<b>0.45</b>	<b>0.45</b>	0.42
4wks	-0.07	0.18	0.38	<b>0.44</b>	<b>0.44</b>	0.39
5wks	0.10	0.25	0.38	<b>0.43</b>	<b>0.42</b>	0.38
6weeks	0.14	0.27	0.39	<b>0.42</b>	<b>0.42</b>	0.37

The correlations between temperature and presence of disease are not as good as those for 'total water input' and tend to be best a bit earlier than those for 'total water input', typically following Week 27 (July 4).

**Table 4:** Correlation between soil moisture and presence of disease

	Week23	Week24	Week25	Week26	Week27	Week28	Week29
1wk	-0.17	-0.23	-0.27	-0.27	-0.27	<b>-0.40</b>	-0.34
2wks	-0.16	-0.24	-0.31	-0.25	-0.34	<b>-0.38</b>	-0.27
3wks	-0.18	-0.26	-0.31	-0.29	<b>-0.35</b>	-0.32	-0.25
4wks	-0.21	-0.26	<b>-0.34</b>	-0.30	-0.31	-0.30	-0.25
5wks	-0.20	-0.29	<b>-0.35</b>	-0.27	-0.29	-0.30	-0.23
6wks	-0.21	-0.29	-0.33	-0.26	-0.30	-0.27	-0.22
7weeks	-0.21	-0.29	-0.31	-0.25	-0.28	-0.26	-0.20

Again the correlations between 'soil moisture' and presence of disease are not as good as those for either 'total water input' or 'soil moisture'. The negative correlations indicated that the disease level went down as soil moisture increased.

Having determined which periods showed the best relationship a stepwise regression was carried out in order to produce a regression equation which best explained the relationship between the weather variables and disease.

All those variables which had been highlighted in the three tables were included in the stepwise regression. A regression analysis of each weather variable against disease was carried out in turn and the weather variable that produced the best fit was selected to be included in the final equation. The variable that fitted the best was total water input (TWI) in the 5 weeks following week 30. This is to be expected as that was the variable that had produced the highest correlation.

The fitted equation was

$$\text{Presence} = 0.01432 * \text{TWI Wk30 (for 5 wks)} - 0.688$$

This equation explained 44.2 % of the variance.

Once this variable had been fitted none of the other variables improved the fit of the equation significantly, so it would appear that the total water input in August seemed to be the main factor in determining disease.

We then looked at the mean precipitation of sites with 'no disease' compared to those 'with disease' in this five-week period and the difference is quite pronounced (79 against 140).

The results here are based on a fairly small set of data and as such can be influenced by variability, i.e. where the results are extreme. Hopefully with another year's data we will be able to better consistency from year to year.

## **Discussion**

The first year of this project indicates that the incidence of cavity spot disease appears to be linked to the total water input (irrigation plus precipitation) and to a lesser degree soil temperature, as recorded at each site. Furthermore there appeared to be a significant period when total water input had a major impact and the critical period was of a 5-week duration from week 30 (25th July). Soil moisture did not seem to have an effect and this is surprising given that increasing total water input would normally lead directly to an increase in soil moisture and therefore a relationship would be expected.

We know from observations and records of commercial results that cavity spot can be severe in early maturing crops harvested during summer so we cannot presume that the critical period for total water input is fixed to calendar dates. It seems more likely that if the effect is real it is related to a crop development stage. In this study of mostly maincrop carrots it seems that late July and August is the critical time for this cultural category and this would correspond to a crop stage of around late pencil to early bulking. We could suggest that this proposition could be applied to other crop cultures but further evidence is required and the second and third year of this study may produce information to clarify this.

This project explores some of the environmental and agronomic factors which are thought to have a major impact on disease so that after the project there may be a much improved understanding of disease outbreaks and how these can be minimised through improved cultural practices. Although growers do not have the opportunity to influence the

precipitation or temperature at each of their sites, they are able to manage the irrigation and through this may be able to reduce the incidence of cavity spot and its financial impact.

## **Conclusions**

- Thirty commercial carrot crops were studied in 2010 and cavity spot disease was recorded in 53% of the sites.
- The incidence of disease was related to site total water input (precipitation plus irrigation)
- Sites which recorded greater total water input during the period from late July through August tended to have more disease
- Soil temperature had less effect than total water input.

## **Knowledge and Technology Transfer**

Articles for the HDC News and the BCGA Newsletter are planned on completion of this report. A combined paper at the Carrot Conference in November 2011 will include findings of this study.

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