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| **Project title:** | Carrots: Incidence of cavity spot in Commercial Crops |
| **Project number:** | FV 373 |
| **Project leader:** | David Martin, Plantsystems Limited |
| **Report:** | Final report, March 2013 |
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| **Location of project:** | England and Scotland |
| **Industry Representative:** | Martin Evans representing the BCGA |
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**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

In the first two years of the project there was a relationship between cavity spot disease incidence and water input at particular stages of root bulking, but these were not confirmed in 2012 which was an extremely wet year throughout.

## Background

Cavity spot is a serious and recurring disease of commercial carrots in the UK which is largely unpredictable. 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 and six target categories have been identified in the strategy. This project is intended to cover a gap under general agronomy and aims to document, as far as possible, the conditions relating to the occurrence of cavity spot in 'high risk' commercial sites 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

Thirty commercial carrot production sites provided by members of the BCGA and representative of the main carrot production areas of England and Scotland 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.

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 log all data and communicate via 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).

Data was collected continuously 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.

Periods when the soil was saturated were noted and used in the analysis of correlations. The 10mm crown crop stage was also recorded and for those sites where accurate records where not taken this crop stage was estimated from the sowing date and the observed rate of growth.

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 1:** Summary of Incidence % and Severity (1 to 5) of Cavity Spot disease in 2012

| ID | Site 2012 | Crop | 10cm crown | % Incidence | 1 to 5 Severity |
|---|---|---|---|---|---|
| 1 | Croxton | Early | 20-Apr | 2 | 1.7 |
| 2 | Alderton | Early | 18-Apr | 19 | 3 |
| 3 | Butley | Early | 22-Apr | 0.7 | 0.7 |
| 4 | Friston | Early | 21-Apr | 1 | 0.7 |
| 5 | Methwold | Early | 20-Apr | 0 | 0 |
| 6 | Riddlesworth | Early | 20-Apr | 2 | 2 |
| 7 | Kellington | m/c | 01-Jul | 0 | 0 |
| 8 | Thoresby | m/c | 21-Jun | 0 | 0 |
| 9 | Ravenshead | m/c | 22-Jun | 0 | 0 |
| 10 | Apley Head | m/c | 03-Jul | 0 | 0 |
| 11 | Edenwood | m/c | 05-Aug | 4.7 | 1.3 |
| 12 | Ladybank | m/c | 00-Jan | 0.7 | 0.3 |
| 13 | Dunshalt | m/c | 20-Aug | 0 | 0 |
| 14 | Bilsthorpe | m/c | 08-Aug | 0.3 | 0.3 |
| 15 | Walesby | m/c | 06-Aug | 0 | 0 |
| 16 | Titchwell | m/c | 24-Aug | 0 | 0 |
| 17 | Papplewick | m/c | 16-Aug | 0 | 0 |
| 18 | Babworth | m/c | 13-Aug | 0.3 | 0.3 |
| 19 | Barmby Moor | m/c | 13-Aug | 0.3 | 0.3 |
| 20 | Holme | m/c | 13-Aug | 12.3 | 1 |
| 21 | Halsall Carr Moss | m/c | 08-Aug | 0.3 | 0.3 |
| 22 | Halsall | m/c | 13-Aug | 1.3 | 1 |

| | | | | | |
|---|---|---|---|---|---|
| 23 | Elveden | m/c | 13-Aug | 7 | 1 |
| 24 | Sutton | m/c | 13-Aug | 10.3 | 1.3 |
| 25 | Isleham | m/c | 07-Aug | 16.3 | 2.3 |
| 26 | Falkenham | m/c | 13-Aug | 0 | 0 |
| 27 | Hillborough | m/c | 13-Aug | 15 | 1.3 |
| 28 | Marham | m/c | 17-Aug | 13 | 2.3 |
| 29 | S. Pickenham | m/c | 07-Aug | 1 | 1.3 |
| 30 | Kentford | m/c | 17-Jun | 0 | 0 |

2012 started in drought up to the end of March but eventually turned out to be an exceptionally wet year with double the normal precipitation and a reduced temperature and evapotranspiration. It might have been expected to have been a year of higher than average cavity spot but this was not the case. In this study the incidence of disease was around average with 62% of study crops affected but the severity of the infections was low. In commercial crops growers report some unexpected severe infections but losses generally have been low.

In our studies the results for the three years have been as follows:

1. In 2012 cavity spot disease was recorded in 64% of sites. Of those sites which were affected the average score for disease severity was 1.2.

2. In 2011, cavity spot disease was recorded in 67% of sites. Of those sites which were affected the average score for disease severity was 1.1.

3. In 2010 the data showed 53% sites with affected roots and an average severity score of 2.0

The tentative relationships which appeared in the first two years between the incidence of cavity spot and the total water inputs in August for maincrop carrots were not particularly evident in 2012. Although the correlation between total water inputs (precipitation plus irrigation) in August and disease remained positive it dropped below a significant level as there were many anomalies. It has not therefore been possible to conclude with any certainty that excessive water particularly in August accounts for the development of cavity spot in maincrop carrots.

There was no correlation between soil temperature and disease in either year.

Overall during the project span of 3 years we have found the following:

- There are indications that disease is related to water input and there may be a susceptible crop stage. Early water seems to suppress disease and later water

increases it. For example in 2010, increasing total water input (precipitation plus irrigation) from the end of July and throughout August increased the incidence of cavity spot. Whilst in 2011 increased water input in early June had a beneficial effect on reducing disease levels; this effect was more marked in 2011 than in 2010. However this apparent relationship does not occur with certainty and we have observed many anomalies throughout the study.

- We introduced a crop stage marker which is the 10mm crown stage and have used this crop stage to see if we could confirm that this represents onset of any susceptibility to disease. We have been unable to confirm if this is the case.

- We have looked at degree of soil saturation and soil temperature with respect to disease and have not found any relationships.

- Factors of variety, pH, major soil nutrients, cropping history, and use of SL567A have not shown a consistent influence on the level of cavity spot disease in this study.

- This project is now extended (FV 373a) for the 2013/14 season to allow further data collection.

### Financial Benefits

We have yet to provide a series of firm guidelines for growers which will lead to defined financial benefits.

Indications of a sensitive period when excessive water inputs could lead to disease have been observed and growers have been urged to manage their irrigation with care during this period in an attempt to reduce the susceptibility of their crops to cavity spot disease. This needs further study over a period of time to fully evaluate and define its financial significance.

## Action Points

Growers are urged to review their knowledge of cavity spot disease (see HDC Research update as Factsheet 06/13) and implement the main recommendations which are as follows:

- Apply fungicides early in the season while ensuring total water input is greater than 15mm per week.

- For maincrop carrots, minimise total water input in August.

# 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 f 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 BCGA Cavity Spot R&D strategy in 2009, 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 second year of this study confirms the seasonality of this effect – 2011 losses appear smaller than in 2010 (c£20m RSV) but remain significant at over £4million Retail Sales Value.

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

## Materials and methods

Members of the BCGA were contacted in the spring of 2012 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 although 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.

**Table 2** Sites monitored in 2012

| ID | Site 2012 | Crop | Lat | Long |
|---|---|---|---|---|
| 1 | VCS Raker Croxton | Early | 52.26N | 0.45E |
| 2 | 3M W Alderton | Early | 52.01N | 1.24E |
| 3 | 3M CSA Butley | Early | 52.06N | 1.27E |
| 4 | 3M AWM Friston | Early | 52.11N | 1.31E |
| 5 | JWS Methwold | Early | 52.31N | 0.33E |
| 6 | TBG Riddlesworth | Early | 52.23N | 0.53E |
| 7 | POS Kellington | m/c | 53.72N | 1.15W |
| 8 | SHW Thoresby | m/c | 53.22N | 1.02W |
| 9 | SHW THS Ravenshead | m/c | 53.07N | 1.14W |
| 10 | SHW Apley Head | m/c | 53.27N | 1.01W |
| 11 | KPL Edenwood | m/c | 56.292N | 3.021W |
| 12 | KPL Ladybank | m/c | 56.272N | 3.171W |
| 13 | KPL Raecruik | m/c | 56.28N | 3.19W |
| 14 | SL Bilsthorpe | m/c | 53.08N | 1.02W |
| 15 | SL Walesby | m/c | 53.221N | 0.983W |
| 16 | SL Titchwell | m/c | 52.93N | 0.60E |
| 17 | FG Papplewick | m/c | 53.04N | 1.16W |
| 18 | FG Babworth | m/c | 53.33N | 0.99W |
| 19 | HF Barmby Moor | m/c | 53.92N | 0.82W |

| ID | Site 2012 | Crop | Lat | Long |
|---|---|---|---|---|
| 20 | HPF Holme | m/c | 53.81N | 0.755W |
| 21 | MF Halsall Carr Moss | m/c | 53.30N | 2.49W |
| 22 | MF Halsall | m/c | 53.35N | 3.00W |
| 23 | VCS Elveden | m/c | 52.37N | 0.63E |
| 24 | VCS TBG Sutton | m/c | 52.07N | 1.39E |
| 25 | VCS TBG Isleham | m/c | 52.36N | 0.37E |
| 26 | VCS AG Falkenham | m/c | 51.99N | 1.33E |
| 27 | VCS SP Hillborough | m/c | 52.57N | 0.68E |
| 28 | VCS SP Marham | m/c | 52.65N | 0.57E |
| 29 | AB S Pickenham | m/c | 52.66N | 0.69E |
| 30 | AB Kentford | m/c | 52.27N | 0.51E |

A consultant agronomist visited each site and installed the monitoring equipment in a representative area as soon after sowing or field confirmation as possible. All equipment was serviced and validated prior to deployment 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 trend of soil moisture and precipitation data


**Figure 5:** Soil moisture and precipitation data showing saturation period

As the crops approached maturity a site visit was made to sample and 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 was allocated to the severity of the disease according to the following system

| Typically small single lesions present | Typically more than one lesion present | Multiple mainly small lesions present | Multiple mainly medium lesions present | Many severe lesions present |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

### *Data*

As in the previous two years of the trial, weather data was provided on a daily basis for the 30 sites in this year's trial. We had precipitation, soil moisture and soil temperature data. In 2012 it was decided to try to analyse the effects of weather factors with reference to the growth stage of the crop rather than the actual date. In previous years we had calculated the water inputs for common dates across the whole data set. This year we decided to use the estimated date where the crown diameter reached 10 mm as a reference point. In this way we hoped to be able to take account of the fact that the sites were spread across the

country and also we could now include the 6 sites which had a much earlier sowing data and which had been looked at separately in the previous years.

In addition the soil moisture data was presented in terms of degree of saturation (%) rather than in terms of the volumetric (%) soil moisture level.

When the data was examined in more detail it was found that there was one site, Site 13 Raecruik, where the weather data provided did not span the 10cm crown date. As it was not possible to obtain the correct data for that site we have left that site out of any analysis, leaving us with 29 sites.

### *Analysis*

With the 10cm crown date as the starting point for each site we calculated the total precipitation in the week before that date and then for weekly periods one week, two weeks, three weeks and 4 weeks after that date .

This process was repeated for the soil moisture data where we calculated the number of days in each of those periods where the soil was at least 90% saturated and for the soil temperature where we calculated the average temperature over those periods.

For each site we had two measures of the extent of cavity spot, incidence and severity. From these two measures we created a further measure which had two classes, either no disease or disease.

In order to see if there was any relationship between the cavity spot figures and any of the environmental variables, the correlation between each of the derived variables and the measures of the disease were calculated.

## Results

### *Total water input (precipitation plus irrigation)*

If we look at the precipitation in the week after the 10cm crown date the only cavity spot measure which showed any relationship was the simple presence/absence of the disease. This showed a correlation of 0.34 which is not quite significant at P=0.05, but does give some indication that increased precipitation at that stage does increase the chances of disease.

However a look at Table 1 shows obvious anomalies in this theory. Sites 5 and 7 both had over 30 mm of precipitation in the time period, but had no disease, while Sites 23 and 24 had virtually no precipitation, but still had relatively high levels of the disease .

Overall, those sites with disease had on average just over 10mm more precipitation than those without disease (27.4 against 16.7)

**Table 3:** Data showing total water input in the week after 10cm crown date

| Site | Site Name | Precipitation | Incidence | Severity | Presence |
|---|---|---|---|---|---|
| 5 | JWS Methwold | 35.4 | 0 | 0 | 0 |
| 7 | POS Kellington | 33.6 | 0 | 0 | 0 |
| 8 | SHW Thoresby | 6.4 | 0 | 0 | 0 |
| 9 | SHW THS Ravenshead | 12 | 0 | 0 | 0 |
| 10 | SHW Apley Head | 17.2 | 0 | 0 | 0 |
| 15 | SL Walesby | 2.4 | 0 | 0 | 0 |
| 16 | SL Titchwell | 6.6 | 0 | 0 | 0 |
| 17 | FG Papplewick | 29.2 | 0 | 0 | 0 |
| 26 | VCS AG Falkenham | 17.6 | 0 | 0 | 0 |
| 30 | AB Kentford | 6.2 | 0 | 0 | 0 |
| 1 | VCS Raker Croxton | 43 | 2 | 1.7 | 1 |
| 2 | 3M W Alderton | 34.8 | 19 | 3 | 1 |
| 3 | 3M CSA Butley | 59.4 | 0.7 | 0.7 | 1 |
| 4 | 3M AWM Friston | 38.4 | 1 | 0.7 | 1 |
| 6 | TBG Riddlesworth | 36.4 | 2 | 2 | 1 |
| 11 | KPL Edenwood | 8.2 | 4.7 | 1.3 | 1 |
| 12 | KPL Ladybank | 47.2 | 0.7 | 0.3 | 1 |
| 14 | SL Bilsthorpe | 29 | 0.3 | 0.3 | 1 |
| 18 | FG Babworth | 30.8 | 0.3 | 0.3 | 1 |
| 19 | HF Barmby Moor | 20.2 | 0.3 | 0.3 | 1 |
| 20 | HPF Holme | 25.6 | 12.3 | 1 | 1 |
| 21 | MF Halsall Carr Moss | 17 | 0.3 | 0.3 | 1 |
| 22 | MF Halsall | 42.2 | 1.3 | 1 | 1 |
| 23 | VCS Elveden | 0 | 7 | 1 | 1 |
| 24 | VCS TBG Sutton | 0.8 | 10.3 | 1.3 | 1 |
| 25 | VCS TBG Isleham | 24.2 | 16.3 | 2.3 | 1 |
| 27 | VCS SP Hillborough | 28.4 | 15 | 1.3 | 1 |
| 28 | VCS SP Marham | 21 | 13 | 2.3 | 1 |
| 29 | AB S Pickenham | 14.8 | 1 | 1.3 | 1 |

We also looked at the number of days in the time period where we had at least 10mm precipitation, but that did not help. As can be seen from Table 2, in the week after 10cm crown date we had one site (Site 3) with 3 days with >10mm, but the majority had 1 day and there didn't appear to be any obvious trend.

**Table 4:** Number of days in the week after 10cm crown date with at least 10mm precipitation

| No of days with >10mm precipitation | Presence or absence of disease | |
|---|---|---|
| | **0** | **1** |
| 0 | 3 | 6 |
| 1 | 6 | 11 |
| 2 | 1 | 1 |
| 3 | 0 | 1 |

We looked at successive weekly periods over the period one week before 10cm crown date to 5 weeks after, but there didn't appear to be any relationship. Looking over a 5 week period after the 10cm crown date , there was a slight increase in days with >10mm (3.9 against 3.4) but nothing significant. Table 3 shows spread of days

**Table 5:** Number of days with at least 10mm precipitation in the 5 weeks after 10cm crown date.

| No of days with >10mm precipitation | Presence or absence of disease | |
|---|---|---|
| | **0** | **1** |
| 0 | 0 | 0 |
| 1 | 1 | 1 |
| 2 | 2 | 0 |
| 3 | 2 | 6 |
| 4 | 2 | 7 |
| 5 | 3 | 4 |
| 7 | 0 | 1 |

### *Soil Moisture (saturation)*

A similar process was carried on the saturation data

**Table 6:** Number of days when soil was saturated in the week after 10cm crown date

| Site | Site | No of days saturated | Incidence | Severity | Level | Presence |
|---|---|---|---|---|---|---|
| 5 | Methwold | 7 | 0 | 0 | 0 | 0 |
| 7 | Kellington | 7 | 0 | 0 | 0 | 0 |
| 8 | Thoresby | 5 | 0 | 0 | 0 | 0 |
| 9 | Ravenshead | 6 | 0 | 0 | 0 | 0 |
| 10 | Apley Head | 3 | 0 | 0 | 0 | 0 |
| 15 | Walesby | 2 | 0 | 0 | 0 | 0 |
| 16 | Titchwell | 6 | 0 | 0 | 0 | 0 |
| 17 | Papplewick | 2 | 0 | 0 | 0 | 0 |
| 26 | Falkenham | 7 | 0 | 0 | 0 | 0 |
| 30 | Kentford | 3 | 0 | 0 | 0 | 0 |
| 1 | Croxton | 2 | 2 | 1.7 | 1 | 1 |
| 2 | Alderton | 7 | 19 | 3 | 2 | 1 |
| 3 | Butley | 0 | 0.7 | 0.7 | 1 | 1 |
| 4 | Friston | 0 | 1 | 0.7 | 1 | 1 |
| 6 | Riddlesworth | 7 | 2 | 2 | 1 | 1 |
| 11 | Edenwood | 7 | 4.7 | 1.3 | 2 | 1 |
| 12 | Ladybank | 7 | 0.7 | 0.3 | 1 | 1 |
| 14 | Bilsthorpe | 0 | 0.3 | 0.3 | 1 | 1 |
| 18 | Babworth | 1 | 0.3 | 0.3 | 1 | 1 |
| 19 | Barmby Moor | 7 | 0.3 | 0.3 | 1 | 1 |
| 20 | Holme | 7 | 12.3 | 1 | 2 | 1 |
| 21 | Halsall Carr Moss | 0 | 0.3 | 0.3 | 1 | 1 |
| 22 | Halsall | 7 | 1.3 | 1 | 1 | 1 |
| 23 | Elveden | 4 | 7 | 1 | 2 | 1 |
| 24 | Sutton | 0 | 10.3 | 1.3 | 2 | 1 |
| 25 | Isleham | 3 | 16.3 | 2.3 | 2 | 1 |
| 27 | Hillborough | 4 | 15 | 1.3 | 2 | 1 |
| 28 | Marham | 7 | 13 | 2.3 | 2 | 1 |
| 29 | Pickenham | 2 | 1 | 1.3 | 1 | 1 |

Table 6 shows that there was a large range in the number of days saturated, but there was no obvious relationship between these numbers and the presence of disease.

**Table 7:** Distribution of number of days saturated in the week following 10cm crown date

| No. of days saturated | Presence or absence of disease | |
|---|---|---|
| | **0** | **1** |
| 0 | 0 | 5 |
| 1 | 0 | 1 |
| 2 | 2 | 2 |
| 3 | 2 | 1 |
| 4 | 0 | 2 |
| 5 | 1 | 0 |
| 6 | 2 | 0 |
| 7 | 3 | 8 |

Table 7 shows the distribution of the number of days saturated split into 'Presence or Absence of disease' and again shows no obvious pattern

This lack of any relationship is repeated across the whole period tested, i.e. from 1 week before 10cm crown date to 5 weeks after

### *Soil Temperature ºC*

We looked at soil temperature but as in previous years there did not appear to be any relationship between temperature and disease. The average temperature for sites with disease was actually about 1 degree lower (15.01) against 15.93 for sites with no disease. Sites 1-6 were early sown but it made no difference when these were excluded from the analysis. The figures for Site 1-6 excluded were 16.62 ºC for sites with no disease and 16.15 ºC for sites with disease.

These differences were not significant and not consistent. For instance, the two sites with the highest temperature Site 18 and 23 both had disease so it is not possible to draw any conclusions from this data .

**Table 8:** Average temperature in week after 10cm crown date

| Site | Site | Average temp | Incidence | Severity | Level | Presence |
|---|---|---|---|---|---|---|
| 5 | Methwold | 9.73 | 0 | 0 | 0 | 0 |
| 7 | Kellington | 17.13 | 0 | 0 | 0 | 0 |
| 8 | Thoresby | 15.91 | 0 | 0 | 0 | 0 |
| 9 | Ravenshead | 16.09 | 0 | 0 | 0 | 0 |
| 10 | Apley Head | 17.21 | 0 | 0 | 0 | 0 |
| 15 | Walesby | 16.18 | 0 | 0 | 0 | 0 |
| 16 | Titchwell | 16.56 | 0 | 0 | 0 | 0 |
| 17 | Papplewick | 16.35 | 0 | 0 | 0 | 0 |
| 26 | Falkenham | 17.56 | 0 | 0 | 0 | 0 |
| 30 | Kentford | 16.60 | 0 | 0 | 0 | 0 |

| Site | Site | Average temp | Incidence | Severity | Level | Presence |
|---|---|---|---|---|---|---|
| 1 | Croxton | 10.70 | 2 | 1.7 | 1 | 1 |
| 2 | Alderton | 12.96 | 19 | 3 | 2 | 1 |
| 3 | Butley | 11.66 | 0.7 | 0.7 | 1 | 1 |
| 4 | Friston | 12.53 | 1 | 0.7 | 1 | 1 |
| 6 | Riddlesworth | 11.25 | 2 | 2 | 1 | 1 |
| 11 | Edenwood | 16.21 | 4.7 | 1.3 | 2 | 1 |
| 12 | Ladybank | 12.14 | 0.7 | 0.3 | 1 | 1 |
| 14 | Bilsthorpe | 15.85 | 0.3 | 0.3 | 1 | 1 |
| 18 | Babworth | 17.85 | 0.3 | 0.3 | 1 | 1 |
| 19 | Barmby Moor | 16.93 | 0.3 | 0.3 | 1 | 1 |
| 20 | Holme | 14.23 | 12.3 | 1 | 2 | 1 |
| 21 | Halsall Carr Moss | 16.14 | 0.3 | 0.3 | 1 | 1 |
| 22 | Halsall | 15.92 | 1.3 | 1 | 1 | 1 |
| 23 | Elveden | 17.85 | 7 | 1 | 2 | 1 |
| 24 | Sutton | 15.79 | 10.3 | 1.3 | 2 | 1 |
| 25 | Isleham | 16.90 | 16.3 | 2.3 | 2 | 1 |
| 27 | Hillborough | 17.28 | 15 | 1.3 | 2 | 1 |
| 28 | Marham | 15.76 | 13 | 2.3 | 2 | 1 |
| 29 | S. Pickenham | 17.26 | 1 | 1.3 | 1 | 1 |

## Discussion

This project explored 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 an improved understanding of disease outbreaks and how these can be minimised through improved cultural practices.

### *In 2010 we found:*

- 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 on disease and the critical period for maincrop carrots was of a 5 week duration from the end of July.

### *In 2011 we found:*

- That increasing levels of soil moisture were positively related to increased levels of disease throughout the growing period but especially during the middle of August. This relationship was not apparent in 2010 but the effect of total water input during the same period was significant.
- An indication of a period in June when increasing total water input can reduce the incidence of disease.

- No relationship between soil temperature and disease incidence.

***In 2012 we found:***

- A non significant but positive correlation between total water input (precipitation plus irrigation) and presence of disease. A number of anomalies were present so we cannot say this is a solid relationship.
- A large range in the number of days when the soil moisture was at saturation but no obvious relationship appeared with presence of disease.
- No relationship between soil temperature and presence of disease was seen.

Overall we have seen evidence of a relationship between total water input and the presence of disease.

We know from this study and from observations and records of commercial results that cavity spot can also 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 and possibly to the onset of the main period of root expansion (bulking).

We have looked at the 10mm crown stage as a crop development marker to represent the onset of bulking but have yet to find any relationship with this crop stage and sensitivity to total water inputs.

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 therefore may be able to reduce the incidence of cavity spot and its financial impact. It is hoped that through further work the detailed agronomic approaches required to implement this will be substantiated.

## Conclusions

Looking at the three years results, the level of water input appears to be the main influence on disease of the three weather variables that we have looked at. The correlations appear to highlight two time periods of importance:

1. The early part of June which was more important in 2011, but also showed some evidence of a slight relationship in 2010. This negative correlation showed that increased water input at this time appeared to reduce disease.

2. August was most important in 2010 but there is a positive correlation for that period also in the 2011 data. This positive correlation shows that increased precipitation plus irrigation during this period appears to increase disease.

3. In 2012 we found a positive correlation between total water input (precipitation plus irrigation) and presence of disease but this was not at a significant level and a number of anomalies were present so we cannot confirm this is a solid relationship.

Looking at these results it is difficult to draw any firm conclusions from them. Water input has had some influence on disease development but it is not possible to say with any confidence what amount or time period is important. The time around the onset of the main period of root expansion appears to be important but it would be impossible to predict with any confidence the incidence of disease from excess water at that time.

Soil temperature and soil saturation do not seem do have any relation to disease presence or absence.

## Knowledge and Technology Transfer

1. HDC Field Veg review supplement April 2011
2. HDC News project news updates October 2011
3. Carrot Conference 17th November 2011 Cavity spot update - Dr Peter Gladders
4. BCGA R&D Committee March 2012: Cavity spot review - FV373 - David Martin
5. HDC Field Veg review supplement April 2012
6. HDC News project news updates October 2012
7. BCGA R&D Committee January 2013: Presentation of overview and the 2012 results - David Martin

8. HDC News featured FV373 in March issue (p19) - Rosie Atwood
9. BCGA Grower Technical Conference March 2013: Presentation of overview and the 2012 results - David Martin
10. HDC Factsheet 06/13 Carrot cavity spot - an HDC research update - Rosie Atwood
11. Carrot Conference November 2013: Paper on Cavity spot work including an overview of FV373 - Dr John Clarkson

## References

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Suffert, F., Delalande, D., Prunier, M. and Andrivon, D. (2008). Modulation of primary and secondary infections in epidemics of carrot cavity spot through agronomic management practices. Plant Pathology 57: 109-121.

Whipps, J., Clarkson, J. and Barbara D.J. (2009) Factors affecting the inoculum potential of soil-borne plant pathogens. Defra Final report project HH3203SFV.

Barbara, D.J. (2010) Carrot cavity spot: (i) using quantitative PCR to predict disease in strawed crops; (ii) controlling moisture for optimum disease management. AHDB Final report project FV353.

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## Appendices

Appendix 1 Site soil analysis results 2010

Appendix 2 Site soil analysis results 2011

Appendix 3 Site soil analysis results 2012

Appendix 4 Weather Data summaries 2012 - Available on request from HDC

HDC holds the site weather data summaries files in electronic format.

### Appendix 1

Site soil analysis results 2010

| | | Soil | Analysis | | |
|---|---|---|---|---|---|
| ID | Location | pH | Pindex | Kindex | Mgindex |
| 1 | Thoresby | 6.7 | 3 | 0 | 3 |
| 2 | Caister | 7.3 | 6 | 3 | 1 |
| 3 | Worksop | 6.8 | 3 | 0 | 3 |
| 4 | Langdyke | 5.8 | 3 | 2- | 4 |
| 5 | Norton | 6.3 | 3 | 1 | 3 |
| 6 | Carburton | 7.2 | 2 | 0 | 3 |
| 7 | Barton | 6.7 | 4 | 3 | 5 |
| 8 | Retford | 7.4 | 3 | 1 | 3 |
| 9 | Shawbury | 6.9 | 3 | 2 | 2 |
| 10 | Elveden | 7.5 | 3 | 2 | 1 |
| 11 | Butley | 7.0 | 3 | 1 | 2 |
| 12 | Sutton | 6.6 | 5 | 2 | 3 |
| 13 | Thompson | 7.6 | 4 | 1 | 1 |
| 14 | Alderton | 7.6 | 3 | 2- | 1 |
| 15 | Bucklesham | 7.2 | 3 | 3 | 2 |
| 16 | Shirdley Hill | 7.2 | 4 | 3 | 6 |
| 17 | Collumpton | 6.6 | 4 | 3 | 2 |
| 18 | Cockley Cley | 6.7 | 3 | 1 | 2 |
| 19 | Wantisden | 6.9 | 4 | 2- | 2 |
| 20 | Isleham | 7.9 | 3 | 1 | 2 |
| 21 | Drayton | 6.9 | 3 | 1 | 2 |
| 22 | Houghton | 8.2 | 2 | 1 | 1 |
| 23 | Torworth | 7.3 | 2 | 1 | 3 |
| 24 | Tichwell | 8.4 | 2 | 2- | 1 |
| 25 | Shottisham | 6.8 | 3 | 2 | 1 |
| 26 | Thornton | 7.0 | 3 | 1 | 1 |
| 27 | Cupar | 6.1 | 4 | 2+ | 3 |
| 28 | Dunshalt | 5.8 | 3 | 2- | 4 |
| 29 | Rainworth | 6.3 | 3 | 1 | 2 |
| 30 | Pinchbeck | 8.0 | 1 | 2 | 3 |

**Appendix 2**

Site soil analysis results 2011

| | | Soil | Analysis | | |
|---|---|---|---|---|---|
| ID | Location | pH | Pindex | Kindex | Mgindex |
| 1 | Thompson | 7.5 | 5 | 2- | 2 |
| 2 | Alderton | 7.1 | 4 | 2- | 1 |
| 3 | Butley | 6.1 | 4 | 1 | 1 |
| 4 | Aldeburgh | 7.7 | 4 | 2- | 2 |
| 5 | Thoresby | 6.1 | 3 | 2- | 2 |
| 6 | Blidworth | 5.5 | 4 | 1 | 2 |
| 7 | Worksop | 6.3 | 3 | 0 | 2 |
| 8 | Cupar | 6.1 | 4 | 2+ | 3 |
| 9 | Dunshalt | 5.8 | 3 | 2- | 4 |
| 10 | Glenrothes | 5.1 | 4 | 3 | 2 |
| 11 | Hardwick | 5.2 | 4 | 2- | 2 |
| 12 | Torworth | 7.3 | 3 | 2- | 3 |
| 13 | Heacham | 7.8 | 4 | 3 | 2 |
| 14 | Waddingham | 7.9 | 2 | 1 | 1 |
| 15 | Babworth | 6.4 | 3 | 2- | 3 |
| 16 | Crockey Hill | 6.3 | 3 | 1 | 3 |
| 17 | Holme | 7.2 | 2 | 1 | 1 |
| 18 | Formby | 6.7 | 4 | 3 | 6 |
| 19 | Ainsdale | 7.2 | 4 | 3 | 6 |
| 20 | Bickerstaffe | 7.0 | 4 | 2 | 5 |
| 21 | Elveden | 7.8 | 3 | 2+ | 1 |
| 22 | Sutton | 6.1 | 5 | 3 | 2 |
| 23 | Trimley | 7.4 | 3 | 3 | 1 |
| 24 | Larling | 7.6 | 3 | 2+ | 1 |
| 25 | Cockley Cley | 6.9 | 2 | 2- | 2 |
| 26 | Iken | 6.8 | 4 | 2- | 2 |
| 27 | Isleham | 7.8 | 3 | 1 | 1 |
| 28 | Euston | 5.8 | 3 | 1 | 1 |
| 29 | Gt Cressingham | 7.8 | 3 | 1 | 1 |
| 30 | Chatteris | 7.5 | 3 | 3 | 2 |

**Appendix 3**

Site soil analysis results 2012

| | | Soil | Analysis | | |
|---|---|---|---|---|---|
| ID | Location 2012 | pH | Pindex | Kindex | Mgindex |
| 1 | Croxton | 8.0 | 4 | 2 | 2 |
| 2 | Alderton | 6.9 | 3 | 1 | 1 |
| 3 | Butley | 7.4 | 3 | 2 | 1 |
| 4 | Friston | 6.1 | 4 | 1 | 2 |
| 5 | Methwold | 7.8 | 5 | 2 | 2 |
| 6 | Riddlesworth | 7.8 | 4 | 2 | 1 |
| 7 | Kellington | 7.3 | 4 | 2 | 3 |
| 8 | Thoresby | 7.2 | 2 | 0 | 3 |
| 9 | Ravenshead | 7.4 | 3 | 1 | 3 |
| 10 | Apley Head | 6.6 | 3 | 1 | 2 |
| 11 | Edenwood | 7 | 3 | 2 | 3 |
| 12 | Ladybank | 6.7 | 4 | 2 | 2 |
| 13 | Raecruik | 5.8 | 3 | 2- | 4 |
| 14 | Bilsthorpe | 7.8 | 5 | 1 | 2 |
| 15 | Walesby | 7.6 | 4 | 3 | 2 |
| 16 | Titchwell | 8.1 | 2 | 2- | 1 |
| 17 | Papplewick | 7.2 | 3 | 1 | 3 |
| 18 | Babworth | 6.9 | 3 | 3 | 3 |
| 19 | Barmby Moor | 6.9 | 3 | 1 | 2 |
| 20 | Holme | 7.5 | 2 | 1 | 1 |
| 21 | Halsall Carr Moss Lane | 6.3 | 3 | 2 | 6 |
| 22 | Halsall Ben Lane | 6.3 | 4 | 1 | 3 |
| 23 | Elveden | 7.3 | 3 | 2 | 1 |
| 24 | Sutton | 6.3 | 4 | 2 | 3 |
| 25 | Isleham | 7.5 | 3 | 1 | 2 |
| 26 | Falkenham | 6.6 | 4 | 3 | 2 |
| 27 | Hillborough | 6.8 | 3 | 1 | 2 |
| 28 | Marham | 6.9 | 3 | 1 | 2 |
| 29 | S Pickenham | 7.7 | 2 | 1 | 1 |
| 30 | Kentford | 7.3 | 2 | 1 | 3 |