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Sclerotinia in oilseed rape – a review of the 2007 epidemic in England

by

Peter Gladders, Denise Ginsburg and Julie A. Smith

ADAS Boxworth, Battlegate Road, Boxworth, Cambridge CB23 4NN

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Contents

ABSTRACT

This review examined factors contributing to the sclerotinia stem rot (caused by *Sclerotinia sclerotiorum*) epidemic in winter oilseed rape in 2007. The epidemic was the most severe yet recorded in England, with 5.7% plants affected in random disease survey samples and the worst since 1991. The local and regional distribution of stem rot was examined in relation to crop and pathogen monitoring and weather variables. Comparisons were made between 2006 (an ‘average’ year) and 2007 and between ADAS farms at Boxworth, Cambs and Rosemaund, Hereford between 1991 and 2007. Criteria for sclerotinia infection used in the German model SkleroPro were evaluated.

Disease survey and reports from consultants and farmers indicated the most severe stem rot in the south west and parts of the West Midlands. In south and central regions including parts of Essex and Hertfordshire, there were also high levels of stem rot. However, most of Eastern and northern England showed only low levels of stem rot and disease incidence was in some cases lower than in 2006. Petal tests and field observations indicated higher levels of ascospore inoculum in 2007 than in 2006. The dry 2007 spring led some to believe that the risk was low, though dry days are favourable for spore dispersal if apothecia (the fruiting bodies of sclerotinia) are present. A monitoring network indicated that apothecia were present during flowering except at one site on the Yorkshire Wolds.

Stem rot infection took place first in late April in the Hereford area where there was some rainfall, but a second and larger phase of infection took place towards the end of flowering (in mid May) in both the west and the south. Fungicides applied at early flowering (11 April) gave good control (70-80%) when high rates of application were used. The decision not to use fungicides and late applications contributed to the high disease incidence. The SkleroPro model identified days when infection might have occurred during flowering in 2006 and 2007 and during 1991-2007 at Boxworth and Rosemaund. No infection conditions were recorded at Bracknell or Coltishall in 2007. The weather during flowering was compared for six crops with severe stem rot (>25% plants affected) identified at Rosemaund (5 crops) and Boxworth (one crop) during 1991-2007 and all other ‘low’ disease crops, but no significant differences were identified to explain the differences between high and low disease sites. There were indications that high rainfall had a negative effect on stem rot. At Boxworth, inoculum on petals was known to be low in most years and this limited the severity of sclerotinia epidemics. Variation in stem rot incidence reflects both variation in inoculum and the occurrence of favourable weather for infection.

The SkleroPro model showed considerable promise for identifying ‘infection periods’ when used retrospectively. To be a practical tool to improve decision making, infection periods need to be predicted as fungicides show little curative activity. The development and use of rapid DNA tests to measure sclerotinia inoculum would be a significant advance to support decision making as it appears that inoculum is a limiting stem rot infection in many crops. With increased crop values, two fungicide treatments may be worthwhile at high risk sites to protect the crop throughout flowering. A Sclerotinia Decision Guide on the HGCA website was updated and made available for the 2008 season.

TECHNICAL REPORT

1. Introduction

Stem rot caused by *Sclerotinia sclerotiorum* is a common disease of oilseed rape, though there have been only limited numbers of severe attacks in England in most years. There were numerous severe attacks in winter oilseed rape in Scotland in 2006 and in southern and western England in 2007 and sclerotinia management has assumed greater economic importance than hitherto. Defra-funded oilseed rape disease surveys reported by CropMonitor indicated that the 2007 epidemic was the most serious sclerotinia epidemic since 1991. Some analyses of the 1991 epidemic have been reported (Gladders *et al.,* 1993). However, there was more monitoring and disease data for 2007 than 1991 and this was the first opportunity to analyse a severe epidemic in England since 1991.

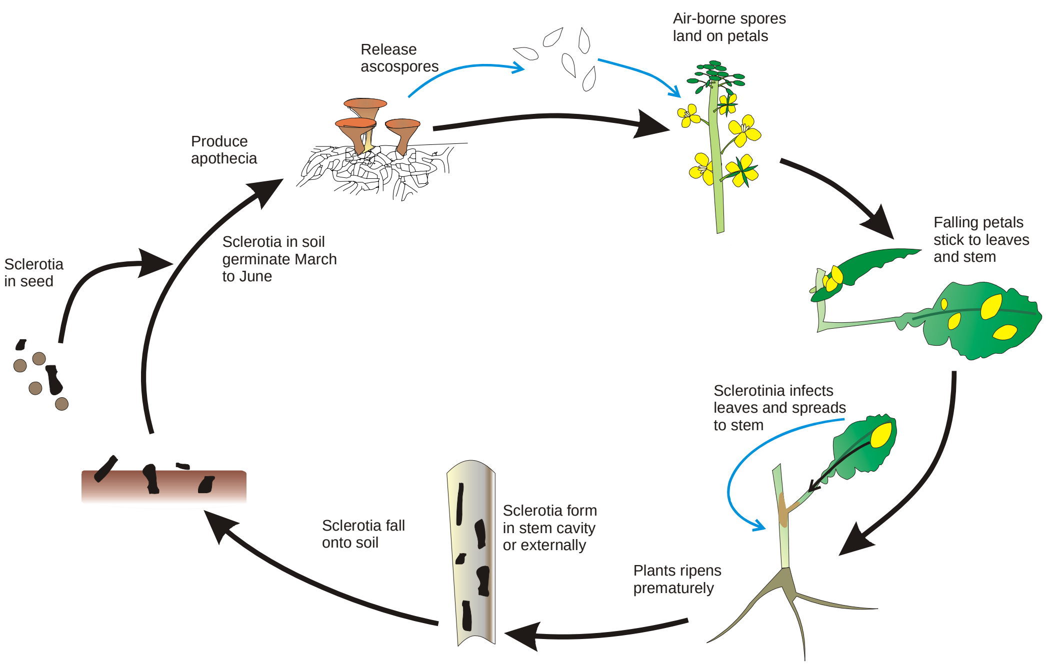

Figure 1. Disease cycle for *Sclerotinia sclerotiorum* in oilseed rape.

The disease cycle for sclerotinia stem rot in oilseed rape is shown in Fig. 1. There are several key stages that must be synchronised and completed for crop infection to occur. Weather conditions must also be suitable for the pathogen at each stage. Soil-borne sclerotia are the main source of inoculum for most crops. The sclerotia germinate in spring to produce fruiting bodies (apothecia) at the soil surface. Large numbers of ascospores are discharged from the apothecia and these air-borne spores pose a threat to broad-leaved crops in the same field and in nearby fields. Ascospores require exogenous nutrients to enable them to infect plants and this is provided mainly by petals in oilseed rape. Ascospores infect the petals and when petals stick to the leaves or stems, plants become infected and show symptoms within 7-14 days. New sclerotia form within the stem cavity and sometimes on the outside of the plant and are returned to the soil at harvest. Some sclerotia may be harvested with the seed and introduce inoculum into other fields if present in seed.

The history of stem rot problems on individual farms and the weather during flowering have been considered the two most important factors in decision making. Other factors may be included and are incorporated into an HGCA decision guide (www.hgca.com). New information from this review will be used to improve the decision guide.

The occurrence and quantification of soil-borne inoculum is often unknown, particularly at the individual field level. *Sclerotinia sclerotiorum* is a common pathogen and assumptions have to be made about the degree of risk based on previous crops and disease outbreaks (Davies *et al*., 1999). Archer *et al*. (1992) found oilseed rape plants produced 4.5 sclerotia per plant whilst peas produced 6.3 sclerotia per infected plant. Heavily infected crops produced large numbers of sclerotia (>50 m^{-2}) posing a long term threat to susceptible crops for many years. Sclerotia near the soil surface may germinate to produce apothecia and then decay whilst others may lose viability. The half life of sclerotia in the cultivated soil layers has been estimated at 2.5 years (Archer *et al*., 1992). Short rotations of oilseed rape and/or other susceptible crops are likely to increase sclerotial inoculum (Archer *et al*., 1992; Koch *et al*., 2006). Sclerotia produced on weeds are thought to be of minor importance (Archer *et al*., 1992).

Analysis of sclerotinia epidemics depends on examination of the classical interactions of the disease triangle where the factors are the host plant, the pathogen and the environment. Host factors are undoubtedly involved as field reports indicated differences between cultivars in the same field or in adjacent fields. There were more severe sclerotinia problems in western and southern England than in the north and east, suggesting that weather factors and/or variation in pathogen inoculum might be involved. CropMonitor has often reported regional variation in sclerotinia incidence between regions and in 1991, the epidemic showed a westerly distribution (Gladders *et al.,* 1993). Data on Sclerotinia activity in spring is available from monitoring the appearance of fruiting bodies (apothecia) of sclerotinia. This was previously investigated in HGCA project OS17/1/91 (Sansford et al. (1994) Project Report OS07 Oilseed rape: Sclerotinia risk forecasting, HGCA). A continuation of this monitoring work is now funded by BASF plc and is included in this report. Petal testing using agar media has also been continued using established methods (Davies *et al*., 1999) and enables inoculum levels in individual crops to be quantified.

The environmental factors to consider relate mainly to the weather during April to June as these will be critical for production and dispersal of inoculum and for crop infection. Unsettled weather with dry periods interspersed with scattered showers is considered very favourable for sclerotinia infection. Recent research in Germany has led to the development of a new sclerotinia infection model known as SkleroPro (Koch *et al*., 2006) and it is opportune for this to be evaluated against UK weather data. The model is able to analyse epidemics retrospectively and should enable regional and sub-regional variation in infection conditions in 2006 (an average year) with 2007 to be compared. In addition, year to year variation in weather data to be appraised systematically during 1991 to 2007 using site specific data on disease incidence is available for the same period from ADAS sites at Boxworth and Rosemaund. National disease survey data is also available for the same period though may be confounded by changes in fungicide use. Fungicide use increased after the 1991 epidemic from 9% crops treated at flowering to 44% by 1993 (Turner and Hardwick, 1995).

Agronomic factors may also influence sclerotinia incidence. In Germany, cultivar, date of sowing, and soil type, but not soil cultivation, crop density or nitrogen treatment had a significant effect on stem rot (Koch *et al*., 2006). Evidence that minimum tillage reduces the risk of sclerotinia is inconsistent (Koch *et al*., 2006). Logically establishing oilseed rape by direct drilling into cereal stubbles should minimise disturbance of buried sclerotia, and sclerotia near the soil surface should have germinated in the cereal crop and decayed. High rates of spring nitrogen treatments have been reported to delay the production of apothecia (Archer *et al*., 1992). Cultivar effects are complex because of variation in flowering and plant growth and there are no resistant cultivars. Sweet *et al*. (1992) found that sclerotinia levels were positively correlated with earliness of flowering and negatively correlated with plant height.

Sclerotinia infection conditions

There is an extensive literature on sclerotinia infection requirements in a wide range of crops that is beyond the scope of this review. Some new information is available for lettuce and oilseed rape which extends previous knowledge. From recent experiments done at Warwick HRI in a Defra-funded project on lettuce, ascospore germination on leaves occurred from >5^{o}C to <30^{o}C with no germination below 97% r.h. The optimum temperature for germination was about 20^{o}C. The lettuce studies also showed that ascospores can remain viable for several weeks on leaf surfaces, longer than expected from previous work. Thus, there may not be close synchrony between the appearance of apothecia or ascospore dispersal and plant infection. Disease development showed rather similar temperature requirements, but plant infection occurred even where plants were kept at 50% r.h. This suggested that humidity on plant surfaces, particularly in leaf axils may often be suitably moist for infection to occur (Clarkson *et al*., 2004; Young *et al*., 2004).

In laboratory experiments reported by (Koch *et al*., 2006), ascospore germination occurred after 4 days at 16-22 ^{o}C, but was much slower at 8-10^{o}C and 22-24 ^{o}C. There was no germination below 7 ^{o}C or above 26 ^{o}C. The studies were done with ascospores placed in the leaf axil directly or with petals inoculated with ascospores and placed in the leaf axil. Only 23% of ascospores germinated in the axils without petals, but 100% germinated when petals were present (Koch *et al*., 2006).

Sclerotinia modelling

A new sclerotinia infection model known as SkleroPro has been developed in Germany (Koch *et al*., 2006). Controlled environment studies showed that stem infection by ascospores required a minimum period of 23 hours with relative humidity above 80% at 7ºC. Under conditions in Germany, the incidence of sclerotinia at harvest was significantly correlated with the number of ‘infection’ hours above 23 during flowering. In this project, the number of infection hours above 23 (>7 ºC; >80% r.h.) will be calculated for individual meteorological stations in April, May and June 2006 and 2007 and for the Boxworth and Rosemaund locations for 1991-2007. The influence of infection hours and rainfall on sclerotinia incidence was explored using regression analyses with various combinations of flowering and post flowering events.

Fungicides

Current fungicides have little curative activity and treatments are advised after an assessment of risk. Assessment of disease risk is of fundamental importance to decision making if routine treatment applications are to be avoided. The dry weather in April 2007 was judged by many to have been unfavourable for sclerotinia development and yet sclerotinia became severe in many crops in western and southern England. In the absence of resistant cultivars, fungicides are widely used to protect crops against stem rot. Where fungicides were applied at early to mid-flowering, good control of sclerotinia was generally observed. This was supported HGCA fungicide performance experiments in 2007 (www.hgca.com).

This review compares the contrasting sclerotinia epidemics in England in 2006 and 2007 and discusses how management of the disease could be improved. Industry will now be increasingly cautious about leaving crops untreated at flowering. There are gaps in knowledge of the disease in the industry and a review of the 2007 epidemic will assist future decision making if key indicators of problems are known. Up to date information for UK growers and advisers is required urgently to formulate disease management at flowering in 2008. Wider issues of sclerotinia management will be considered including use of biological control, rotation and soil treatments and recommendations made where gaps in knowledge are identified.

Objectives

i) Collate hourly weather data from April to June at 12 locations to represent England in 2007 (severe sclerotinia) and 2006 (average to low risk year)

ii) Use the SkleroPro infection model (from Germany) to identify the infection events and seasonal risk

iii) Use the infection model to compare risks across years at two sites since 1991

iv) Review fungicide timing and yield response data from industry experiments and field reports in relation to sclerotial germination and petal tests

v) Update sclerotinia decision guide

2. Materials & Methods

Sclerotinia depots

A network of 'depots' of sclerotia of *S. sclerotiorum* (usually five per year) has been monitored in England for over 20 years (Gladders *et al*., 1990). The depots are established in winter oilseed rape crops in autumn with 100 sclerotia collected from a local, naturally infected oilseed rape crop. Sclerotia are buried 2cm deep in soil in an oilseed rape crop in plastic mesh grids with one sclerotium per grid square. The production of apothecia in each grid is recorded weekly during March to May together with the surrounding crop growth stage. The cumulative percentage germination data is presented from six sites for 2006 and 2007. Results from depots sited at Longforgan, Perthshire in 2006 and Ellon, Aberdeenshire in 2007 are also included.

Petal testing

Petal testing using agar plates has been used by ADAS to quantify the inoculum of *S. sclerotiorum* in farm crops and field experiments (Davies *et al*., 1999). Results from tests made at early to mid-flowering in 2006 and 2007 at various experimental sites and some farm crops are presented as the percentage of petals producing sclerotinia colonies on agar.

Field experiments

Small plot experiments with four-fold replication were carried out on commercial varieties of winter oilseed rape at a range of sites in England in 2006 and 2007. Two separate experimental protocols for spray timing and product comparison were used at some sites. Fungicides treatments were applied mainly at early to mid-flowering using hand-held OPS spray equipment in 200 litres of water/ha and disease assessments made on a minimum of 100 plants per plot pre-harvest. Disease severity was recorded as a disease index (0-4 where 0 – healthy and 4 – dead) for each plant and converted to a 0-100 index per plot. Plots (minimum area 48 m^2) were combine harvested and yields adjusted to 90% dry matter. The yield response to a single spray of boscalid 0.25 kg a.i./ha (as Filan) is presented to show the benefits of disease control in individual experiments.

Crop monitoring

A Defra-funded survey of about 100 commercial oilseed rape crops has been carried out annually in England since 1986 and is now reported by CropMonitor (http://www.cropmonitor.co.uk). Sclerotinia stem rot incidence and severity has been recorded in samples collected in late June or early July on samples of 25 plants. National data for the percentage of crops affected and the percentage of plants affected are presented. Regional data for 2006 and 2007 has also been provided by CropMonitor to allow more detailed examination of disease and weather interactions. A significant proportion of survey crops (30-40% in recent years) had received a fungicide treatment at flowering, but variation in sclerotinia is still evident. There have been many other reports of sclerotinia from consultants and farmers and a distribution map has been prepared based on all available records to show the occurrence of sclerotinia in 2007.

As severe epidemics occur infrequently, individual farm records of sclerotinia in winter oilseed rape from the ADAS farms at Boxworth and Rosemaund since 1991 have been collated. In some years, data are from survey samples of 25 plants, but most years are based on assessments of untreated plots in replicated field experiments. The contrasting locations of Boxworth in the east and Rosemaund in the west have been used to explore disease-weather interactions.

Flowering period

The onset and duration of flowering in winter oilseed rape shows considerable seasonal, varietal and local variation. There was a marked contrast between 2006 and 2007. Crops flowered late and for only about four weeks in 2006, but started to flower in early April in 2007 and continued for about six weeks. Records of flowering have been collated from reports of experiments and other observations and used to define the main periods for testing infection models. Whilst flowering is almost certainly the main period for sclerotinia infection, very late infection may occur through senescent leaves or damaged plant tissues. In lodged crops, sclerotinia can continue to spread after flowering by mycelial growth where stems are in contact with each other.

2.1 Weather data

2006-2007

Fifteen weather sites were chosen in England that provided a geographical spread similar to areas in which oilseed rape was grown (Figure 2). Hourly weather data for April, May and June in 2006 and 2007; rain, relative humidity and maximum and minimum temperatures were collected and assembled in a Microsoft Excel database. Where small numbers of missing datapoints were present, averages of the nearest data points were used to estimate the missing data records.

Estimating infection conditions

A visual basic macro was written to extract information on the occurrence and duration of weather conditions favourable for sclerotinia development based on the criteria used in the German model SkleroPro (Koch *et al*., 2006). The macro calculated when temperature was above 7°C and relative humidity was > 80% for each site and the number of consecutive hours with these conditions summed. In the model, sclerotinia infection periods require a minimum of 23 consecutive hours at >80% r.h. when temperatures are above 7°C. The date, time of the beginning of the episodes and the duration of the period were noted for each site during April to June (Table 4, 5, 6 & 7). Further analyses were then limited to events occurring during the main flowering period.

Long term analyses

Hourly weather data was available for Boxworth and Rosemaund for most of the long-term analysis period. The Boxworth dataset was enhanced with data from Wyton for 1990 to 1993 and Church Lawford weather was used for Rosemaund from 1991 to 1998. Missing data for rainfall for Rosemaund in 2007 was obtained from Credhill. Short periods of missing data in April 2003, 2004 and 2005 were supplemented by data from the Cambridge University Weather station. This data was then summarised in a similar fashion to the short term data for Boxworth (east) and Rosemaund (west) and used to explore factors affecting sclerotinia infection in crops on these ADAS farms each year.

Model testing

A new sclerotinia infection model known as SkleroPro has been developed in Germany (Koch *et al*., 2006). Controlled environment studies showed that

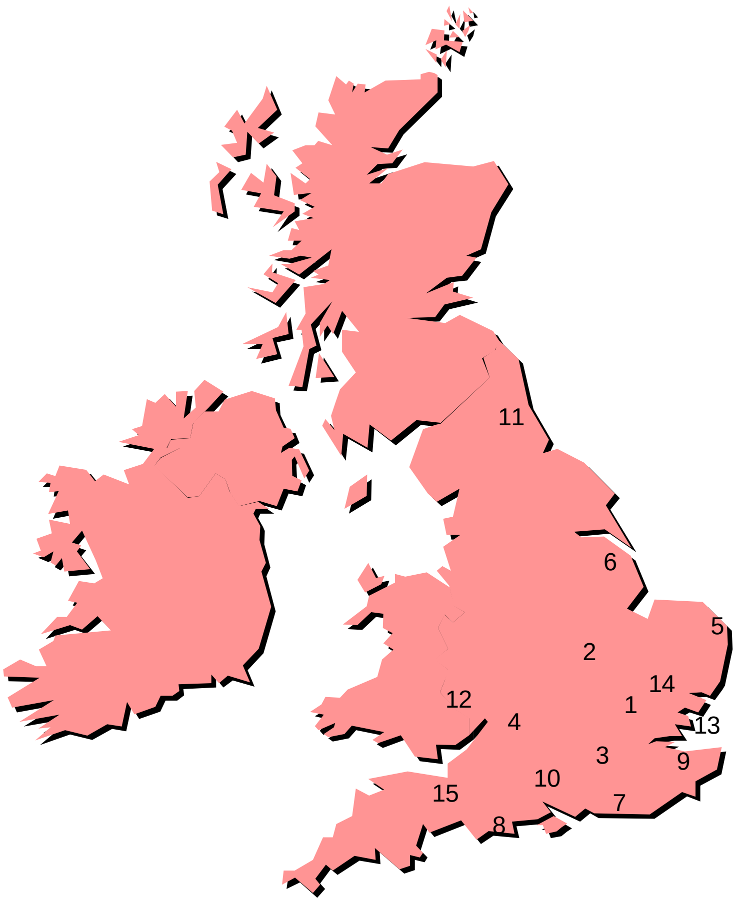

Figure 2. Location of Meteorological stations used for weather data (see Table 1 for site identification)

Table 1. Meteorological stations used for weather data for April to June 2006 and 2007

Code No.	Met.station	Region
1	Andrewsfield	East
2	Boxworth	East
3	Bracknell	South east
4	Brize Norton	South west
5	Coltishall	East
6	Donna Nook	East
7	Herstmonceaux	South east
8	Hurn	South west
9	Manston	South east
10	Middle Wallop	South east
11	Newcastle	North
12	Rosemaund	Midlands & west
13	Walton	East
14	Watisham	East
15	Yeovilton	South west

stem infection by ascospores required a minimum period of 23 hours with relative humidity above 80% at 7ºC. Under conditions in Germany, the incidence of sclerotinia at harvest was significantly correlated with number of ‘infection’ hours above 23 during flowering. In this project, the number of infection hours above 23 (>7 ºC; >80% r.h.) has been calculated for individual met stations in April, May and June 2006 and 2007 and for the Boxworth and Rosemaund locations for 1991-2007. The influence of infection hours and rainfall on sclerotinia incidence was explored using regression analyses with various combinations of flowering and post flowering events.

3. Results

3.1 Sclerotinia depots

Crop development was delayed in a cold spring and sclerotial germination started on 3 April at Boxworth, Cambs and Rosemaund, Hereford in 2006, six weeks earlier than High Mowthorpe, North Yorkshire. Apothecia were produced before flowering at Boxworth and Rosemaund and peak numbers occurred at mid-flowering (Fig. 3). At the Kent site near Ashford, sclerotial germination was very rapid between 24 April and 15 May in 2006. In the north at High Mowthorpe, little germination had occurred by mid-flowering.

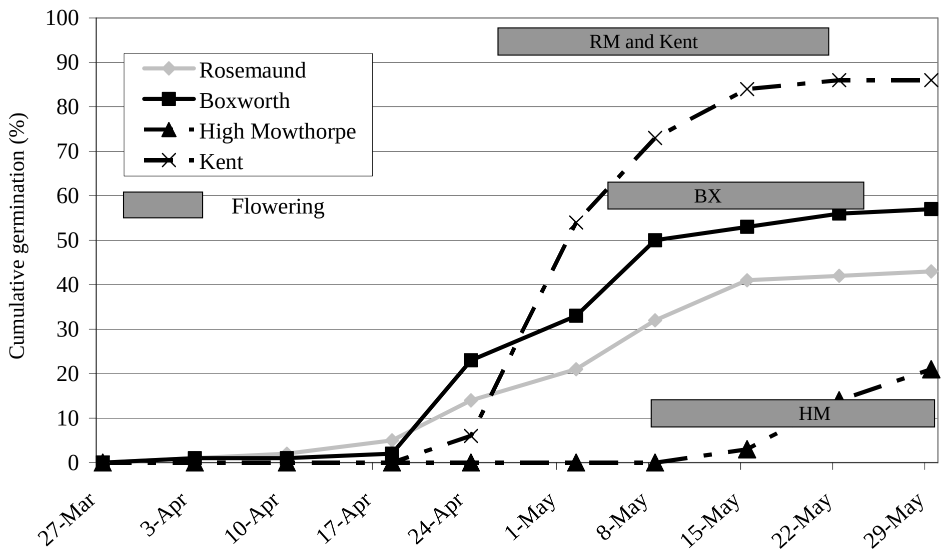

Figure 3. The cumulative percentage germination of sclerotia of *S. sclerotiorum* in winter oilseed rape at four sites in relation to flowering of the crop 2006.

In 2007, after a winter with above average temperatures, the first apothecia were found on 6 March at Boxworth. There was very little rainfall during the period from late March to early May, but sclerotial germination still occurred at Boxworth and Rosemaund during April (Fig. 4). The overall percentage germination in the depots was lower than usual in 2007. At the depot sited on heavy soil at Boxworth, apothecia developed in cracks below the soil surface. At High Mowthorpe, germination only started in early May when crops had almost finished flowering. The Kent site near Ashford showed some early germination, but dry weather appeared to have restricted germination until mid-May. This delayed germination would have resulted in high levels of inoculum during mid- to late May so that infection could have occurred in late flowering crops or possibly via senescent leaves. There were several reports from the south that later flowering varieties showed more sclerotinia infection than earlier flowering types.

The sclerotinia epidemic in the 2007 season in southern England bears some comparison with the epidemic in Scotland in 2006, which was also severe and late-developing. Data on the production of apothecia are limited in Scotland. At Longforgan, Perthshire, sclerotia germination started on 13 May 2006, when the most advanced crops were starting to flower. Peak germination occurred between 12 June and 12 July 2006, when the most backward crops were still in flower. In 2007, germination started on 14 May 2007, at early flowering in Aberdeenshire.

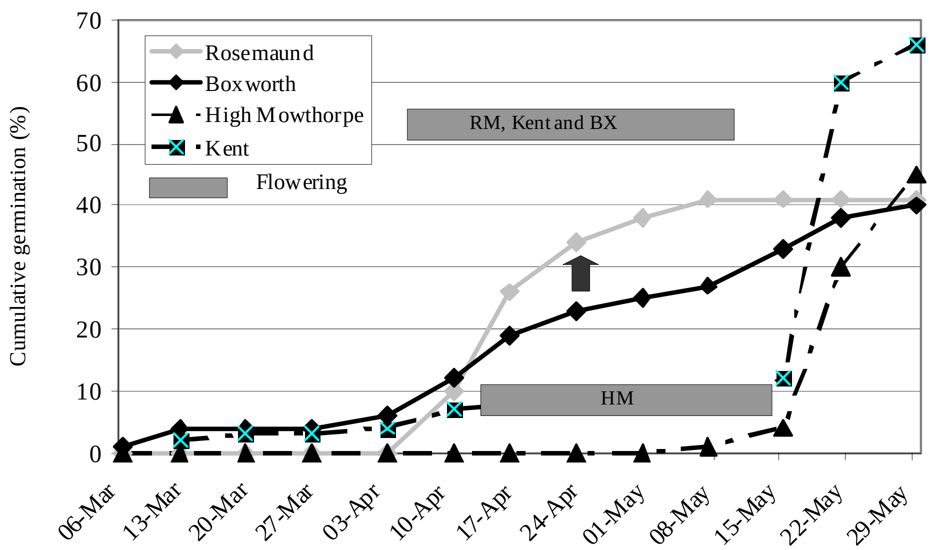

Figure 4. The cumulative percentage germination of sclerotia of *S. sclerotiorum* in winter oilseed rape at four sites in relation to flowering of the crop 2007. The arrow indicates when the first infection occurred in the Hereford area.

Petal testing

The incidence of sclerotinia on petals at the early to mid-flowering stage was higher in 2007 than in 2006 at high risk sites in Kent and Hereford (Table 2). At ADAS Boxworth, two farm crops were tested each year and petals had 0 and 2.5% sclerotinia in 2006 and 12.5 and 27.5% in 2007. Only low levels of stem rot developed in these fields and inoculum was considered limiting for disease development. In previous years at Boxworth, petal tests have shown low levels of inoculum, even in the field that had 60% plants affected in 1992.

Petal tests indicated that inoculum was high at some sites in 2007, countering widely-held views that dry weather had restricted sclerotial germination. A threshold of 50% petals with sclerotinia has been used as a guide for economic damage. All the sites with >50% petal infection developed severe sclerotinia. Hereford 1 in 2006 and Hereford 2 in 2007 both had damaging sclerotinia attacks though petals tests showed 35% and 25% infection respectively. Arguably, a lower threshold of 25% petals affected might have been used when rapeseed is worth >£300/tonne. In Aberdeenshire, petals were not tested in 2006, when disease pressure was high. In 2007, no sclerotinia was detected in the petal tests, and no disease was reported in the region.

Field experiments

Stem rot was particularly severe in experiments in the Hereford area in 2007 where up to 81% of untreated plants were affected. Large numbers of petals stuck to the foliage following rainfall during 23-25 April in the Hereford area. At Hereford 1, stem rot symptoms were detected on 12 May and an assessment on 1 June gave 33% plants affected in the untreated control and 4% incidence where boscalid was applied on 19 April (early to mid-flowering). Very high rainfall in late May and June favoured further stem rot development and 80% of untreated plants were affected pre-harvest at the Hereford 1 site. Pre-harvest, there was c.80% control of stem rot at high disease sites. Other crops in the area showed severe stem rot and fungicides gave significant yield responses up to 2.1 t/ha (Table 2).

Table 2. Incidence of sclerotinia on petals, stem rot severity pre-harvest, untreated yield and yield response to a flowering fungicide application of boscalid in individual field experiments in England in 2006 and 2007 (Data from Gladders *et al*., 2008).

Site	Year	Cultivar	Petal test % sclerotinia	Stem rot index (untreated)	Stem rot index (treated)	Untreated yield (t/ha)	Yield response (t/ha)
Kent	2007	Castille	62.5	34.6	5.2*	3.23	0.21
Hereford 1	2007	Catalina	69.0	57.3	9.6*	2.98	1.76*
Hereford 2	2007	Lioness	25.0	4.7	2.2	2.68	0.68
Hereford 3	2007	Castille	52.0	72.3	13.0*	2.60	0.79*
Devon	2007	Tequila	2.5	1.0	0.04*	4.83	0.18
N. Yorks	2007	Lioness	Not tested	0.7	0.3	3.81	0.25
Kent	2007	Castille	62.5	36.6	4.4*	2.87	0.63
Hereford 1	2007	Catalina	69.0	67.7	11.7*	2.43	2.10*
Hereford 2	2007	Lioness	25.0	21.9	1.2*	2.68	0.74*
Hereford 3	2007	Castille	52.0	44.8	8.4*	2.41	0.91*
Devon	2007	Tequila	2.5	1.0	0.2*	4.83	0.16
Boxworth	2007	Winner	27.5	2.0	n/a	n/a	
Boxworth	2006	Winner	2.5	0.1	n/a	n/a	
Kent	2006	Es Astrid	12.5	1.0	0.5	3.45	0.23
Hereford 1	2006	Lioness	35.0	20.9	0.7*	4.04	0.69*
Hereford 2	2006	Lioness	25.0	0.05	0.1	4.21	-0.15
Kent	2006	Es Astrid	12.5	1.0	0.1	3.86	-0.23
Hereford 2	2006	Lioness	25.0	0.05	0.01	4.10	0.47

*Significant control of stem rot and/or significant yield responses in these experiments (P<0.05)

In Kent, most stem rot developed from late May onwards and treatment with boscalid gave significant yield responses of up to 1.0 t/ha in some experiments in 2007. Stem rot incidence was low in the experiments in North Yorkshire and Devon in 2007, where inoculum levels were low. Plots inoculated with sclerotia in autumn 2006 at High Mowthorpe showed very low levels of stem rot, supporting ‘depot’ records that few sclerotia germinated during flowering. At Boxworth, farm crops were not sprayed for sclerotinia because of the low incidence on petals and most crops showed only 2% stem rot.

Stem rot caused significant yield loss in one experiment in 2006, but most sites showed very low disease and no significant responses to fungicide treatment. Fungicides applied in late April (24-27 April) or early May (3-5 May) gave good sclerotinia control in 2006. When oilseed rape was valued at £230/t, yield responses of 0.2 t/ha were required to cover the cost of fungicide and application including a small loss from wheeling damage. At £350/tonne, responses of 0.15 t/ha would justify treatment. The benefits from treatments in low risk situations should not be based on single year as there may be benefits to future crops if sclerotial inoculum is decreased.

3.2 Weather data

There were small differences in mean maximum and mean minimum temperatures between met. stations in central, eastern and southern England in both 2006 and 2007 (Table 3). Newcastle showed the lowest mean temperatures overall. Temperatures were higher in 2007 than in 2006 except at Rosemaund and for maximum temperatures at Yeovilton. Rainfall totals were very variable between sites and were lowest near coastal locations at Herstmonceaux, Manston and Walton in both years. Bracknell and Yeovilton had the highest rainfall in 2006, 210.9 and 195.3 mm respectively. Brize Norton, Rosemaund, Wattisham and Yeovilton all had more than 350 mm rain during April to June in 2007.

The distribution of rainfall is shown in Fig.5. The flowering of winter oilseed rape was late in 2006 and lasted for about 4 weeks during May. In 2007, flowering started in early April and lasted until mid-May. There was frequent rain during flowering in 2006 with some heavy rain in early May. The period from late March to early May was very dry in many areas in 2007, but some sites had rainfall in late April. There was frequent and heavy rain in mid May to late May and in the second half of June in 2007.

Table 3. Summary of mean temperature and rainfall data for April to June 2006 and 2007.

Met.station	Region	2006 Average maximum temperature °C	2006 Average minimum temperature °C	2006 Total rain mm	2007 Average maximum temperature °C	2007 Average minimum temperature °C	2007 Total rain mm
Andrewsfield	East	16.81	8.03	170.5	17.72	8.66	220.5
Boxworth	East	18.03	7.73	118.2	19.19	8.06	187.4
Bracknell	South east	17.70	8.79	210.9	19.11	10.26	260.2
Brize Norton	South west	16.06	8.40	138.0	18.00	9.09	352.0
Coltishall	East	16.57	7.55	155.2	16.92	8.44	236.8
Donna Nook	East	16.22	7.65	176.1	16.58	8.14	197.6
Herstmonceaux	South east	16.36	6.66	64.5	17.59	7.41	107.3
Hurn	South west	17.10	7.34	96.7	18.51	7.56	167.0
Manston	South east	16.93	6.15	57.4	17.64	7.13	62.1
Middle Wallop	South east	16.56	6.40	88.7	17.64	7.18	144.9
Newcastle	North	15.21	5.74	178.8	15.33	7.24	234.0
Rosemaund	Midlands & west	16.69	7.22	126.2	13.69	6.84	357.4
Walton	East	17.48	5.99	45.4	17.79	7.20	76.5
Wattisham	East	17.14	8.53	77.3	18.06	9.27	351.6
Yeovilton	South west	17.12	7.91	195.3	17.04	8.48	389.9

Figure 5. Daily rainfall for 16 met. Stations April to June 2006 and 2007

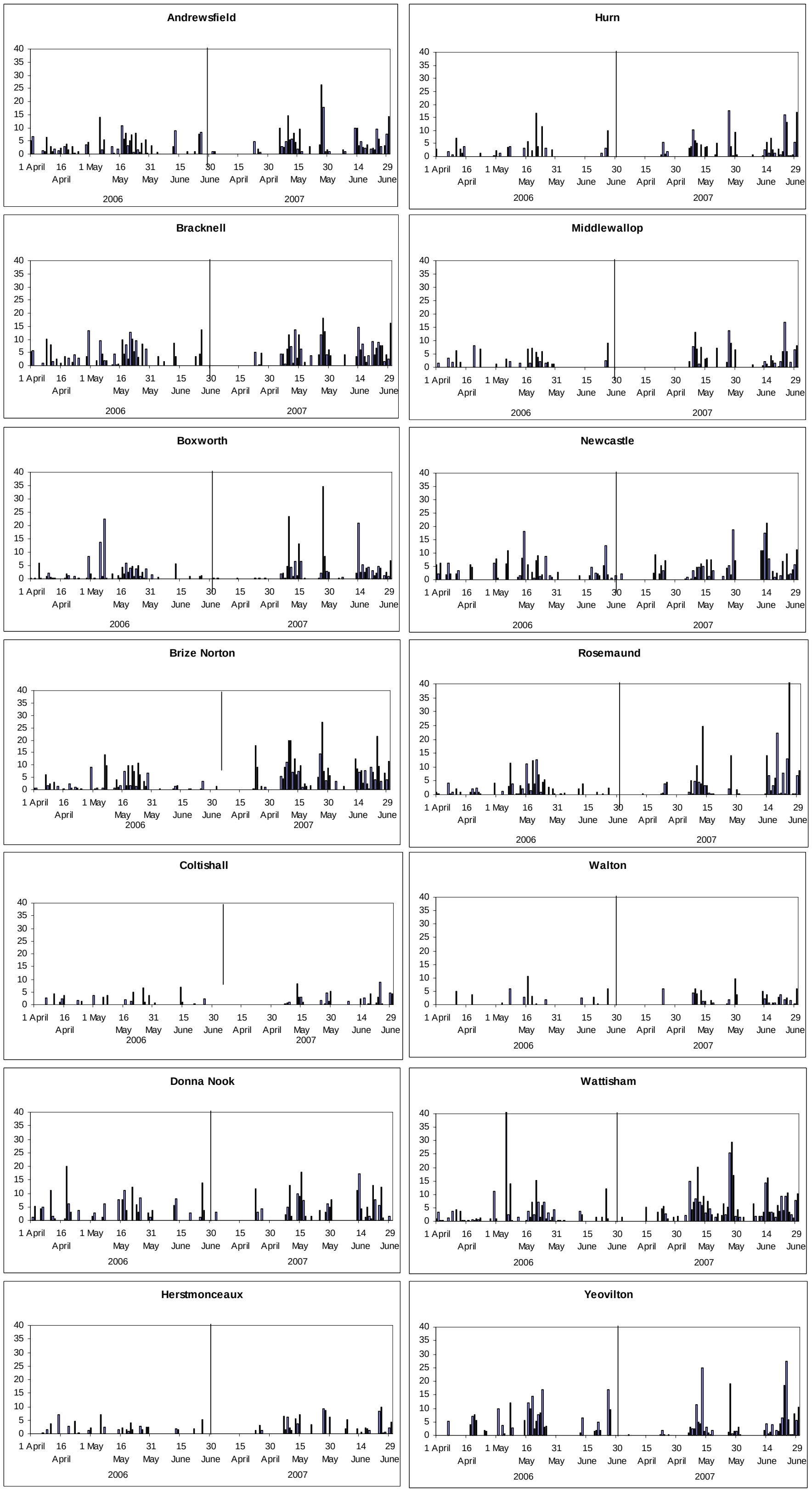

Table 4. Sclerotinia infection ‘events’ during flowering 2006

Met. Station	Region	Date of infection ‘events’	Time ‘event’ started GMT (h)	Duration of infection ‘events’(h)
Andrewsfield	East	6 May	18	68
Andrewsfield	East	13 May	16	24
Andrewsfield	East	15 May	20	41
Boxworth	East	6 May	18	40
Boxworth	East	8 May	12	25
Boxworth	East	12 May	23	40
Boxworth	East	14 May	19	40
Boxworth	East	20 May	20	23
Boxworth	East	21 May	20	28
Boxworth	East	26 May	21	36
Brize Norton	South west	7 May	21	43
Brize Norton	South west	14 May	23	37
Brize Norton	South west	16 May	21	38
Brize Norton	South west	19 May	15	52
Brize Norton	South west	25 May	23	58
Coltishall	East	6 May	21	37
Coltishall	East	12 May	22	84
Donna Nook	East	6 May	20	40
Donna Nook	East	12 May	23	83
Donna Nook	East	20 May	20	25
Herstmonceaux	South east	14 May	18	37
Herstmonceaux	South east	17 May	16	23
Hurn	South west	14 May	19	38
Hurn	South west	16 May	21	41
Hurn	South west	25 May	20	23
Manston	South east	7 May	0	24
Middle Wallop	South east	16 May	21	39
Newcastle	North	6 May	19	39
Newcastle	North	14 May	19	42
Rosemaund	Midlands & west	16 May	19	37
Rosemaund	Midlands & west	20 May	21	39
Walton	East	16 May	21	32
Wattisham	East	14 May	20	38
Wattisham	East	16 May	21	39
Wattisham	East	20 May	23	41
Yeovilton	South west	14 May	22	23
Yeovilton	South west	16 May	21	39

The dates, starting time (Greenwich Mean Time (GMT)) and duration of infection ‘events’ for 2006 and 2007 were calculated using the temperature and relative humidity criteria from the SkleroPro model for each met station (Tables 4 & 5). In 2006, there were infection ‘events’ on 6 or 7 May at seven locations followed by further events at mid-May at 13 locations. Boxworth, Cambs had seven infection ‘events’, only Bracknell had none at all (Table 4).

In 2007, there were suitable infection conditions in late April (mainly 22 or 23 April) at eight sites distributed across the east, south-east and south-west regions (Table 5). These were followed by one or two infection events during 8-16 May, though sites had these on different dates. Brize Norton and Coltishall had no infection events in 2007 whilst Bracknell, Herstmonceaux and Newcastle had no events during May (Table 5).

Early sclerotinia infection is usually the most important as plants are likely to ripen prematurely and produce little yield. There was potential for early infection in 2007 during 22-23 April at some locations (Table 7) and this was confirmed in the Hereford area. More widespread infection appears to have occurred in May given the observations that there was development of stem rot after the end of May. Some sites had at least two phases of infection and the SkleroPro model has given good indications of when infection events occurred.

Most infection events started late in the evening after 19.00 hours in 2006 (Table 6), but in 2007 there were more events started in the early morning to early afternoon period (02.00-14.00) (Table 7). The duration of events was variable, ranging from the minimum of 23 h up to 84 h at Coltishall on 12 May 2006. There was no clear relationship between the total duration of infection events, the number of infection events, the timing of infection events relative to the start of flowering and stem rot incidence (Fig. 7). Likewise mean temperature and the number of rain days during flowering did not differ significantly between high and low disease sites (Figs 11, 12 & 13).

Table 5. Sclerotinia infection ‘events’ during flowering 2007.

Met. Station	Region	Date of infection ‘events’	Time ‘event’ started GMT (h)	Duration of infection ‘events’(h)
Andrewsfield	East	12 May	17	31
Boxworth	East	22 April	20	68
Boxworth	East	26 April	17	23
Boxworth	East	2 May	20	39
Boxworth	East	4 May	16	23
Boxworth	East	12 May	17	54
Boxworth	East	15 May	7	76
Brize Norton	South east	23 April	0	27
Brize Norton	South east	12 May	22	23
Donna Nook	East	23 April	0	31
Donna Nook	East	13 May	0	24
Herstmonceaux	South east	22 April	19	39
Hurn	South west	22 April	22	27
Hurn	South west	8 May	21	39
Hurn	South west	15 May	0	34
Middle Wallop	South east	23 April	0	34
Middle Wallop	South east	9 May	0	30
Middle Wallop	South east	15 May	8	23
Rosemaund	Midlands & west	22 April	22	39
Rosemaund	Midlands & west	12 May	21	37
Rosemaund	Midlands & west	16 May	6	27
Walton	East	9 May	4	32
Wattisham	East	23 April	2	39
Wattisham	East	8 May	21	39
Wattisham	East	10 May	13	39
Yeovilton	South west	23 April	14	23
Yeovilton	South west	13 May	0	38

Table 6. First infection 'event' and potential onset of epidemic 2006.

Met. Station	Date of infection 'event'	Time 'event' started GMT (h)	Duration of infection 'events' (h)
Andrewsfield	6 May	18	68
Boxworth	6 May	18	40
Bracknell	none		
Brize Norton	7 May	21	43
Coltishall	6 May	21	37
Donna Nook	6 May	20	40
Herstmonceaux	14 May	18	37
Hurn	14 May	19	38
Manston	7 May	0	24
Middle Wallop	16 May	21	39
Newcastle	6 May	19	39
Rosemaund	16 May	19	37
Walton	16 May	21	32
Wattisham	14 May	20	38
Yeovilton	14 May	22	23

Table 7. First infection 'event' and potential onset of epidemic 2007.

Met. Station	Date of infection 'events'	Time 'event' started GMT (h)	Duration of infection 'events' (h)
Andrewsfield	12 May	17	31
Boxworth	22 April	20	68
Bracknell	none		
Brize Norton	23 April	0	27
Coltishall	none		
Donna Nook	23 April	0	31
Herstmonceaux	22 April	19	39
Hurn	22 April	22	27
Manston	3 June	0	44
Middle Wallop	23 April	0	34
Newcastle	5 June	17	24
Rosemaund	22 April	22	39
Walton	9 May	4	32
Wattisham	23 April	2	39
Yeovilton	23 April	14	23

3.3 Disease monitoring

Regional mean data for the percentage of crops with sclerotinia stem rot pre-harvest and the percentage plants affected have been provided by CropMonitor.

Table 8. Regional and national mean percentage of crops and mean percentage of plants with sclerotinia stem rot in winter oilseed rape in Defra-funded monitoring of farm crops, 2006 and 2007.

Region	**% crops with stem rot**		**% plants with stem rot**	
	2006	**2007**	**2006**	**2007**
East	22.5	20.5	2.5	1.9
Midlands & West	15.4	31.3	2.8	2.5
North	25.0	25.0	2.8	1.6
South east	12.5	56.3	0.5	6.5
South west	25.0	77.8	3.5	34.7
England	20.6	34.0	2.4	5.7

Sclerotinia has been found in farm crops in all regions during the last two years. Samples consisted of 25 plants so affected crops had at least 4% plants affected. Sclerotinia is likely to have been present in many more crops but at levels below 4% plants affected. The south west had the highest incidence in 2006 and had the highest regional mean ever recorded in 2007 when 34.7 % plants were affected (Table 8). The previous highest was 11.5% in the north in 2003. Stem rot affected 6.5% of plants in the south east region in 2007, the highest ever recorded. The north, east and Midlands and west had less sclerotinia than in 2006.

The percentage of crops affected nationally in 2007 was lower than in 1991 (46%) and 2000 (37%) (Fig.8). The high incidence in the south west has strongly influenced the national mean of 5.7% plants affected, which was only slightly higher than the 5.4% plants affected in 1991. The south west region included samples from Dorset, Somerset, Wiltshire and Gloucestershire, all counties where other severe attacks have been reported. The south west was the worst affected region in 2005 when 8.5% plants were affected. Severe other years showed regions with problems including 2000 (Midlands & west 9.4% plants affected; north 6.9%) and 2003 (north 11.5%). In national surveys during 1991 to 2007, the percentage crops with sclerotinia was highly correlated with the percentage plants affected (r^2= 0.95) (Fig. 9). The incidence in any one region was rather weakly correlated with national incidence (range r^2 =0.30 in the north to 0.43 in the south west). This indicated considerable variation in the location and severity of sclerotinia outbreaks from year to year.

The distribution of sclerotinia in England in 2007 is shown in Figure 6. Regional disease survey means and favourable weather conditions for stem rot development are shown in Figure 7 for both 2006 and 2007.

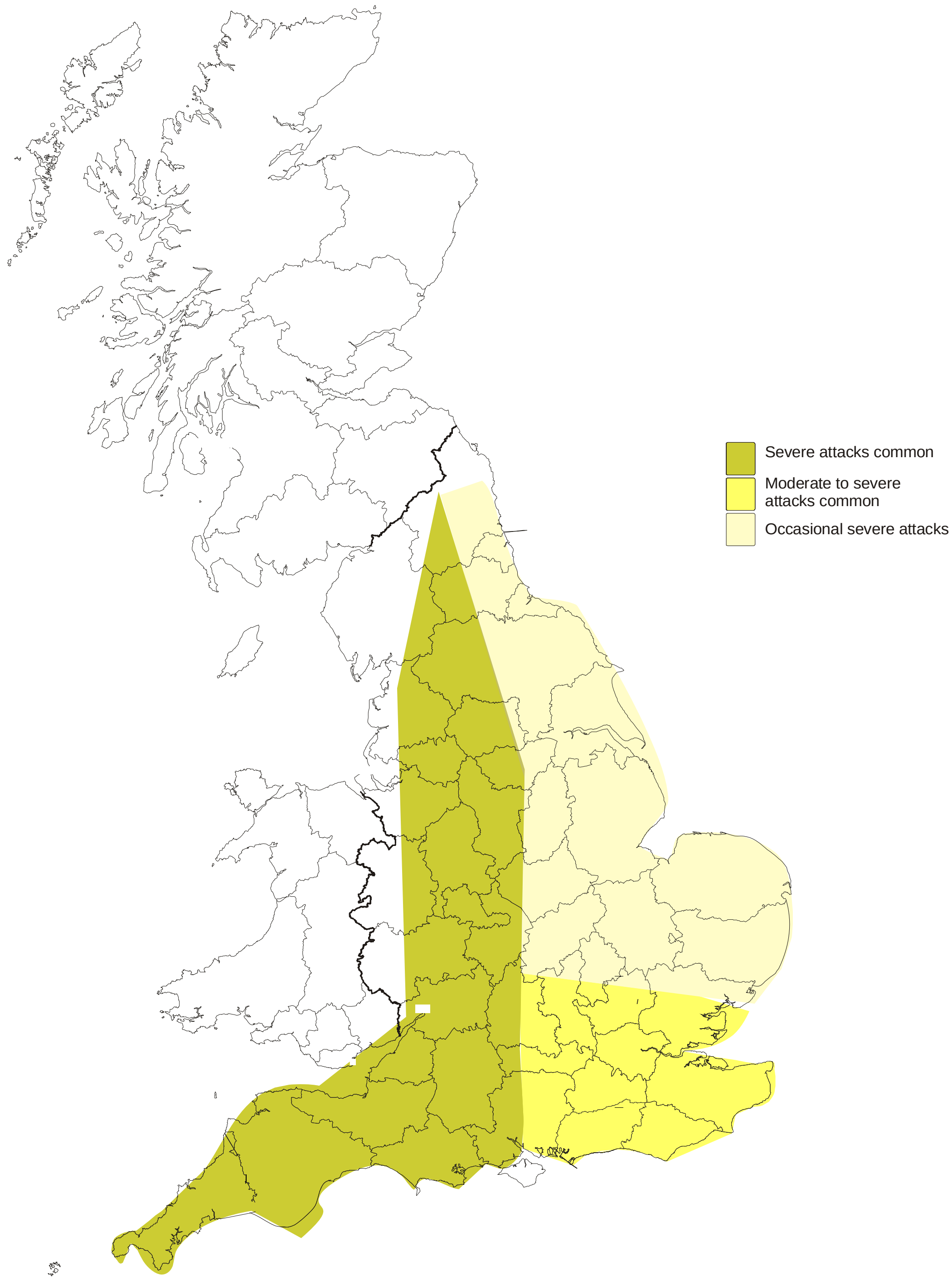

Figure 6. Sclerotinia severity in winter oilseed rape in England, 2007 (based on field reports, experimental sites and CropMonitor surveys).

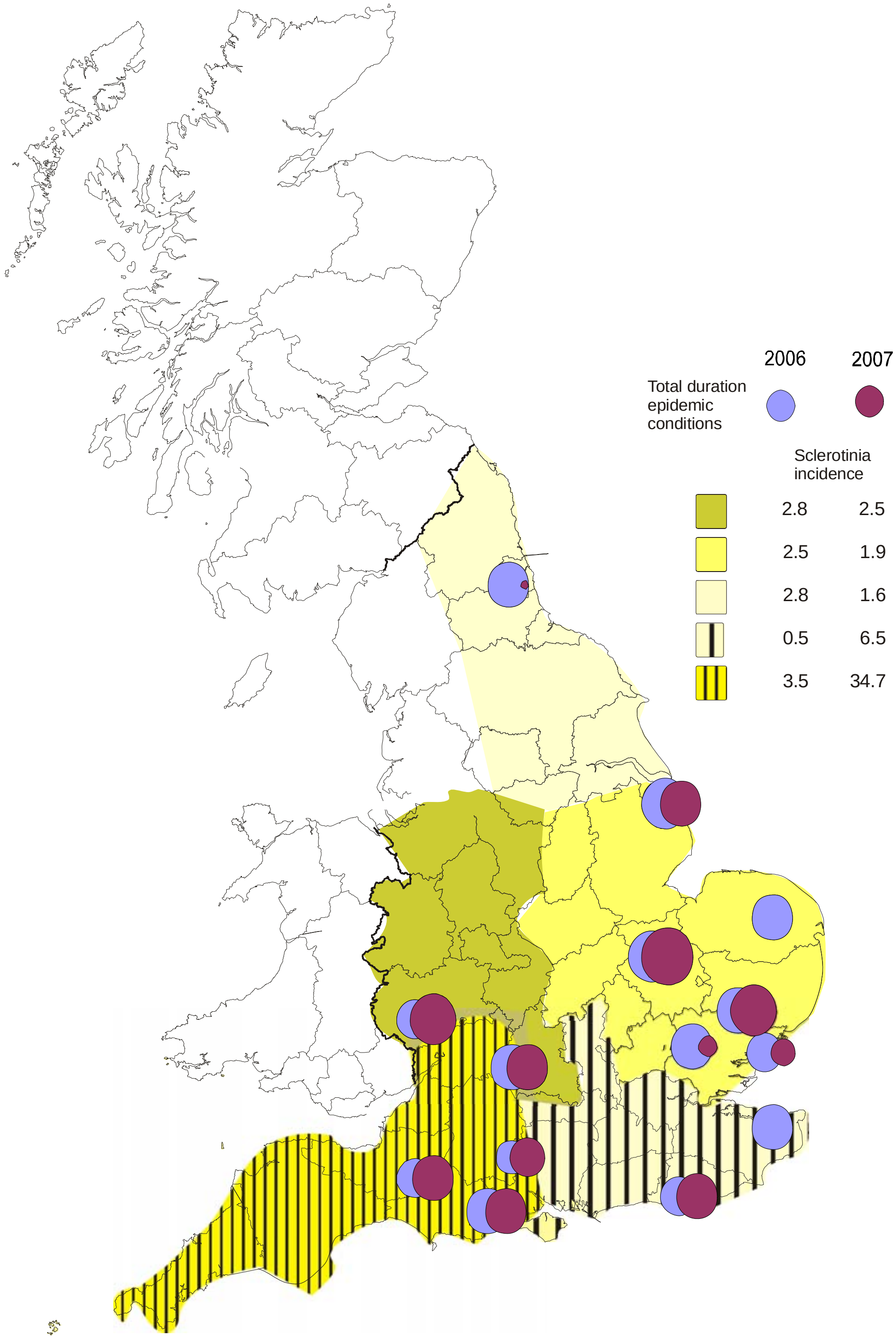

Figure 7. Regional sclerotinia incidence from CropMonitor and epidemic conditions in 2006 and 2007 (Size of blue and purple circles indicate duration of weather conditions favourable for sclerotinia infection at each Met. Station)

3.4 Sclerotinia incidence and inoculum 1991-2007

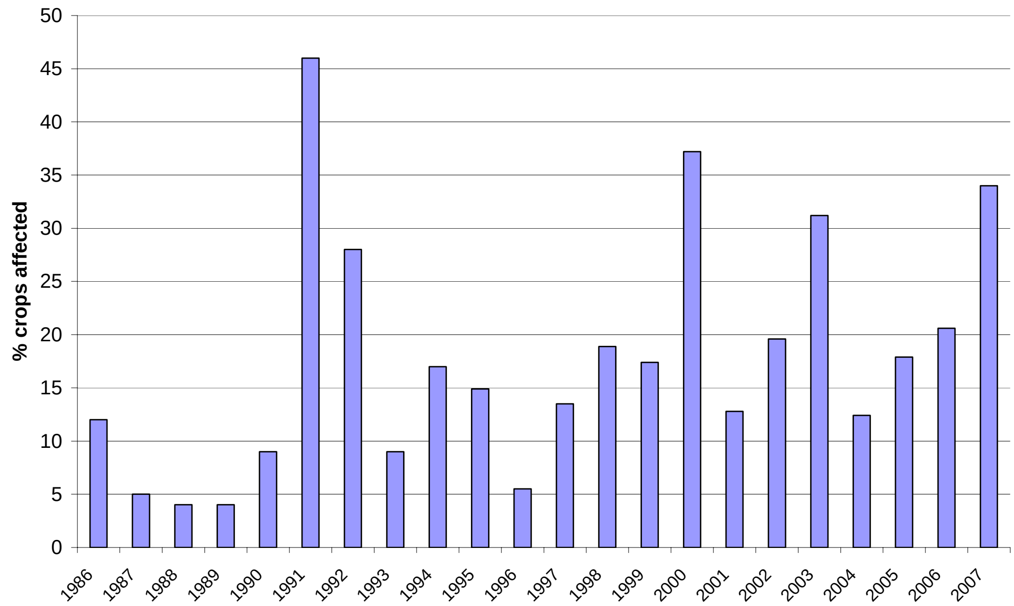

Figure 8. Mean percentage of crops with sclerotinia stem rot in Defra surveys of winter oilseed rape crops, 1986-2007.

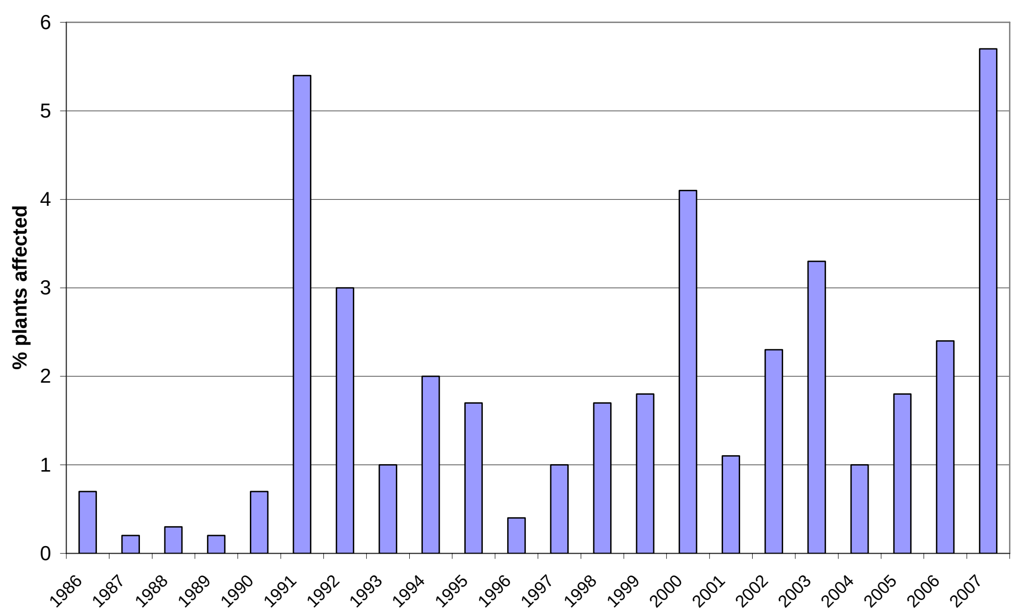

Figure 9. Mean percentage of plants with sclerotinia stem rot in Defra surveys of winter oilseed rape crops, 1986-2007.

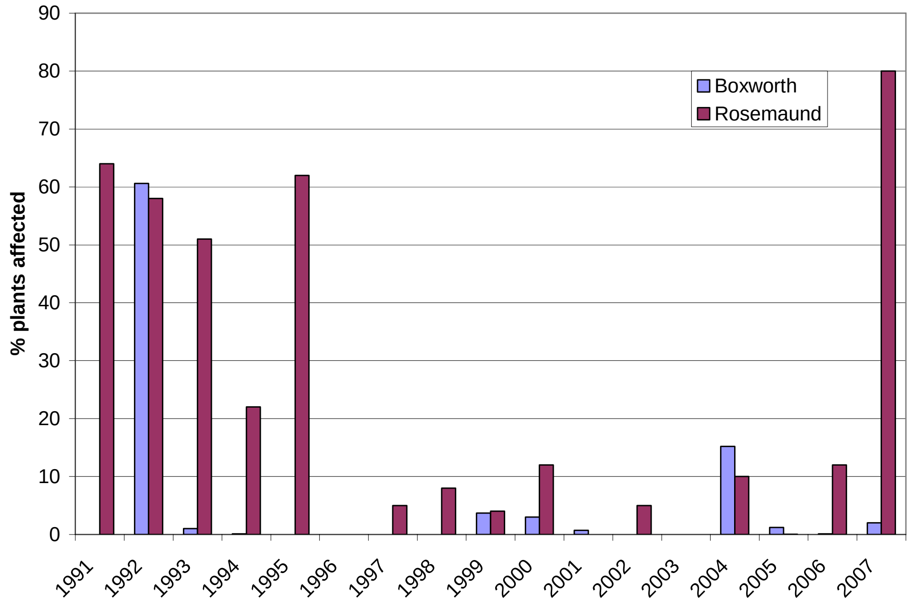

Figure 10. Mean percentage of plants with sclerotinia stem rot in winter oilseed rape crops at ADAS Boxworth and ADAS Rosemaund, 1991-2007.

Very severe attacks of stem rot have been recorded since 1991 at Rosemaund and since 1992 at Boxworth (Fig. 10). Prior to this, sclerotinia incidence had been low, though there was clearly a background level of inoculum that was sufficient to generate a severe infection. At Boxworth, there was some moderately severe infection in 2004 (15% plants affected) and in 2007 most crops had 2% sclerotinia, though 10% was recorded in some plots of cv. Castille. Winter oilseed rape was grown continuously between 1988 and 2002 on the field affected in 1992 but petal tests at Boxworth have indicated that inoculum levels have been low after 1992 apart from the continuous oilseed rape field in 1995 when 52.5% petals had sclerotinia at early flowering. Only low levels of sclerotinia inoculum have been evident at Boxworth subsequently. At Rosemaund, there have been very severe attacks (>50% plants affected) in 1991, 1992, 1993, 1995 and 2007. In addition, stem rot affected 10-22% plants in 1994, 2000, 2004 and 2006 at Rosemaund, indicating that both inoculum and weather conditions were favourable for infection. Petal tests at Rosemaund showed high petal infection in 1994 (70% at early flowering, 97.5% at mid flowering) and in 1995 (70% at early flowering, 52.5% at mid flowering). There was lower inoculum on petals in 1996 and 1997 (25-30% petals infected) and this was higher at early flowering than at mid-flowering.

There were six occasions when severe sclerotinia (>25% plants affected) developed at Rosemaund (5 years) or Boxworth (1992 only) (Fig. 10). The influence of weather factors on epidemic development was explored using comparisons between the six ‘high’ events with 28 ‘low’ events.

Weather data at Boxworth and Rosemaund 1991-2007

Monthly rainfall data for the period from April to June each year are presented in Table 9. There were large variations in rainfall each month during the period 1991-2007, though the overall monthly average at both Boxworth and Rosemaund was about 50 mm. Temperature data is not presented in detail but has been used to explore relationships with sclerotinia incidence.

Weather records have been analysed to identify the number of infection events (using the SkleroPro model criteria) and their duration during April to June each year from 1991 to 2007. The main flowering period varied in date of onset and duration. In recent years, flowering started in early April and continued for about six weeks. There was later flowering of crops in 1996 and 2006 and in these years, crops were considered to be at risk during May.

Table 9. Monthly rainfall April, May and June and total rainfall April-June at Boxworth and Rosemaund 1991-2007.

Year	Monthly rainfall (mm)							
	Boxworth				Rosemaund			
	April	May	June	Total	April	May	June	Total
1991	40.6	15.2	82.4	138.2	46.2	12.4	66.4	125
1992	39.2	50.8	26.0	116.0	37.2	64.6	18.8	120.6
1993	86.2	55.2	58.0	199.4	68.0	18.8	45.0	131.8
1994	71.8	51.5	23.8	147.1	50.4	57.0	5.0	112.4
1995	10.6	25.8	20.2	56.6	20.0	37.6	12.0	69.6
1996	11.6	18.6	27.8	58.0	36.6	34.6	24.4	95.6
1997	8.8	34.4	139.2	182.4	23.0	77.0	86.2	186.2
1998	94.4	22.8	115.6	232.8	126.0	25.2	104.6	255.8
1999	48.0	47.0	59.0	154.0	66.6	47.6	63.8	178.0
2000	105.4	81.2	19.4	206.0	117.8	20.6	0.6	139.0
2001	72.0	21.0	24.8	117.8	33.6	42.4	49.2	125.2
2002	34.0	46.8	1.8	82.6	35.6	89.8	24.4	149.8
2003	25.8	35.8	52.0	113.6	29.6	49.2	57.0	135.8
2004	71.8	56.8	30.4	159.0	97.0	51.4	43.2	191.6
2005	54.6	37.4	43.0	135.0	42.6	32.0	55.2	129.8
2006	15.4	97.6	12.4	125.4	25.8	97.0	20.8	143.6
2007	1.4	117	66.4	184.8	9.6	81.2	141.0	231.8
Average monthly rain	46.6	47.9	47.2		50.9	49.3	48.1	

Table 10. Number of potential infection events* at Boxworth and Rosemaund during April to June 1991-2007.

Year	Flowering period	Rosemaund April	Rosemaund May	Rosemaund June	Boxworth April	Boxworth May	Boxworth June
1991	Late April -May	2	1	3			3
1992	Late April -May		2	2	1	1	2
1993	midApril-midMay	4	1	3	1	2	1
1994	midApril-midMay		2	2		3	
1995	midApril-midMay	1		2			4
1996	May	5	1	1	1	4	
1997	April-midMay	2	1	4	2	2	4
1998	April-midMay	1	1	3	2	1	9
1999	April-midMay	3	2		2	1	1
2000	April-midMay		1	1	1	2	1
2001	midApril-midMay		1			1	2
2002	April-midMay		2	2		2	1
2003	midApril-midMay	1	3			2	2
2004	April-midMay	3	1	1	2	3	2
2005	April-midMay	1	1	1	2	3	4
2006	May	1	4		1	7	
2007	April-midMay	1	2		2	7	7

*Infection events defined as >23 hours, >7°C and 80%RH

Table 11. Dates of potential infection events* at Boxworth and Rosemaund during flowering in April and May 1991-2007.

Year	Flowering period	Rosemaund April	May	June	Boxworth April	May	June
1991	Late April -May	18 April	16 May	3			3
1992	Late April -May		28,31 May	2	30 April	29 May	2
1993	midApril-midMay	16,22 , 29 April		3	28 April	2	1
1994	midApril-midMay		5 May	2		6 May	
1995	midApril-midMay	24 April		2			4
1996	May		22 May	1		22, 23 , 26,28 May	
1997	April-midMay	25,30 April	15 May	4	25,26 April	15 May	4
1998	April-midMay	1 April	11 May	3	1, 21 April	11 May	9
1999	April-midMay	3,20, 25 April	6 May		3,20 April	1	1
2000	April-midMay			1	27 April	8 May	1
2001	midApril-midMay		13 May			13 May	2
2002	April-midMay		6, 12 May	2		8, 12 May	1
2003	midApril-midMay	24 April	16 May			16 May	2
2004	April-midMay	16, 27,29 April		1	27, 29 April	2, 7 May	2
2005	April-midMay	25 April		1	25, 29 April	3 May	4
2006	May		16,20 May,			6, 8, 12, 14 20, 21, 26 May	
2007	April-midMay	22 April	12, 16 May		22,26 April	2, 4, 12, 15 May	7

*Infection events defined as >23 hours, >7°C and 80%RH

At Boxworth in 1992, fungicides applied at about the mid-flowering stage on 15 May gave up to 99% control (Bowerman and Gladders, 1993). This very high efficacy suggested that all the infection had occurred soon after fungicide application. There was dry weather during 16-22 May and wet weather after this. The SkleroPro model identified infection conditions on 29 May, which has some credibility from the fungicide data. In 2004, there were four potential infection periods during 27 April - 7 May at Boxworth, enabling stem rot to develop even though petal inoculum was low. Similarly in 2007, there were potentially six infection opportunities, though perhaps the events on 12 and 15 May were the most important and resulted in more disease in later flowering crops. It is perhaps surprising that there was little stem rot in 2006 when there were apparently seven infection periods at Boxworth during flowering in May. The rainfall in May 2006 was very high (97.6 mm) and this can reduce disease risk if apothecia are flooded and petals are washed off the foliage.

A fungicide timing experiment at Rosemaund in 1992 indicated that a spray applied on the 18 May at the late flowering stage (GS 4,8) significantly reduced stem rot incidence on the main stem. Untreated plots showed 66% main stems affected on 16 June and 58% plants with lesions on main stems and 34% plants with lateral stem lesions (total 84% plants affected) on 14 July. A combination of 29 April (GS 4,7) and 18 May treatments gave slightly improved control (Sansford *et al*., 1996). SkleroPro identified infection conditions on 28 and 31 May, so mid May fungicide treatments would be expected to give good control. It is possible that late April fungicide persisted about 4 weeks and contributed to stem rot control. In 1993, at Rosemaund, sclerotinia control was rather variable, but trends suggested mid flowering sprays on 6 May gave some control, whilst late flowering sprays had little effect. SkleroPro suggested infection events might have taken place during 16 -29 April and this might well explain why fungicide effects from 6 May applications were weak.

At Rosemaund in 1994, sprays applied at mid-flowering on 6 May gave up to 96% control of moderate stem rot (untreated index = 17) (Spink, 1995). Infection may have started on 5 May and this could explain some of the variation in control between fungicides because they differed in their curative activity.

At Rosemaund in 2007, there were at least two phases of sclerotinia infection judged from fungicide performance. The first infection on 22 April was identified from SkleroPro, rainfall and petal sticking records and well controlled with fungicides applied about 11 April. The

SkleroPro model identified further favourable periods for infection on 12 and 16 May. Fungicide experiments showed lower percentage control of sclerotinia than in some previous work and this could be explained by product persistence being stretched when infection occurs more than 3-4 weeks after application. As at Boxworth, more stem rot might have been expected in 2006 though there were only infection periods and rainfall was also very high at 97 mm in May.

Statistical analyses (boxplots) showed that there were no significant differences between high and low disease sites for the number of infection hours during flowering, the average temperature, the number of days with rain, the total rainfall in April and May or the period from the first infection event to the end of flowering (Fig. 11). When the data were examined using stepwise regression, individually none of the variates were significant, but when two variates were used at a time, the number of rainy days and the time from the onset of the first epidemic condition (first 23 hr period) to the end of flowering did show a significant difference. However, the dataset is small (only six sites with high infection) and there was an outlier at Rosemaund for one of the duration periods, so these factors may not always make a significant contribution.

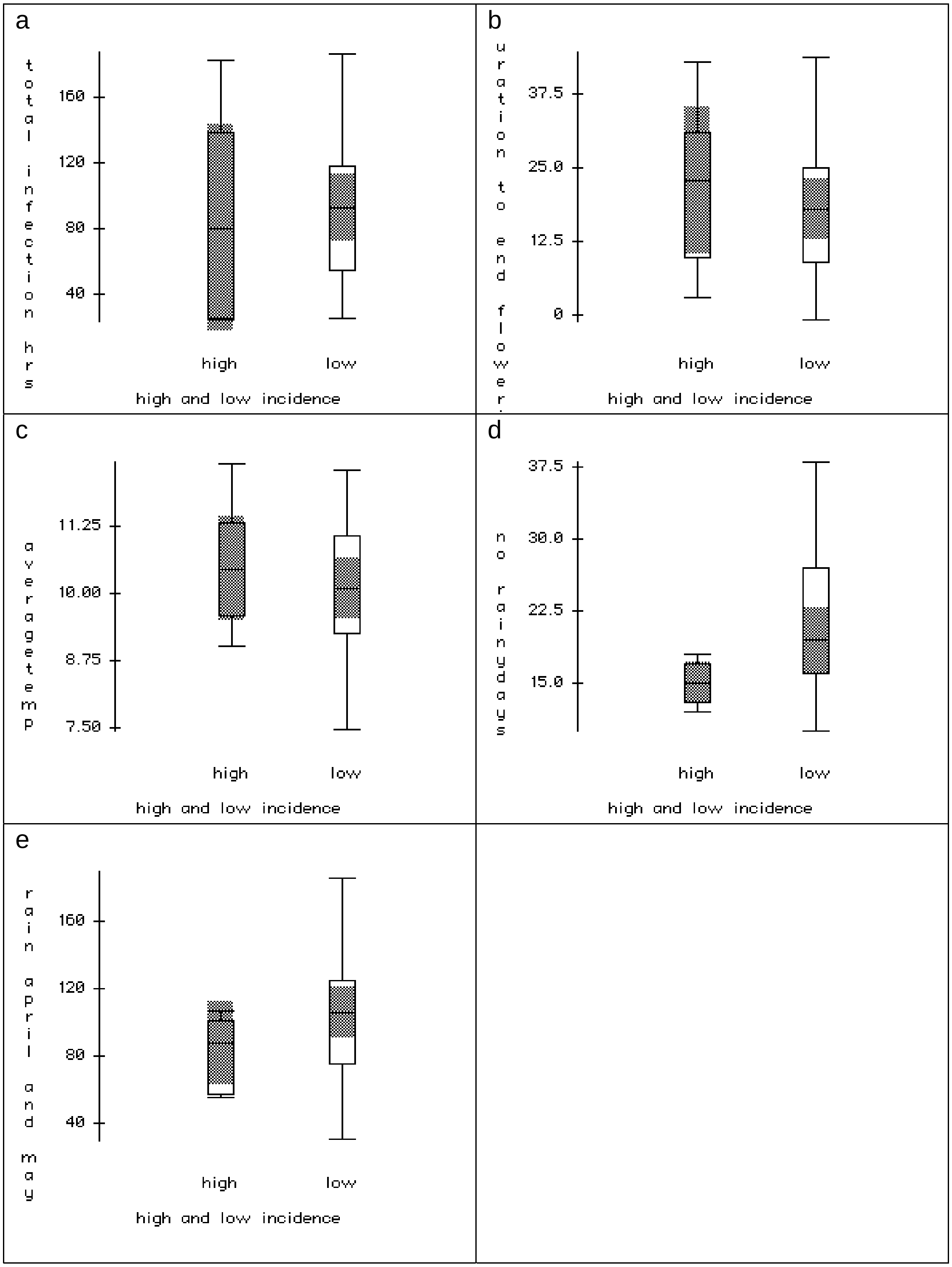

Figure 11. Differences between high (>25% plants) and low incidences of sclerotinia for a) total infection conditions in hours during flowering period, b) duration from onset of epidemic conditions to end of flowering, c) average temperature, d)number of rainy days and e) total rain (mm) in April and May.

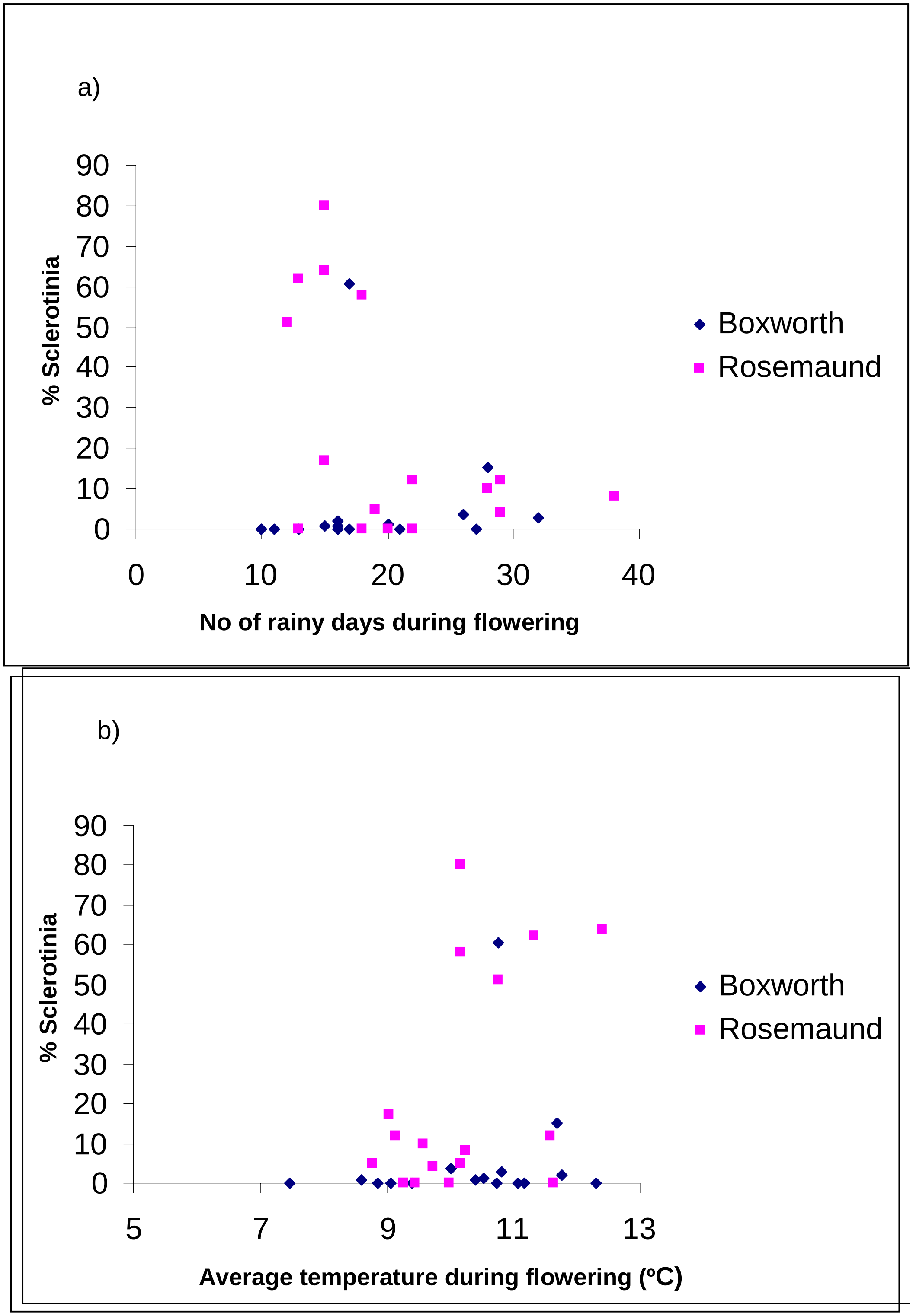

Figure 12. Relationships between the percentage plants with sclerotinia at Boxworth and Rosemaund during1991-2007 and a) the number of rainy days during flowering and b) average temperature during flowering.

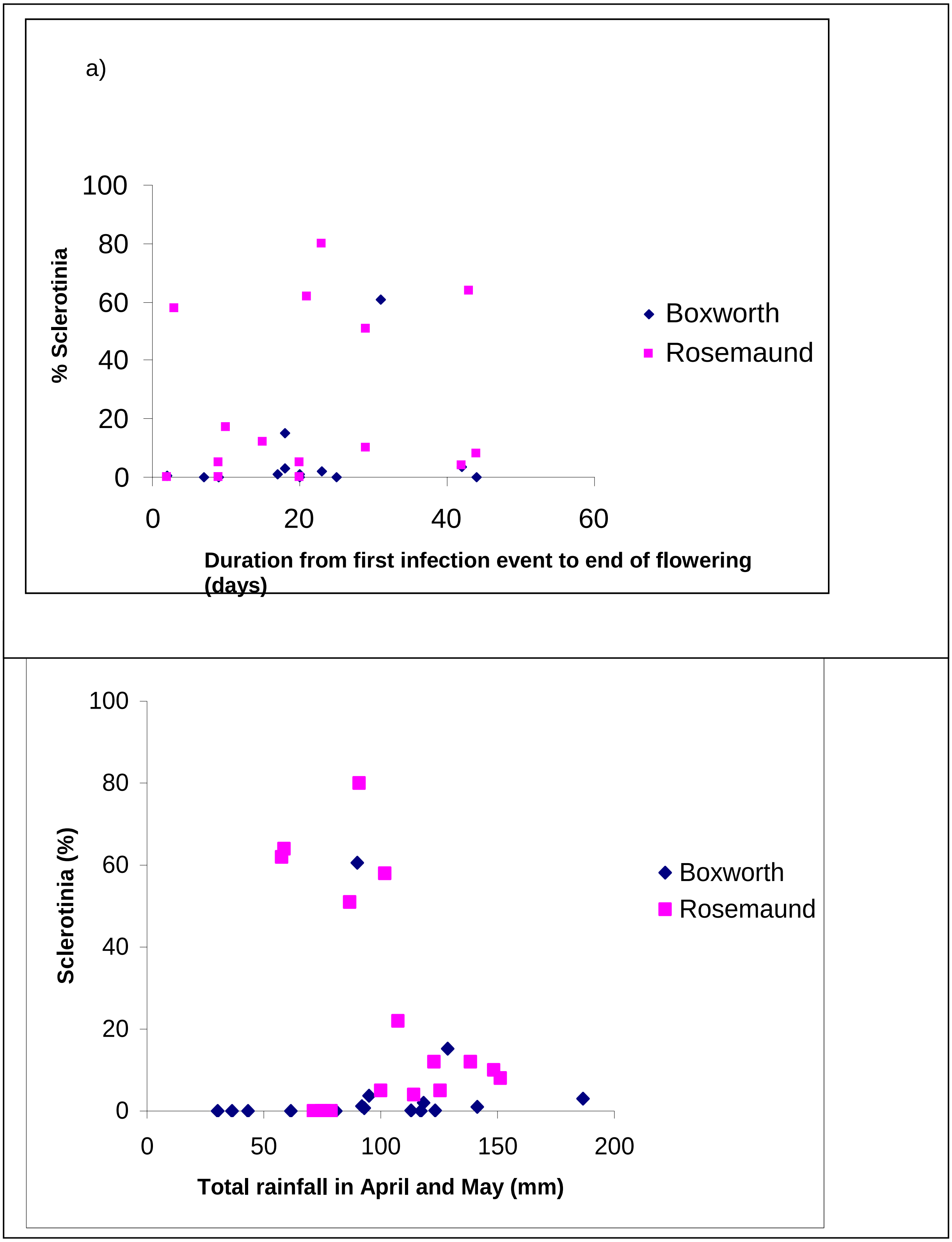

Figure 13. Relationships between the percentage plants with sclerotinia at Boxworth and Rosemaund during 1991-2007 and a) the duration of flowering after the first infection event (days) and b) total rainfall in April and May.

The scatterplots (Figs 12 & 13) gave indications that moderate rainfall was more favourable for sclerotinia than high rainfall. The severe epidemics occurred when there was 10-20 days with rain during flowering and 50-110 mm rain in April and May. The negative effects of high rainfall include washing off fallen petals and reductions in ascospore dispersal if apothecia are flooded. Higher temperatures during flowering in the range 10-13ºC appeared to be more conducive than lower temperatures. Sclerotinia activity is low at 7ºC and optimal at 16-22ºC (Koch *et al*., 2006) so these trends fit well with biological data. The influence of weather factors cannot be defined fully in the absence of data for inoculum. Inoculum levels were generally low at Boxworth and favourable weather would not have therefore produced stem rot disease.

Comparing two models of sclerotinia infection conditions.

There was little or no rain in Kent during April and early May in 2007, yet sclerotinia incidence was high in many crops prior to harvest. Heavy dews had been noticed during flowering, raising questions about infection occurring in the absence of rain when dew was present.

Kruit *et al*., (2004) presented a simple model of leaf wetness at 26th Conference on Agricultural and Forest Meteorology 2004. This combined times of hours above 87% relative humidity (r.h.) extended by those periods where r.h. increased by more than 3% per half hour period at r.h. above 70%. As data from the weather stations used in this study were collected in one hour periods, the threshold was extended by periods where r.h. increased by >6% per hour. The results from the leaf wetness model and the SkleroPro model were similar (within 10%) at many sites (Table 12). However, there were some sites where only the leaf wetness model gave positive values (eg Bracknell 2006, Coltishall 2007, Manston 2007 and Newcastle 2007) or much higher duration periods (eg Wattisham 2006, Walton 2007). There were no infection conditions identified by either model at Bracknell in 2007, yet there appear to have been infected crops in the area.

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Table 12. Comparison of SkleroPro infection model with a leaf wetness model.

Met station	Duration of leaf wetness or infection conditions during flowering (hours)			
	2006		2007	
	SkleroPro model	Leaf wetness model	SkleroPro model	Leaf wetness model
Andrewsfield	397	392	115	107
Bracknell	0	70	0	0
Brize Norton	400	376	312	276
Coltishall	299	263	0	260
Donna Nook	340	320	341	322
Herstmonceaux	242	279	335	302
Hurn	258	401	315	304
Manston	274	222	0	181
Middle Wallop	143	138	256	199
Newcastle	238	225	0	99
Walton	197	278	149	291
Wattisham	282	392	357	368
Yeovilton	243	320	341	332
Total	3313	3676	2521	3041

3.5 Decision guide

The Sclerotinia Decision Guide has been revised and is available on the HGCA website. More farms will now be considered ‘high risk’ after the 2007 epidemic and more detailed information from petal tests and depots should be sought. The higher risk and higher value of rapeseed make it easier to justify a two-spray programme during flowering. Currently recommended fungicide products are listed and links provided to CropMonitor and the HGCA Fungicide Performance data.

4. Discussion

The 2007 season was very favourable for the production and dispersal of air-borne ascospores of *S. sclerotiorum*. This was confirmed by petal tests from early flowering onwards and supported by field reports of unusually high disease for the first time in some areas and apparent spread between fields. Inoculum levels were higher in the south, east and west in 2007 than in 2006. The dry weather did check the germination of sclerotia in the spring at some monitoring sites, but activity was not completely arrested. As growth of wheat was also affected by the dry spring, it is possible that more ascospores were dispersed from fields in wheat than usual because of smaller wheat crop canopies.

Some advisers underestimated sclerotinia activity in the spring and decided not to use fungicides at flowering because they considered that the risk was low. Petal tests in 2007 were used to influence decisions on a few sites. A wider established network of petal tests could help overcome similar problems in future. In France, the establishment of networks for petal testing have been proposed as testing large numbers of individual fields will not be practical (Taverne *et al*., 2003).

The flowering period in 2007 was longer than in 2006 so the number of days available for infection was higher. In 2007, infection periods were recorded about 22 April in some areas and followed by further infection periods in mid-May. The latter were more important for most crops, and appear to explain why later flowering varieties tended to show more sclerotinia. This infection at the end of flowering occurred about four weeks after fungicide treatments were applied at early flowering (10-15 April 2007) and this had stretched the protectant activity of fungicides. Under high disease pressure, treated crops may still have had 10% or more sclerotinia where fungicides had given 70-80% control. There have been no reports of fungicide resistance problems with sclerotinia in the UK, but MBC resistance has been found quite widely in France (Penaud *et al*., 2003). Whilst the situation is assisted by the availability of fungicides with different modes of action, further monitoring is required to ensure resistant strains are not present so that only effective fungicides are used.

It is perhaps less obvious why there was not more sclerotinia in 2006. There were numerous infection periods in May 2006, particularly at Boxworth where there were seven events. There were longer infection conditions during flowering using SkleroPro models in

2006 than in 2007 even though flowering was of shorter duration in 2006. It has not been possible to show that dew formation was a significant factor in 2006 or 2007. Previous Defra projects indicated that few petals stuck when dew formed compared with favourable rainfall events. When both petals and leaves are wet, surface tension forces give strong petal sticking and the best prospects for plant infection (ADAS unpublished data). Temperatures were only slightly lower in 2006 than in 2007 at most sites so negative effects of rainfall and lower inoculum appear to be the main factors. Given negative effects of rainfall in 2007, better understanding of the effects of the quantity and rate of rainfall would be useful. At present heavy thunderstorms might be regarded as negative though these are likely to be difficult incorporate into a decision guide because they are localised.

Previous research in England indicated that inoculum of *S. sclerotiorum* was often limiting to disease development in winter oilseed rape crops (Davies *et al*., 1999). This is in contrast to some other areas in Europe where a high proportion of crops may be at risk. However, even in stem rot prone areas there are large annual variations in disease risk (Koch *et al*., 2006). This situation may be changing in the UK as more oilseed rape crops have been grown and shorter rotations are used. The south-west has shown higher stem rot infection than other regions in previous years and 2007 problems may be due to inoculum produced in 2005. The consequences of the 2007 epidemic may be greater production of ascospore inoculum levels for several years.

SkleroPro is a forecasting model for sclerotinia stem rot that has been validated against historic data in Germany. (Koch *et al*., 2006). In the UK, it appears to be useful for identifying infection periods in the UK. Hourly temperature and relative humidity data are required to identify risk periods. Unfortunately, fungicides have little curative activity and should be applied **before** a risk period has occurred. The usefulness of the SkleroPro model for guiding decision making will therefore depend on how reliably periods of high humidity can be forecast. Currently, spray applications for stem rot control should take into account forecast rainfall so treatment is made before petals are likely to stick to the foliage.

The sclerotinia depots identified general progress of sclerotial germination in relation to flowering. Often germination is protracted and not well synchronised with flowering. In Scotland, however, sclerotia germination coincided with the start of flowering in both seasons. The depots do not indicate the level of inoculum in individual crops and petal testing is therefore a more valuable aid to decision making. The development of rapid molecular tests to quantify inoculum in crops would be a valuable tool to improve decision-making. Such tests could be field based and give a reading above or below a threshold or be processed in a laboratory with perhaps 48 hour turn around.

An unusual feature of 2006 in Scotland and 2007 in England was the late development of stem rot during June, suggesting that there may have been survival of inoculum and plant infection at or after the end of flowering possibly via senescing leaves. The SkleroPro model identified infection periods in mid-May suggesting that infection probably took place at the late flowering stage. The stem symptoms would have appeared in early June and this would be consistent with low disease incidence at some sites in late May. Fungicides applied at early flowering can give good control of this late infection, but protection of the leaves as well as the petals may have been compromised by weather conditions at spraying and also by water volumes used. The benefits of a second fungicide spray at the late flowering stage were not determined, but this approach was adopted by growers in Scotland in 2007 at sites where flowering period was prolonged, and wet weather at late flower was conducive to infection. There may be situations where late infection occurs through leaves but the yield loss should be smaller than from flowering infection and best practice would be to use fungicides at early to mid-flowering to prolong green leaf. There should now be greater awareness of the risk of late flowering infection and multiple infection events.

Forecasting stem rot risk remains a challenge. An integrated approach is required which includes crop rotation, forecasts based on weather, petal tests and monitored crops and sclerotial depots. Treatment options include use of two fungicide applications to protect the crop throughout flowering , plus the use of soil treatments such as fungal biological control agent *Coniothyrium minitans* (as Contans) to kill sclerotia (Trutmann *et al*., 1980). Other biological control agents may also merit further investigation (Savchuk and Fernando, 2003). This approach will help growers and advisers identify where fungicides are required, including situations where more than one treatment is required in high risk situations.

5. Recommendations for future research

1. Methods to quantify inoculum need to be improved and used more widely. Rapid diagnostic tests could be used as an in-field test when appropriate thresholds are defined

and/or be processed in a laboratory within 48 hours. Existing agar based tests are still valuable but take about 10 days to give a final result. They could still be used more widely.

2. Sclerotinia infection events may be predictable using forecast weather. This should be investigated using SkleroPro models and models from other crops. Further testing of SkleroPro should be undertaken at sites where inoculum can be quantified.

3. Modelling of sclerotinia epidemiology should be extended and involve its major host crops and international collaboration. In the UK, datasets are available to extend work on predicting apothecial production that has been done on lettuce.

4. Variation in *S. sclerotiorum* should be investigated further so that potentially dominant types can be identified, characterised and managed. Fungicide sensitivity data should be collated annually to ensure that only effective fungicides are used.

5. Control strategies that decrease reliance on fungicides should be developed. These could include breeding for resistance or tolerance, biological control and soil treatments.

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