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Forecasting sclerotinia infection in UK oilseed rape

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Abstract: *Sclerotinia* stem rot in oilseed rape occurs every year in the UK but incidence varies by region and year, with occasional epidemics that are hard to predict. Control relies on protectant foliar fungicides ahead of any infection, but it is currently difficult to determine the optimum timing of sprays. The aims of this work were to provide forecasting alerts and reports of risk factors for sclerotinia infection to growers during the oilseed rape flowering phase, and demonstrate that the alerts and risk factors helped to improve predictions of sclerotinia disease.

Weather-based alerts were published three times a week for growers (https://cereals.ahdb.org.uk/) 2015-2017, for 15 sites/year, based on 48 hr forecast weather data, crop stage and % petals testing positive for sclerotinia. A Burkard trap was deployed at five of these sites to detect airborne spores, and at three of these sites there was a fungicide timing field experiment. Forecast weather data was used to guide fungicide spray timings, for comparison with sprays at yellow-bud, early-, mid- or late-flower. The number of weather based alerts during flowering from 2015-17 varied from zero to three, with the most alerts in the SW and S area. The main difference across the years was the occurrence of alerts in 2017 in E and NE east areas, whereas in 2015 and 2016 these regions were drier and had few alerts.

For analysis of the benefits of risk forecasting, data from fungicide timing experiments in 2015-2017 was combined with data from similar experiments in 2010-2012, to give a total of 23 site-years. Zero weather-based alerts were a correct predictor of no- or low-infection (≤ 1% stem rot incidence). But where there were weather-based alerts (at 15 sites), about half of these sites (7) also had an infection incidence of ≤ 1%. Including the results of sclerotinia inoculum on petals with analysis of weather alerts helped to improve the predictions of infection, by correctly identifying the very-low risk sites. The relationship between % of petals testing positive and untreated disease incidence varied with timing of sample (e. g. R^2 = 0.54 for petals sampled at yellow-bud), but when combined with weather-based alerts, petal data improved the accuracy of the risk forecast. In summary, when inoculum was zero, infection risk was zero. Positive inoculum indicated risk, but infection was variable. Spore trap results helped explain where infection did or did not occur, by showing the variation during flowering of daily levels of spores in air samples for each site.

Key words: *Sclerotinia*, oilseed rape, disease forecasting, integrated control

Introduction

Sclerotinia stem rot in oilseed rape occurs every year in the UK, at generally low levels but with occasional major outbreaks which are difficult to predict. Infection occurs mainly during the flowering phase, via petals (Young & Werner, 2012). The long-term mean UK sclerotinia incidence from 2006-2015 was 14% crops and 2% stems affected, based on fungicide treated crops (www.CropMonitor). In the past two years, incidence has declined to 8% crops and 1% stems affected in 2016 and 2017, respectively. But the use of fungicides targeted at sclerotinia has remained at similar levels each year since 2011, with 95% or more of the UK oilseed crop area treated three times with fungicides (Pesticide Usage Statistics, https://secure.fera.defra.gov.uk/pusstats), and with over 50% of fungicide applications timed during flowering (Garthwaite *et al.*, 2016) and targeted mainly at sclerotinia control. However, high disease pressure has occurred in recent years in some regions, as seen in untreated trial plots, e. g. 43% incidence in 2017 (Gosling & Ritchie, 2018). Therefore, infection risk can be high and the use of protectant fungicides is justified in some cases, but not all. The aims of this work were to analyse the use of weather-based forecasting alerts and infection-risk factors for sclerotinia, to provide improved guidance to growers as to the need for fungicide treatment, and if needed, the optimum time to apply.

Material and methods

Sclerotinia infection risk factors were recorded during flowering from sites across England and Scotland in 2015-17, as follows. For 15 sites in total per year, 48 hr forecast hourly weather data (air temperature, relative humidity and rain) was purchased from the UK MetOffice (www.metoffice.gov.uk), and crop growth stage and % petals testing positive for sclerotinia (agar plate test) were recorded at intervals during flowering. At three of the 15 sites, field experiments were set up to test control from fungicides applied once, timed according to weather-based alerts, or growth stage: yellow-bud, early-flower, mid-flower or late-flower. At five of the 15 sites, air-sampler traps to detect airborne spores were deployed.

The forecast weather data was used to calculate if and when infection alerts were predicted. Results were updated three times a week by e-mail to each site during flowering. Alerts were based on conditions conducive to infection by sclerotinia, which were: temperatures ≥ 7 °C and RH ≥ 80% for ≥ 23 consecutive hours (based on Koch *et al.*, 2007). Burkard spore traps, located within each field trial, were run continuously from prior to flowering to after end of flower. The Burkard drums were changed weekly and tested by qPCR (Rogers *et al.*, 2009), to give daily amounts of sclerotinia DNA. Petals were sampled just before each fungicide timing, and tested on agar plates (Young *et al.*, 2014). For analysis of the benefits of risk forecasting, data from fungicide timing experiments in 2015-2017 was combined with data from similar experiments in 2010-2012, to give a total of 23 site-years. Sites were allocated into categories of stem incidence > 1%, or ≤ 1%, and these categories were subdivided into the number of sites with both a weather-based alert and positive petals, or sites which experienced neither of these factors, or one factor only.

Results and discussion

Pattern of weather based infection alerts

The number of forecast weather based alerts during flowering from 2015-17 varied from zero to three at individual sites (Figure 1), but with many more occurring outside of flowering, mostly afterwards with increasing temperatures, particularly at night time. In practice, this means there are relatively few occasions during flowering where weather conditions are conducive to infection, and depending in the year, a fungicide application could be timed in response to the first infection alert during flowering. In the UK, flowering onset and duration can vary widely within regions, and between fields and varieties, and it is important to monitor crop flowering progress locally to help with assessing sclerotinia infection risk. In 2015 and 2016, the alerts occurred in the south and south west regions, which is the most commonly seen distribution, with eastern crops generally assumed to be at less risk. However, in 2017 there were more alerts in the east and north east regions, where the limiting factor is usually lower humidity, but in these years there was higher than normal eastern rainfall and coastal mists and consequent higher humidity.

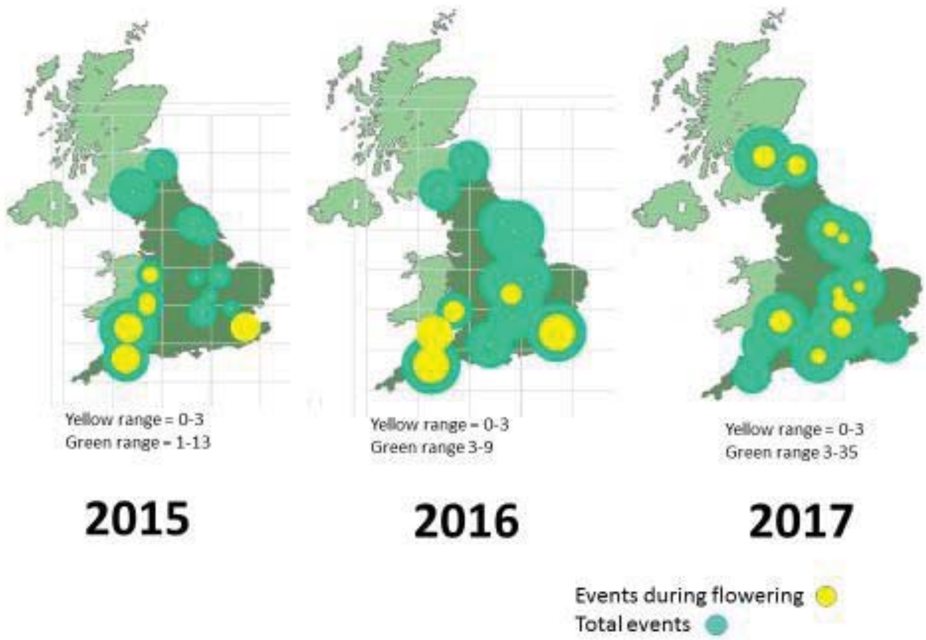

Figure 1. Number of weather-based sclerotinia infection alerts in England and Scotland during oilseed rape flowering (inner circles) and cropping season (outer circles), 2015-17.

Sclerotinia inoculum

Spore trap results helped explain where infection did or did not occur, by showing details of daily levels of spores in air samples varying during flowering for each site. For example, in 2016 (Figure 2) there were peaks of airborne spore numbers during mid-flower for the Devon site in the south west, and during late-flower in particular for the Herefordshire site in the west midlands. The timing of spore peaks coincided with some of the weather-based alert occurrences and helped explain final disease incidence. For example, at the Herefordshire site in 2016 there were spore peaks of 380 spores/m^3 of air on 19 April during the early-mid flower growth stage (Figure 2), a key infection risk phase, which led to 5% incidence on main stems in untreated plots. The Herefordshire site also had a high late-flower peak of over 1400 ascospores per m^3 of air on 8th May 2016 (Figure 2) which very likely explained the incidence of 3% Sclerotinia stem rot on lateral branches in untreated plots at the same site. By contrast, there were low levels of spores during flowering at the Lincolnshire site in the east. There was high spore production after flowering had ended at the Lincolnshire site (Figure 2, 2784 spores/m^3 of air, but this did not pose an infection risk, as evidenced by lack of sclerotinia disease development in the crop.

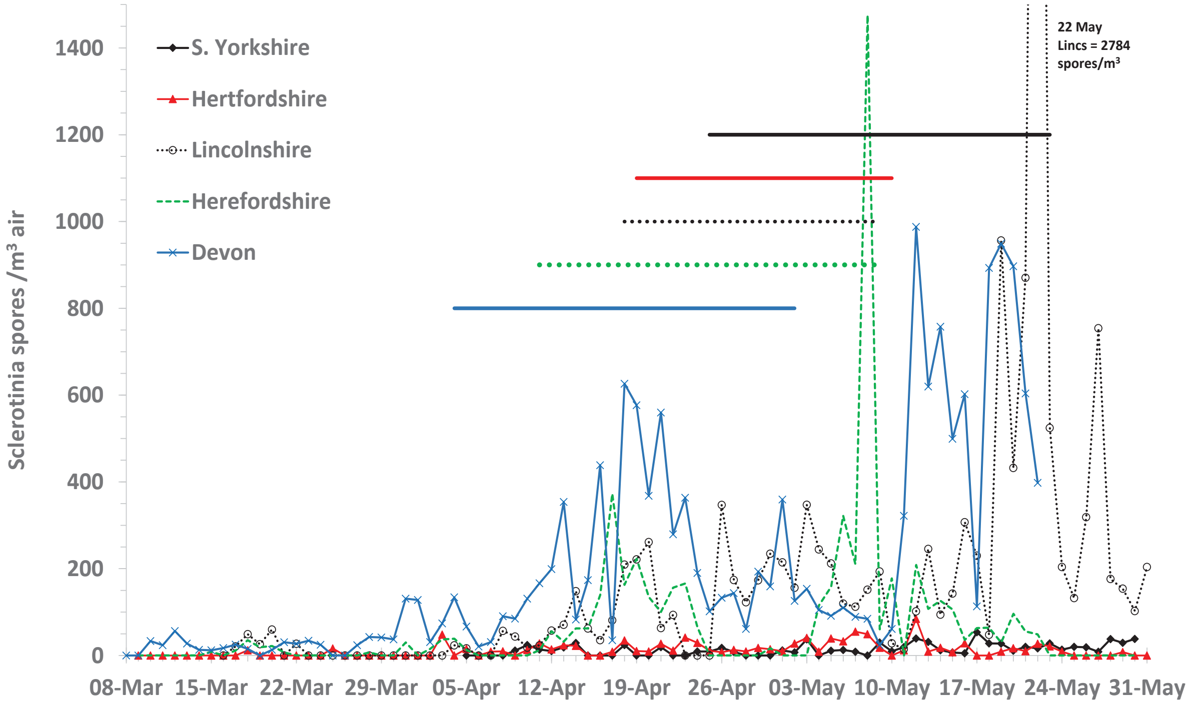

Figure 2. Sclerotinia ascospore inoculum in UK oilseed rape field trials 2017.

The relationship between % of petals testing positive and untreated disease incidence varied with timing of sample, with the best results seen from the earliest sample time at yellow-bud (R^2 = 0.54, Figure 3). Petal testing has been used to help evaluate sclerotinia infection risk with some promising results (e. g. Turkington *et al.*, 1991; Becka *et al.*, 2016) and developments with molecular tests have speeded up test-result availability such that results could be obtained in time to make spray decisions (e. g. Ziesman *et al.*, 2016). However, petal results alone, even if tests are quick, are unlikely to be good predictors of infection levels unless interpreted alongside weather conditions. The results from agar plate tests in the current work show that zero-petal infection is a good predictor of very low infection. However, if petals test positive, the relationship between % petals positive and final stem rot incidence is variable. A quicker test for sclerotinia in-field would be useful (e. g. Almquist *et al.*, 2015), but further work is needed to develop a cost-effective test, ideally for use in-field.

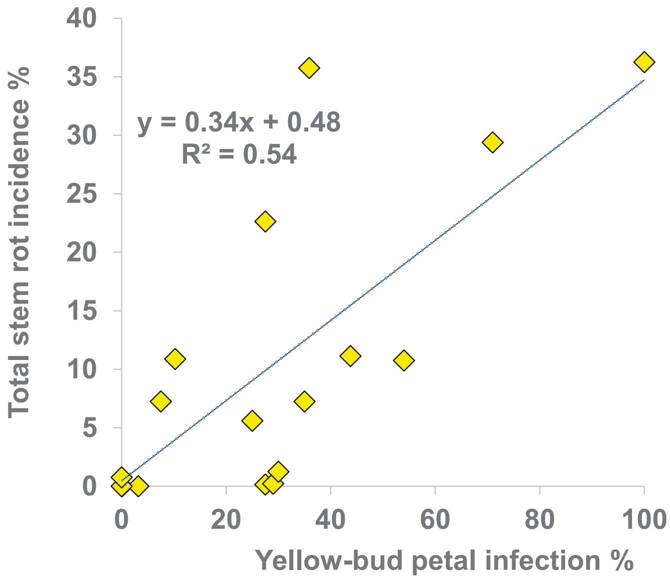

Figure 3. Percentage of oilseed rape petals sampled at yellow-bud stage testing positive for sclerotinia, and % incidence stem rot pre-harvest, UK field experiments 2010-2017.

Evaluation of predictions, based on weather and inoculum

Allocating sites to categories according to sclerotinia infection and risk factors showed the number of cases of false negatives and true positives. It is particularly important for disease forecasting schemes to minimise false negative predictions, i. e. where disease is not forecast and no treatment is advised, but disease occurs. It is also important to minimise the occurrence of situations with false positives, where the forecast indicates high risk, and treatment is applied but in hindsight was not justified. In the current work, minimising the occurrence of false negative situations was achieved by setting a requirement for sites to experience both a weather based alert and a positive petal test result with a threshold of ≥ 5% with sclerotinia. Sites experiencing both factors were correctly predicted to be at risk, i. e. they had subsequent disease (Table 1; 13 sites with sclerotinia stem rot > 1%). Sites expeiencing only one of the factors, or neither, had zero stem rot (Table 1; zero sites with sclerotinia stem rot > 1%) or very low stem rot (Table 1; 10 sites with stem rot ≤ 1%). By contrast, there were no false positives using these criteria (Table 1: zero sites with sclerotinia stem rot ≤ 1%). Therefore, combining the results of agar plate petal tests with the occurrence of weather-based alerts helped to improve the predictions of infection, by correctly identifying the very-low risk sites which would in hindsight not normally justify a fungicide treatment.

Table 1. Evaluation of predictions of sclerotinia stem rot occurrence in UK oilseed rape field experiments 2010-2017 (23 sites).

	NUMBER OF SITES	
	Sclerotinia stem rot incidence > 1%	**Sclerotinia stem rot incidence ≤ 1%**
Weather alert* AND ≥ 5% petals positive**	**13**	**0**
Weather alert OR petals positive OR neither	**0**	**10**

*Weather alert based on infection criteria in Koch *et al.*, 2007.
**40 petals tested by agar plating; positive result threshold = ≥ 5% with sclerotinia.

In summary, (a) when there were no weather based alerts, or inoculum was zero, infection risk was zero, and (b) the occurrence of weather-based alerts and positive inoculum correctly predicted infection, but the infection levels were variable. Spore trap results helped explain where infection did or did not occur, by showing daily levels of spores in air samples varying during flowering for each site. Sclerotinia forecasting schemes based on weather, crop stage and agronomic factors, but not including inoculum measurements, can be reliable if it is established that inoculum is always present and therefore not limiting (Koch *et al.*, 2007). The current study has shown that there is great variability in the presence of sclerotinia inoculum in the UK, which most likely explains why inclusion of inoculum detection in weather-based infection models helps to improve the accuracy of sclerotinia infection predictions. The challenge now is to improve the forecasting to discriminate between sites which have high infection, and those which have low infection which will not justify a fungicide treatment.

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