Project title:	Carrots: Incidence of cavity spot in Commercial Crops
Project number:	FV 373a
Project leader:	David Martin, Plantsystems Limited
Report:	Final report, March 2014
Previous report:	None
Key staff:	Colin Noble James Martin Tom Will, VCS
Location of project:	Agrovista UK Ltd, Nottingham David Martin Associates, Wisbech
Industry Representative:	Martin Evans representing the BCGA
Date project commenced:	1 April 2013
Date project completed (or expected completion date):	31 March 2014

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 2013, there was no correlation between water inputs, soil saturation, soil temperature and other field variables such as soil nutrient levels and the incidence or severity of cavity spot disease.

Background

Cavity spot is a serious and recurring disease of commercial carrots in the UK but its occurrence 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.

Previous survey work in HDC FV373 of the incidence of cavity spot in commercial crops did not lead to significant correlations between any of the variables recorded and disease incidence or severity. The BCGA decided to extend the work for an additional year to determine if the additional data collected would help inform of the factors which lead to disease in carrot crops.

Summary

The workplan in 2013 was a direct replicate of the work undertaken in the three year period 2010 to 2012. Twenty nine 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. In addition one experimental site 'Cottage Field' at HRI Warwick known to be a high risk site was also monitored. 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 development 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 the GPRS network together with an automatic tipping bucket total water input sensor (resolution 0.2mm per tip) and soil moisture (SM) probe. 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 to record soil temperature values.

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 at the early establishment stage) to just prior to harvest of the crop or just prior to strawing down for late lifted crops. The resultant data file was converted to hourly values and then to daily summaries for analysis.

Periods when the soil was saturated were calculated and used in the analysis of correlations. The 10mm crown crop stage was also recorded and for those sites where accurate records were not available this crop stage was estimated by using a weather model using local weather data.

2013 started with an exceptionally cold spring which was followed by the warmest summer since 2006. The most notable weather of the summer was a prolonged warm period from 3 to 22 July, when high pressure was established across the UK. Overall for the UK was drier than the long-term with 78% average rainfall and it was the driest summer since 2003. Parts of southern and south-west England and East Anglia received less than half the average rainfall. Nevertheless, there were some notably wet days, particularly in July and August, with localised heavy downpours. The year ended with a stormy outlook and the late autumn and winter proved exceptionally wet for the south and south west of England.

Crops were sampled when mature and before commercial 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 the 2013 BCGA field study.

ID	Site 2013	date sown	date 10mm crown	% Incidence	1 to 5 Severity
1	HRIW Cottage CS Trial	03/06/2013	20/08/2013	0.5	0.5
2	SF Old School House	20/03/2013	16/06/2013	3.3	1.0
3	TBG Foxhall	28/05/2013	10/08/2013	0.0	0.0
4	TBG Kenny Hill	05/06/2013	20/08/2013	0.0	0.0
5	HPF Holme	22/04/2013	12/07/2013	0.7	1.0
6	HPF Waplington	30/05/2013	14/08/2013	0.0	0.0
7	HG Barnby Moor	05/05/2013	23/07/2013	1.3	0.8
8	HG Apley Head	11/06/2013	29/08/2013	0.0	0.0
9	TP Thoresby	22/04/2013	12/07/2013	0.7	0.7
10	KPL Ladybank	27/04/2013	14/07/2013	3.0	1.0
11	KPL Kirkforthar	28/04/2013	15/07/2013	2.0	0.3
12	KPL Edenwood	26/04/2013	13/07/2013	5.0	1.0
13	SL Holton	12/05/2013	29/07/2013	3.7	1.7
14	SL Blyth	22/05/2013	06/08/2013	0.0	0.0
15	SL Walesby	01/05/2013	18/07/2013	0.3	0.3
16	MHP Kellington	29/04/2013	17/07/2013	40.7	4.3
17	FG Haywood Oaks	21/05/2013	05/08/2013	0.0	0.0
18	FG Bilsthorpe	05/05/2013	23/07/2013	6.3	1.2
19	HF Crockey Hill	17/04/2013	07/07/2013	14.0	3.0
20	Mols New Cut Lane	23/04/2013	04/07/2013	16.0	4.0
21	Mols Carr Moss Lane	03/05/2013	10/07/2013	28.7	4.5
22	Wils Knowsley	03/06/2013	06/08/2013	0.0	0.0
23	AB Red Lodge	13/05/2013	28/07/2013	1.0	1.3
24	AB Burnham Deepdale	22/05/2013	03/08/2013	0.0	0.0
25	VCS Fos Ufford	22/04/2013	08/07/2013	0.0	0.0
26	VCS Gr Hilborough	14/05/2013	29/07/2013	0.0	0.0
27	VCS Gr Gooderstone	07/05/2013	22/07/2013	0.0	0.0
28	VCS Elveden	08/05/2013	23/07/2013	0.7	1.3
29	VCS PF Wormegay	18/05/2013	01/08/2013	0.7	0.3
30	VCS Caple St Andrew	01/05/2013	16/07/2013	4.0	2.7

The data in Table 1 shows a range of disease levels with occasional very high values of over 40% affected to more typical lower levels.

It might have been expected to have been a year of lower than average cavity spot due to dry summer conditions and this was certainly the case for the early part of the autumn when levels were low in studied crops and this was also the normal position in other commercial crops. In 2013 the incidence of disease was around average for the study as a whole with

62% of crops affected but the severity of the infections was generally low. In other commercial crops growers reported some severe infections during the later autumn and winter periods especially in the midlands growing areas.

The results for all four years studies have shown the following:

1. In 2010 the data showed 53% sites with affected roots and an average severity score of 2.0
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 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.
4. In 2013 cavity spot disease was recorded in 62% of sites. Of those sites which were affected the average score for disease severity was 1.0.

The tentative relationship which appeared in the first two years between the incidence of cavity spot and the total water inputs in July/August for maincrop carrots was not repeated in 2012 or in 2013. Although the correlation between total water inputs (precipitation plus irrigation) in August and disease remained positive in 2012 it dropped below a significant level and there were many anomalies.

It has not therefore been possible to conclude with any certainty that excessive water particularly in July/August accounts for the development of cavity spot in maincrop carrots.

There was no correlation between soil temperature and disease in any 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. 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 th 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.

Financial Benefits

It is not possible from this study 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. However we can conclude that this sensitivity exists only in certain seasons and our current knowledge does not allow us to predict which seasonal characteristics are involved.

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 improve it's understanding. The projects listed below were conducted largely by a team at HRI led 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 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 results in a considerable 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 and this is particularly damaging when late strawed crops are lost as these are the most expensive to produce.

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.

This report summarises the monitoring exercises and records obtained during the fourth year of this study and brings together summaries of all 4 years work.

Materials and methods

Members of the BCGA were contacted in the spring of 2013 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 2013 with locations and sowing dates

ID	Site 2013	Lat	Long	Type	sown
1	HRIW Cottage CS Trial	52.211303	1.607104	maincrop	03/06/2013
2	SF Old School House	52.525266	0.677084	maincrop	20/03/2013
3	TBG Foxhall	52.040595	0.433742	maincrop	28/05/2013
4	TBG Kenny Hill	52.040595	1.255725	maincrop	05/06/2013
5	HPF Holme	53.8218	-0.7482	maincrop	22/04/2013
6	HPF Waplington	53.9127	-0.8339	maincrop	30/05/2013
7	HG Barnby Moor	53.35971	-1.02351	maincrop	05/05/2013
8	HG Apley Head	53.277495	-1.016428	maincrop	11/06/2013
9	TP Thoresby	53.229251	-1.063249	maincrop	22/04/2013
10	KPL Ladybank	56.267073	-3.144708	maincrop	27/04/2013
11	KPL Kirkforthar	56.223053	-3.103512	maincrop	28/04/2013
12	KPL Edenwood	56.291384	-3.032978	maincrop	26/04/2013
13	SL Holton	53.469048	-0.378469	maincrop	12/05/2013
14	SL Blyth	53.350824	-1.062519	maincrop	22/05/2013
15	SL Walesby	53.272818	-0.9797733	maincrop	01/05/2013
16	MHP Kellington	53.7074	-1.1738	maincrop	29/04/2013
17	FG Haywood Oaks	53.085184	-1.085587	maincrop	21/05/2013
18	FG Bilsthorpe	53.128054	-1.077862	maincrop	05/05/2013
19	HF Crockey Hill	53.913881	-1.061769	maincrop	17/04/2013
20	Mols New Cut Lane	53.608145	-2.9866	maincrop	23/04/2013
21	Mols Carr Moss Lane	53.599618	-3.012925	maincrop	03/05/2013
22	Wils Knowsley	53.46807	-2.820273	maincrop	03/06/2013
23	AB Red Lodge	52.31392	0.504302	maincrop	13/05/2013
24	AB Burnham Deepdale	52.95432	0.6839	maincrop	22/05/2013
25	VCS Fos Ufford	52.126051	1.359424	maincrop	22/04/2013
26	VCS Gr Hilborough	52.563447	0.638682	maincrop	14/05/2013
27	VCS Gr Gooderstone	52.580576	0.636759	maincrop	07/05/2013
28	VCS Elveden	52.350935	0.611317	maincrop	08/05/2013
29	VCS PF Wormegay	51.778376	0.43024	maincrop	18/05/2013
30	VCS Caple St Andrew	52.094976	1.469531	maincrop	01/05/2013

A consultant agronomist visited each site and installed the monitoring equipment in a representative area as soon after sowing and field confirmation as possible. All equipment was serviced and validated prior to deployment to ensure the instrumentation was as reliable and consistent as possible.

Figure 1 Monitoring station showing RTU and total water input sensor

Figure 2 Soil moisture sensor showing insertion into carrot bed alongside row

Figure 3 Capacitance 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.

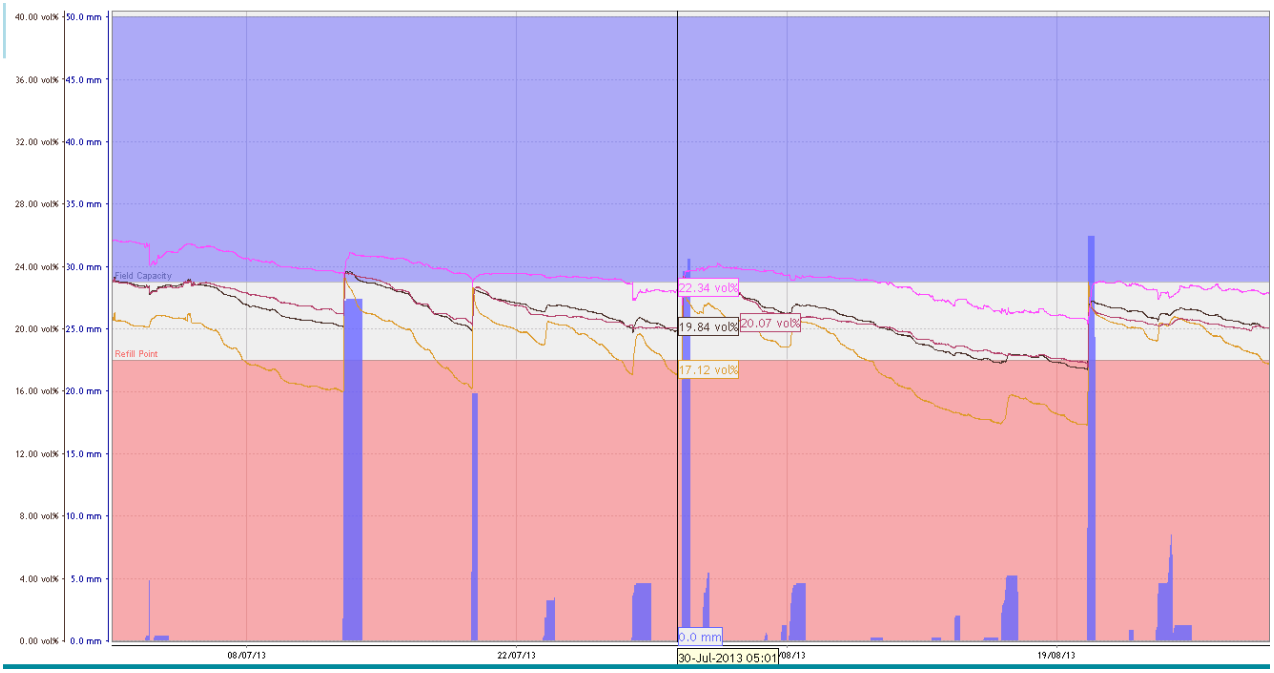

Figure 4 Typical trend of soil moisture and precipitation data

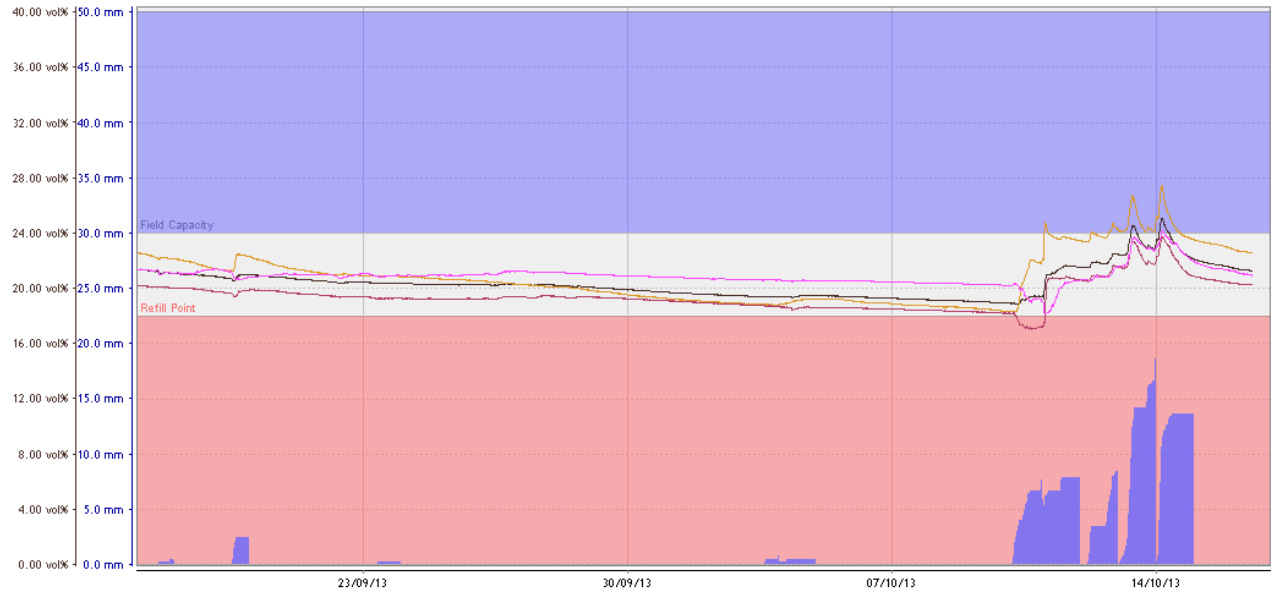

Figure 5 Soil moisture and precipitation data showing saturation period

Crops were visited during the development period to record the data when roots reached an average 10mm crown diameter growth stage. This date was recorded and used as a marker for the alignment of the weather data variables during the analysis.

As the crops approached maturity, or immediately before harvest, a site visit was made to sample and inspect the crop for the presence of cavity spot disease. All sites were sampled

and recorded before the end of October, consistent with previous studies. 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

Results

Table 3 below shows the disease results for the study sites.

Table 3 Disease results from sites monitored in 2013 with sowing date and 10mm crown date

ID	Site 2013	sown	10mm crown	% Incidence	1 to 5 Severity
1	HRIW Cottage CS Trial	03/06/2013	20/08/2013	0.5	0.5
2	SF Old School House	20/03/2013	16/06/2013	3.3	1.0
3	TBG Foxhall	28/05/2013	10/08/2013	0.0	0.0
4	TBG Kenny Hill	05/06/2013	20/08/2013	0.0	0.0
5	HPF Holme	22/04/2013	12/07/2013	0.7	1.0
6	HPF Waplington	30/05/2013	14/08/2013	0.0	0.0
7	HG Barnby Moor	05/05/2013	23/07/2013	1.3	0.8
8	HG Apley Head	11/06/2013	29/08/2013	0.0	0.0
9	TP Thoresby	22/04/2013	12/07/2013	0.7	0.7
10	KPL Ladybank	27/04/2013	14/07/2013	3.0	1.0
11	KPL Kirkforthar	28/04/2013	15/07/2013	2.0	0.3
12	KPL Edenwood	26/04/2013	13/07/2013	5.0	1.0
13	SL Holton	12/05/2013	29/07/2013	3.7	1.7
14	SL Blyth	22/05/2013	06/08/2013	0.0	0.0
15	SL Walesby	01/05/2013	18/07/2013	0.3	0.3
16	MHP Kellington	29/04/2013	17/07/2013	40.7	4.3
17	FG Haywood Oaks	21/05/2013	05/08/2013	0.0	0.0
18	FG Bilsthorpe	05/05/2013	23/07/2013	6.3	1.2
19	HF Crockey Hill	17/04/2013	07/07/2013	14.0	3.0
20	Mols New Cut Lane	23/04/2013	04/07/2013	16.0	4.0
21	Mols Carr Moss Lane	03/05/2013	10/07/2013	28.7	4.5
22	Wils Knowsley	03/06/2013	06/08/2013	0.0	0.0
23	AB Red Lodge	13/05/2013	28/07/2013	1.0	1.3
24	AB Burnham Deepdale	22/05/2013	03/08/2013	0.0	0.0
25	VCS Fos Ufford	22/04/2013	08/07/2013	0.0	0.0
26	VCS Gr Hilborough	14/05/2013	29/07/2013	0.0	0.0
27	VCS Gr Gooderstone	07/05/2013	22/07/2013	0.0	0.0
28	VCS Elveden	08/05/2013	23/07/2013	0.7	1.3
29	VCS PF Wormegay	18/05/2013	01/08/2013	0.7	0.3
30	VCS Caple St Andrew	01/05/2013	16/07/2013	4.0	2.7

Associated Data

All of the weather data variables collected during this year of the study was collated and exported into an MS Excel file. This was submitted for statistical analysis to determine if there were any correlations between the incidence or severity of disease and the variables captured.

As in previous years there were 30 sites included in this year's study. For each site we had total water input (precipitation plus irrigation), soil moisture and soil temperature data.

In 2012 it was decided to work out effects of weather factors based on the growth stage of the crop rather than the calendar date and we continued with this approach for 2013. We also decided to use the recorded or estimated date where the crown diameter reached 10mm as a crop development marker. In this way we hoped to be able to take account of the fact that the sites were spread across the country, had different sowing dates and the crops developed at different rates.

Commercial capacitance sensors were used to record soil moisture conditions (see figure 3). The ones used in this study were 3 level instruments which have been used in research and commercial applications to aid irrigation planning. Such sensors are regarded as good indicators of soil water volume for most non-saline soils. Good performance in sandy soils used in the study is generally assured as these soil types do not shrink or crack and good soil to sensor contact is possible. Particular care must be taken to install correctly and to regularly observe the resultant data so that informed decisions can be made. Trained advisers were used to install all equipment.

As in 2012 we looked at the soil moisture figures in terms of % saturation rather than in terms of the actual volumetric soil moisture level.

Soil moisture data as volumetric soil water content (% water) was collected from 3 levels at each site 100, 200 and 300mm. Because we had a range of soil water holding capacities across the study sites we cannot directly compare the values between each site so it was decided to convert the % water to % saturation so that direct comparisons can be made.

For each site the soil moisture data was examined to find a period or periods when the graphics and data clearly showed excess water was temporarily present in all soil horizons. The values of %water were noted and the soil saturation value of each site was set as 90%

of the value at excess. All the soil moisture data for each site was then able to be transposed to degree of soil saturation (% soil saturation) values.

When the data was examined in detail it was found that for site 20 (Mols New Cut Lane) was the early part of the data file was missing. Good data was available from 9 July and the 10mm crown date for that site was 4 July. This meant that calculating figures for the week around the 10mm crown date was not possible for that site , but calculations were still made for the later periods of development. It was also found that the weather data for 2013 for site 30 (VCS Caple St Andrew) was not adequate to be used in the analysis. Twenty eight full sets of data and one partial set were therefore examined in the analysis.

Analysis

With the 10mm crown date as the starting point for each site we calculated the total water input 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 soil temperature over those periods.

For each site there were two measures of the extent of cavity spot which were incidence and severity. From these two measures a further measure which had two classes was derived - either no disease or disease present.

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

Of the 29 sites with weather data available 18 had cavity spot at various levels (62%) and 11 sites were clear of disease.

Total water input

If we look at the water input in the weeks around the 10mm crown date the only period which showed a relationship between cavity spot measure and water was that which occurred during the week which was two weeks after the 10mm crown date

Table 4 Data showing water input mm in the week, 2 weeks after 10mm crown date

Site	Site Name	mm	Incidence	Severity
3	TBG Foxhall	50.2	0	0
4	TBG Kenny Hill	3.4	0	0
6	HPF Waplington	25.6	0	0
8	HG Apley Head	28	0	0
14	SL Blyth	54.4	0	0
17	FG Haywood Oaks	0	0	0
22	Wils Knowsley	2	0	0
24	AB Burnham Deepdale	39.2	0	0
25	VCS Fos Ufford	31.6	0	0
26	VCS Gr Hilborough	49	0	0
27	VCS Gr Gooderstone	40.4	0	0
11	KPL Kirkforthar	13.6	2	0.33
15	SL Walesby	9	0.33	0.33
29	VCS PF Wormegay	7.2	0.67	0.33
1	HRIW Cottage CS Trial	14.6	0.5	0.5
9	TP Thoresby	18.4	0.67	0.67
7	HG Barnby Moor	11.4	1.33	0.83
2	SF Old School House	0.4	3.33	1
5	HPF Holme	16	0.67	1
10	KPL Ladybank	37	3	1
12	KPL Edenwood	35	5	1
18	FG Bilsthorpe	8.2	6.33	1.17
23	AB Red Lodge	0	1	1.33
28	VCS Elveden	2.4	0.67	1.33
13	SL Holton	7.6	3.667	1.67
19	HF Crockey Hill	25.6	14	3
20	Mols New Cut Lane	6	16	4
16	MHP Kellington	11.4	40.67	4.33
21	Mols Carr Moss Lane	41.6	28.67	4.5

Table 5 Average water input mm for sites with and without cavity spot in the second week after 10 cm crown date

Presence	No observed	Mean
No disease	11	29.44
Disease present	18	14.74

Tables 4 and 5 show the total water input in the second week after the 10mm crown stage and highlight the fact that sites without cavity spot had greater total water than those with cavity spot. This is a reverse of what was found in the 2012 data. However when we look at the week immediately following the 10mm crown date, the average water input for sites without cavity spot and with cavity spot was almost the same (23.16 against 22.80mm) and the large difference does not show up over any other time period.

Another way of looking at the water data is shown in Table 6 which shows the number of days when more than 10mm of rain fell in each of the sites over a 5 week period after the 10mm crown date.

For instance , one site without disease had 4 days with more than 10mm rain, while 6 sites with disease had 4 days with more than 10 mm rain.

One thing it does highlight is the fact that 1 site (Site 26 VCS Gr Hilborough) had 12 days with more than 10 mm of rain but no disease was evident at the time of sampling.

There does not appear to be any clear conclusion from the water input data and the expression of disease in this year of the study.

Table 6 Sites grouped by number of days with >10mm over 5 week period after 10mm crown data

	Presence	
	No disease	Disease present
number of days with >10mm of rain		
0	0	2
1	1	0
2	1	4
3	2	1
4	1	6
5	3	1
6	1	1
7	1	2
8	0	1
12	1	0

Soil Moisture (saturation)

The saturation data was looked at in a similar way. There was no clear relationship between disease and saturation for any of the time periods. .

Table 7 Number of days when the soil was saturated in the week after 10mm crown date

Site	Site Name	Days	Incidence	Severity
3	TBG Foxhall	0	0	0
4	TBG Isleham	0	0	0
6	HPF Waplington	3	0	0
8	HG Apley Head	7	0	0
14	SL Blyth	4	0	0
17	FG Haywood Oaks	7	0	0
22	Wils Knowsley	7	0	0
24	AB Burnham Deepdale	7	0	0
25	VCS Fos Ufford	2	0	0
26	VCS Hilborough	0	0	0
27	VCS Gooderstone	0	0	0
15	SL Walesby	1	0.33	0.33
1	HRIW Cottage CS Trial	7	0.5	0.5
5	HPF Holme	2	0.66	1
9	TP Thoresby	5	0.66	0.66
28	VCS Elveden	0	0.66	1.33
29	VCS Wormegay	7	0.66	0.33
23	AB Red Lodge	5	1	1.33
7	HG Barnby Moor	6	1.33	0.83
11	KPL Kirkforthar	4	2	0.33
10	KPL Ladybank	7	3	1
2	SF Old School House	7	3.33	1
13	SL Holton	3	3.66	1.66
12	KPL Edenwood	0	5	1
18	FG Bilsthorpe	7	6.33	1.16
19	HF Crockey Hill	0	14	3
20	Mols New Cut Lane	0	16	4
21	Mols Carr Moss Lane	1	28.66	4.5
16	MHP Kellington	0	40.66	4.33

Table 7 shows that there was a large range in the number of days when the soil was saturated in the week after 10mm crown date, but there was no obvious relationship between these numbers and the likelihood of having the disease present. The average number of days saturated in this period in the sites with no disease was nearly the same as for the sites with disease (3.37 compared to 3.44 days).

Table 8 below shows the distribution of the number of days saturated split into presence or absence of disease and again shows no obvious pattern.

This shows that of 9 sites where there were no days of soil saturation in the week following the 10mm crown date, 4 had no disease and 5 had disease. Similarly there were 9 sites where the soil was saturated for the whole period (7 days) and again, 4 had no disease and 5 had disease so it is difficult to draw any conclusions regarding the effect of soil saturation on disease.

Table 8 Distribution of number of days saturated in the week following 10mm crown date

No observed	No of sites in each category	
Presence	No disease	Disease present
Days saturated		
0	4	5
1	0	2
2	1	1
3	1	1
4	1	1
5	0	2
6	0	1
7	4	5

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

Soil Temperature

We looked at temperature but as in previous years there did not appear to be any relationship between temperature and disease. In the week following 10mm crown, the average temperature for sites with disease was higher at 18.44 ºC against 17.06 ºC for sites with no disease, but this was not significantly different.

This was the reverse of the results from last year when the average soil temperature of sites with no disease was slightly higher. Table 9 gives the site figures

Table 9 Average soil temperature ºC in week after 10mm crown date

Site	Site Name	Temperature	Incidence	Severity
3	TBG Foxhall	18.16	0.00	0.00
4	TBG Isleham	16.30	0.00	0.00
6	HPF Waplington	15.66	0.00	0.00
8	HG Apley Head	14.76	0.00	0.00
14	SL Blyth	14.92	0.00	0.00
17	FG Haywood Oaks	15.92	0.00	0.00
22	Wils Knowsley	16.15	0.00	0.00
24	AB Burnham Deepdale	17.35	0.00	0.00
25	VCS Fos Ufford	17.25	0.00	0.00
26	VCS Hilborough	19.30	0.00	0.00
27	VCS Gooderstone	21.87	0.00	0.00
15	SL Walesby	18.27	0.33	0.33
1	HRIW Cottage CS Trial	18.59	0.50	0.50
5	HPF Holme	18.96	0.67	1.00
9	TP Thoresby	18.37	0.67	0.67
28	VCS Elveden	20.47	0.67	1.33
29	VCS Wormegay	19.44	0.67	0.33
23	AB Red Lodge	18.42	1.00	1.33
7	HG Barnby Moor	18.40	1.33	0.83
11	KPL Kirkforthar	16.94	2.00	0.33
10	KPL Ladybank	16.69	3.00	1.00
2	SF Old School House	15.26	3.33	1.00
13	SL Holton	17.53	3.67	1.67
12	KPL Edenwood	19.26	5.00	1.00
18	FG Bilsthorpe	17.84	6.33	1.17
20	Mols New Cut Lane	19.29	16.00	4.00
21	Mols Carr Moss Lane	18.68	28.67	4.50
16	MHP Kellington	20.50	40.67	4.33

In 2013 the most obvious effect on cavity spot seems to be region, as can be seen in Table 10 below. In Cambs there were a majority of sites where there is no disease, whereas all other areas have a majority of sites with disease, although the numbers in each group are small except for Notts. However it is known that the incidence of disease is not a function of region and if the study was to be repeated over many more sites and years this effect would disappear.

Table 10 Sites sorted by region and presence/absence of disease

	No disease	Disease present
	0	1
Cambs	6	4
Lancs	1	2
Midlands	0	1
Notts	4	8
Scotland	0	3

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.

In 2013 we found:

- no correlation between total water input (precipitation plus irrigation) and presence of disease.
- no correlation between soil moisture saturation with presence of disease.
- no relationship between soil temperature and presence of disease.

Overall we have seen some evidence of a relationship between total water input and the presence of disease but this has not been a consistent effect.

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 confirm 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 the development of further knowledge on the biology of the disease, new approaches to control will be developed.

Conclusions

Having now looked at 4 years data we have not found any consistent effect of the parameters studied.

Looking at the three years ending 2012, the level of water input appeared to be the main influence on disease. The correlations appeared 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.

However in 2013 we have difficulty in drawing any conclusions from the results. There are no obvious apparent relationships with this year's data and where some trends are present they often are in the opposite direction from previous results.

Looking at these results as a whole 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 the results of this study show 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.

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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 2013

Appendix 2 Weather Data summaries 2013

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

Appendix 1

Site soil analysis results 2013

		Soil	Analysis		
ID	Location	pH	Pindex	Kindex	Mgindex
1	HRIW Cottage CS Trial				
2	SF Old School House	7.8	6	1	1
3	TBG Foxhall	6.9	4	3	2
4	TBG Kenny Hill	7.8	3	2-	1
5	HPF Holme	7.0	3	1	3
6	HPF Waplington	6.4	3	1	1
7	HG Barnby Moor	6.3	4	2-	2
8	HG Apley Head	7.4	4	2+	3
9	TP Thoresby	7.7	5	1	2
10	KPL Ladybank	6.2	2	2-	3
11	KPL Kirkforthar	5.4	4	3	3
12	KPL Edenwood	5.9	4	2+	3
13	SL Holton	6.4	4	2-	1
14	SL Blyth	7.2	4	2+	3
15	SL Walesby	7.2	6	2-	2
16	MHP Kellington	6.9	4	1	3
17	FG Haywood Oaks	6.3	3	3	3
18	FG Bilsthorpe	7.0	7	2+	3
19	HF Crockey Hill	5.4	5	2-	2
20	Mols New Cut Lane	5.8	3	1	5
21	Mols Carr Moss Lane	6.4	3	2-	6
22	Wils Knowsley	5.8	4	1	3
23	AB Red Lodge	8.1	3	2+	2
24	AB Burnham Deepdale	7.2	3	2-	2
25	VCS Fos Ufford	7.7	4	2-	2
26	VCS Gr Hilborough	8.0	2	1	2
27	VCS Gr Gooderstone	7.6	4	2-	2
28	VCS Elveden	7.5	4	2+	2
29	VCS PF Wormegay	7.3	2	1	2
30	VCS Caple St Andrew	7.5	5	1	2