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Provision of oilseed rape decision support systems to the UK arable industry (phoma and light leaf spot forecasts)

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This is the final report of a 44-month project (21510016) that started in August 2017 and transferred to Rothamsted Research in November 2018. The work was originally funded by AHDB for £9,827 and was granted an eight-month extension at an additional cost of £2,990.

CONTENTS

1. Abstract

This project provided decision support system (DSS) tools to inform control strategies for two key diseases of oilseed rape (OSR) – phoma leaf spot (PLS) and light leaf spot (LLS).

PLS is initiated by airborne ascospores in the autumn, with considerable variation in timing (by region and year). The PLS forecast provides an indication of regional disease onset. It predicts a key date – when 10% of the plants are infected (an economic spray threshold), based on mean summer daily maximum temperature and cumulative rainfall (15 July–26 September).

LLS is also initiated by airborne ascospores, which are present from the start of crop emergence. However, it is sporadic and, due to a long symptomless phase of initial infection, the disease can remain unnoticed and go on to cause significant yield losses. The LLS forecast predicts the relative regional severity of the disease, based on the amount of disease the previous season, mean summer temperature and mean autumn rainfall (with historic rainfall data used for the preliminary autumn forecast and actual winter rainfall data for the final spring forecast). It predicts the proportion of OSR crops (with a disease resistance rating of 5) that will have more than 25% disease incidence in the spring. Separately, a crop-specific model indicates the effect of varietal resistance, sowing date and autumn fungicide applications on LLS severity.

The main objective was to maintain and update the tools in the autumn (October) of each year and revise the LLS forecast in the spring of the following year. A second objective was to promote the uptake and use of the DSS tools through Knowledge Transfer (KT) activities.

The forecasts were made each year and promoted on the AHDB website and through a variety of KT activities. There were occasional delays, due to numerous factors, such as difficulty in obtaining meteorological data, disease data or software issues.

Such forecasts improve understanding of field-level risks, focus monitoring efforts and inform spray decisions. The forecasts encourage applications only when necessary, as part of integrated pest management (IPM). This improves disease control and farm profitability, in addition to increasing the durability of varietal resistance and protecting the effective lifespan of fungicides.

2. Introduction

The project was originally planned and started by Dr Neal Evans of Cropsave Ltd and was migrated to Rothamsted Research in November 2018. The project was a continuation of a service to provide DSS tools to AHDB to advise control strategies for two key diseases of oilseed rape (OSR); Phoma leaf spot (PLS; ahdb.org.uk/phoma) and Light leaf spot (LLS; ahdb.org.uk/lightleafspot) (Figure 1).

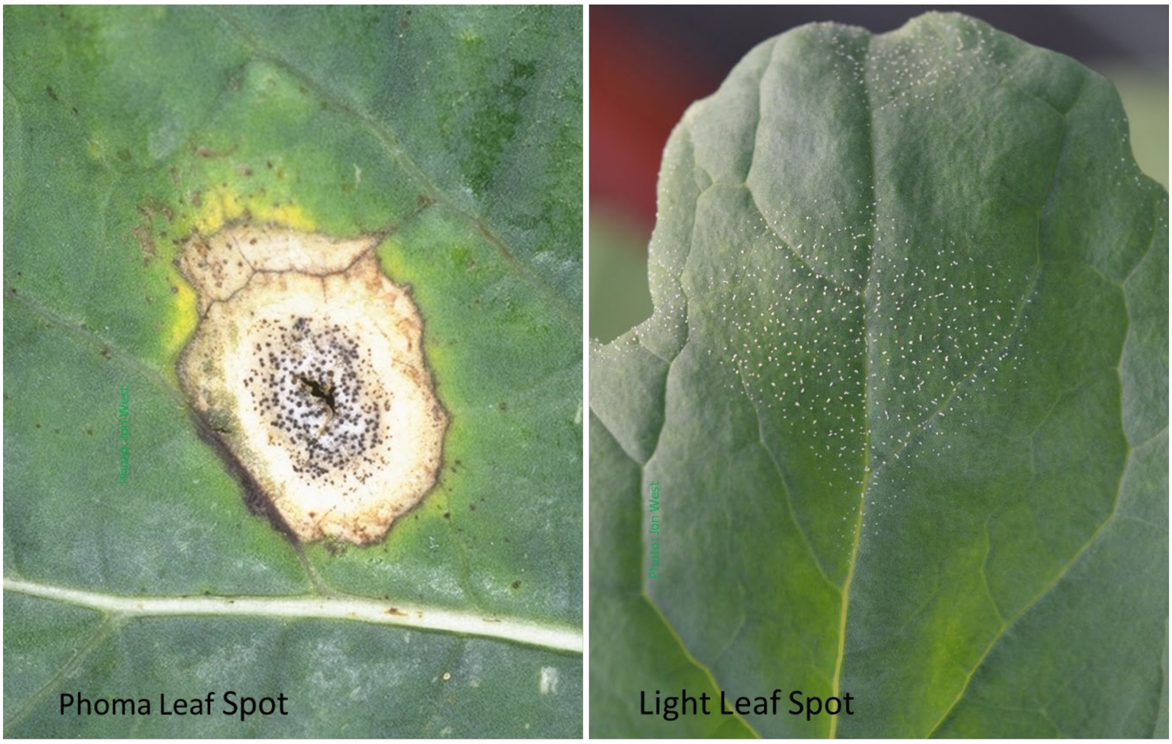

Figure 1. Typical symptoms of Phoma Leaf Spot (PLS) and Light Leaf Spot (LLS)

Phoma leaf spot, caused by *Leptosphaeria maculans* and *L. biglobosa* (two species referred to in literature before 2002 as A & B-group or Tox^0 & Tox^+ *L. maculans*; Shoemaker & Brun, 2001) begins in the autumn from infections caused by airborne ascospores to produce Phoma leaf spots. Early infection leads to severe stem cankers and yield loss at harvest, while late infections are not as important (West et al, 2001). There is often uncertainty as to when to treat due to annual variation in the timing of the initial ascospores as a result of the previous season's disease severity and summer weather. LLS is caused by *Pyrenopeziza brassicae*, which releases ascospores in April-May and again during wet periods in the summer and first half of the autumn in UK conditions (McCartney & Lacey, 1990; Evans et al. 2018). These cause infections on leaves and pods, that are initially very cryptic with visible symptoms appearing only after several weeks of incubation under relatively cool autumn and winter conditions (Boys et al. 2007). The disease develops as concentric rings of white pustules of spores that are rain-splashed throughout the crop canopy, intensifying the disease. Later symptoms of leaf distortions, bleaching of chlorophyll and further sporulation occurs and in severe cases, stunting of the plant can occur if the growing point of the plant is affected. Yield losses occur as a result. Both diseases can be controlled through a combination of cultivar resistance and the use of fungicides.

The LLS risk forecast was developed in the mid 1990s and the PLS forecast in the early 2000s. These had been hosted on a Rothamsted website for over 12 years ahead of the current project. The forecasts for these two damaging diseases work in different ways. The PLS forecast is needed because the timing of PLS varies from year to year at the same location by up to 5-6 weeks typically between the end of September and mid-November. The disease is controlled by cultivar resistance, separation of crops from debris of the previous season and fungicides. Fungicides only affect the leaf spot phase of the disease and can prevent or slow down growth of the fungus to the stem. Once in the stem, current fungicides are ineffective. The timing of the onset of this disease is one factor that affects final stem canker disease severity and the optimal spray regime, whether two, one or no sprays are applied in the autumn. The PLS forecast helps by predicting the date when 10% of plants will be affected by PLS, which is in time for spray applications to protect the remining 90% of plants and still reduce disease progress on the initial infections. In practise, the forecast provides a prompt to growers to check fields visually to pinpoint spray timing.

In contrast to PLS, LLS was shown in Evans et al (2018), to be a threat from emergence onwards because the ascospore primary inoculum is released during the summer and first half of the autumn, even though symptoms are not usually seen until December due to a long latent period. Severity of LLS varies regionally and annually. Therefore, the LLS forecast is designed to answer the question as to whether a fungicide is necessary at all rather than pinpointing the timing. The LLS forecast predicts the proportion of fields that will have severe LLS i.e. the prevalence of fields that will have over 25% LLS incidence.

The PLS forecast is made in early October, while the LLS forecast is also made initially in early October as a ‘preliminary forecast’, which uses a component of historic regional average winter rainfall in the calculation, and this is then updated in early March by using actual winter rainfall data for each region. This is in time to influence Spring fungicide decisions by growers.

Optical sensing is not useful to forecast or monitor these two diseases because symptoms are cryptic or masked by leaves unfolding higher in the crop canopy. Air sampling could be used for disease forecasting but is currently less cost-effective than the two weather-based forecasts currently used. The current weather-based forecasts are often consulted by the industry, for example the combined views of both models on the AHDB website in October 2020 was nearly 300 and positive feedback is often received at KT events.

Objectives were:

1. To maintain and update the OSR LLS and PLS DSS tools in the autumn of each year and revise the LLS forecast in the spring of the following year.
2. To help promote the uptake and use of the OSR DSS tools through a variety of KT activities, some in conjunction with the AHDB KT Team.

3. Materials and methods

3.1. Phoma leaf spot (PLS) forecasts

The Phoma leaf spot forecast uses Equation 2.1 in Evans et al. (2007), which is:

$$S = 196 + (216.5 – 0.24R – 4.55T)$$

Where; ‘S’ is the start date (Julian Day) of 10% phoma leaf spot incidence; 196 is the Julian Day for 15th July; 216.5 is a constant value; ‘R’ is the total rainfall (mm) from the 15th July to 26th September and ‘T’ is the mean maximum daily temperature between the 15th July and 26th September.

In the Autumn, as soon as possible after the 26th September, meteorological data were downloaded from UK synoptic meteorological stations. The data were checked for missing values. In some occasional cases, small errors such as a few days of missing rain or temperature data were substituted using the data for the same dates from the next geographically-nearest meteorological station or an average of two nearby meteorological stations. If a meteorological station had stopped operating, an alternative meteorological station was used. The data were processed for each site to give the average maximum temperature from 15th July to 26th September, which is one input into the existing model. The other input for each site was daily rainfall from 15th July to 26th September. The data were run through the model to obtain a predicted date for 10% PLS. These dates were transferred to a Google map using the corresponding geographic coordinates for the respective meteorological station. Coloured symbols were used to indicate the current status: ‘No Symptoms’, ‘Infections taking place’ or ‘10% incidence predicted’. A link to the map was provided to AHDB and the map was updated on the AHDB website each week. A report in the form of a draft press release was provided to AHDB when the PLS forecast was first made each autumn.

3.2. Light leaf spot (LLS) forecasts

3.2.1. LLS regional forecast

The Light leaf spot forecast uses methods reported in Welham et al (2004). As with the PLS forecast (above), meteorological data were downloaded, checked and processed to provide input data, which were mean summer temperature for each region by averaging the mean summer temperatures of all meteorological stations used within a region (2-5 sites per region, except for Scottish regions, which had only one meteorological station per region). The initial forecast uses mean monthly winter rainfall data per region (1961-1990). The forecast also uses set regional coefficients based on historic levels of LLS and lastly, the forecast uses regional light leaf spot incidence (percentage of plants with affected pods) in June of the previous season. The LLS pod incidence data were kindly provided by Cropmonitor (http://www.cropmonitor.co.uk/) in 2017-2019. In 2020, due to working restrictions resulting from the Covid-19 lockdown up to early July 2020, OSR crop inspection data were not available from Cropmonitor. Instead, a combination of trial data taken in two regions in June 2020 and individual disease assessments made in other regions in mid-July were used as input data. Due to a reduced number of sampled sites compared to other years, and the later assessment period, which makes it harder to observe LLS infection, there was an increased level of uncertainty associated with the result. The forecast was updated in early March 2021 using actual winter rainfall data.

3.2.2. LLS crop-specific interactive forecast

In addition to the regional forecast, a crop specific forecast in an interactive web-based format was previously hosted at Rothamsted Research and then at the AHDB, in which the user could input information such as, location, cultivar used (LLS resistance rating), sowing date and whether an autumn fungicide would be used or not. The output shown gave a prediction of the percentage of plants infected and percentage of crops with over 25% incidence but had to be adapted each year according to that year's regional forecast. Unfortunately, it was not known what source information the interactive forecast was linked to in order to change it according to an updated regional forecast. So, in 2020/21, crop specific information was calculated and was provided in the form of a simple table giving predicted LLS levels to explain the effect of cultivar resistance, sowing date and fungicide use on the prevalence of severe LLS (% crops with over 25% LLS).

4. Results

4.1. Phoma leaf spot (PLS) forecasts

Work package 1.1 - PLS forecasts were due each year on the 10th October and were actually completed on 07/10/17, 09/10/18, 2/10/2019 and 30/9/2020. After each forecast, regular updates of the map displaying current PLS status at each meteorological station location were made. Examples are shown below for 2019 (Figure 2) and 2020 (Figure 3).

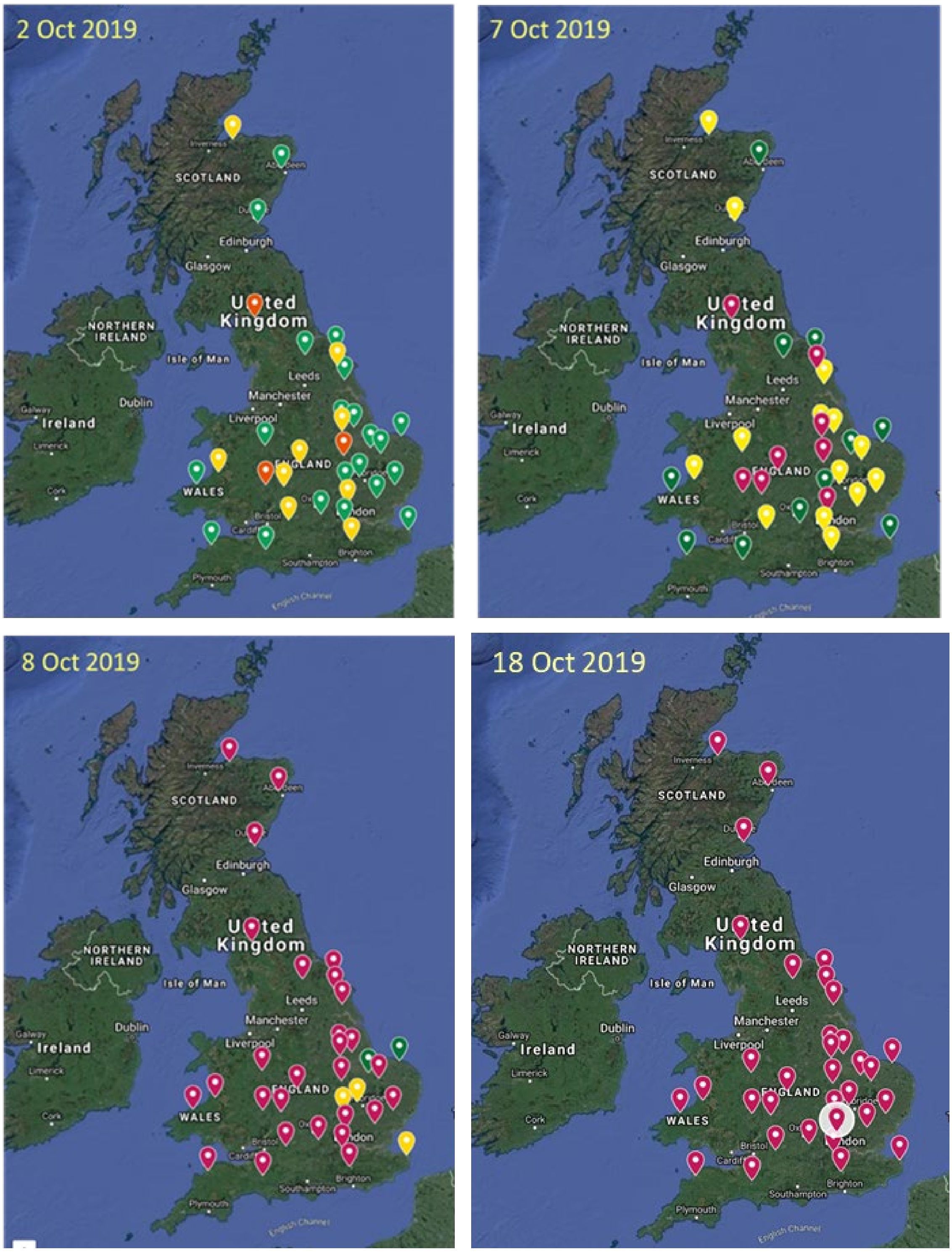

Figure 2. Examples of Phoma Leaf Spot forecast maps used in 2019 illustrating changes in the status of marker positions according to the date show unaffected locations in green, locations with infections taking place in yellow and locations where 10% PLS incidence is predicted in red (colours were changed in later years to improve ease of viewing).

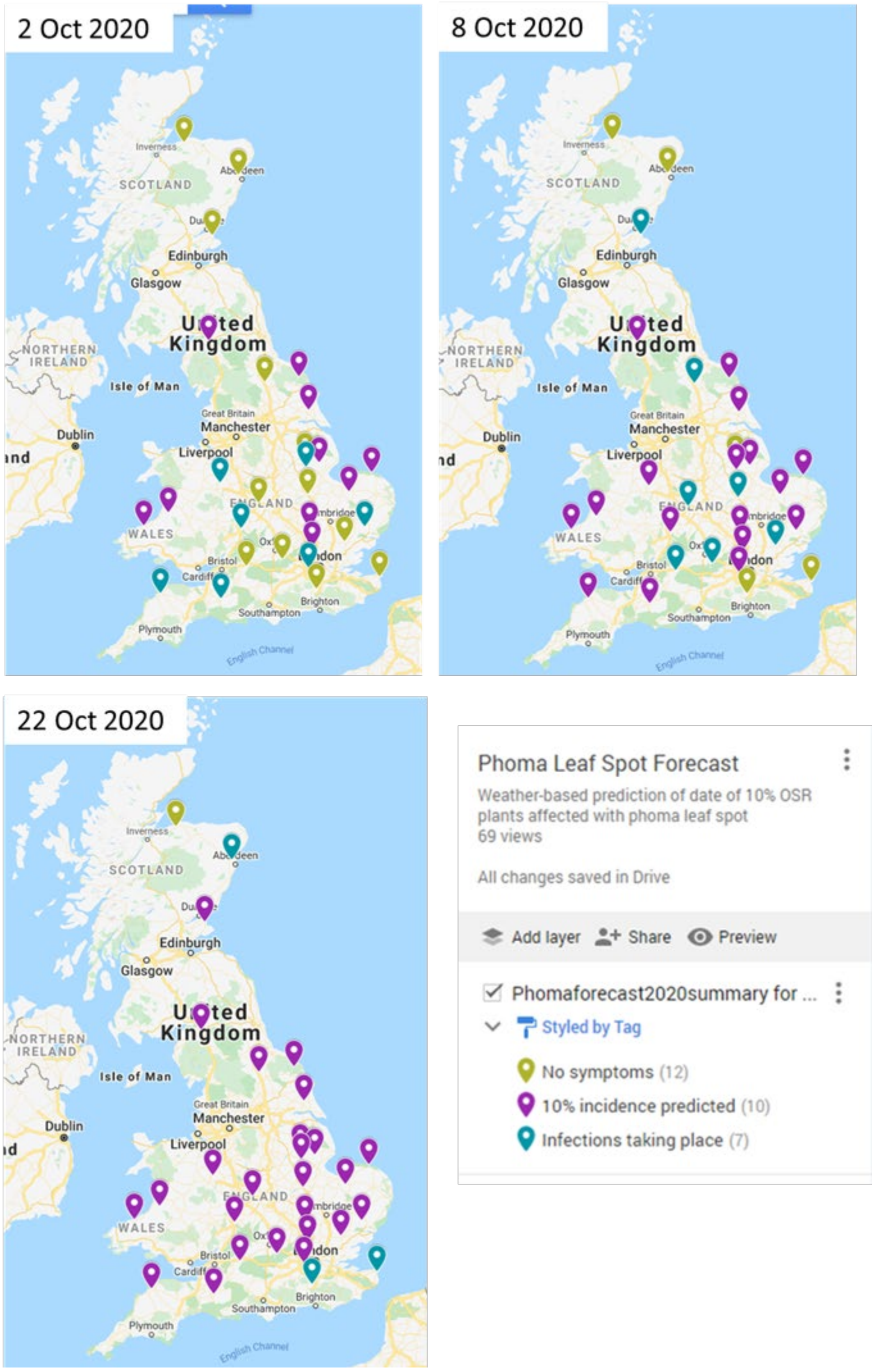

Figure 3. Examples of Phoma Leaf Spot forecast maps used in 2020 illustrating changes in the status of marker positions according to the date.

4.2. Light leaf spot (LLS) forecasts

4.2.1. LLS regional forecasts

WP1.2. – The LLS forecast, had the preliminary forecast due on the 10th October each year and these were actually completed on 07/10/17; 23/10/18 (Delayed obtaining disease data from Cropmonitor and meteorological data due to expiry of Rothamsted's licence with the Met Office), 8/10/2019, and 13/10/2020 (delayed due to problems arranging a new map display consistent with previous years).

The LLS Spring updates (Final Forecast) were due on the 10th March each year and were made on 6/4/2018 (delay due to accessing met data due to a lapsed subscription); 13/3/2019 (slight delay due to a glitch in updated software); 11/3/2020; and 2/3/2021.

The Final Forecasts for the four seasons of the project are shown below (Figure 4) along with the previous four seasons for comparison.

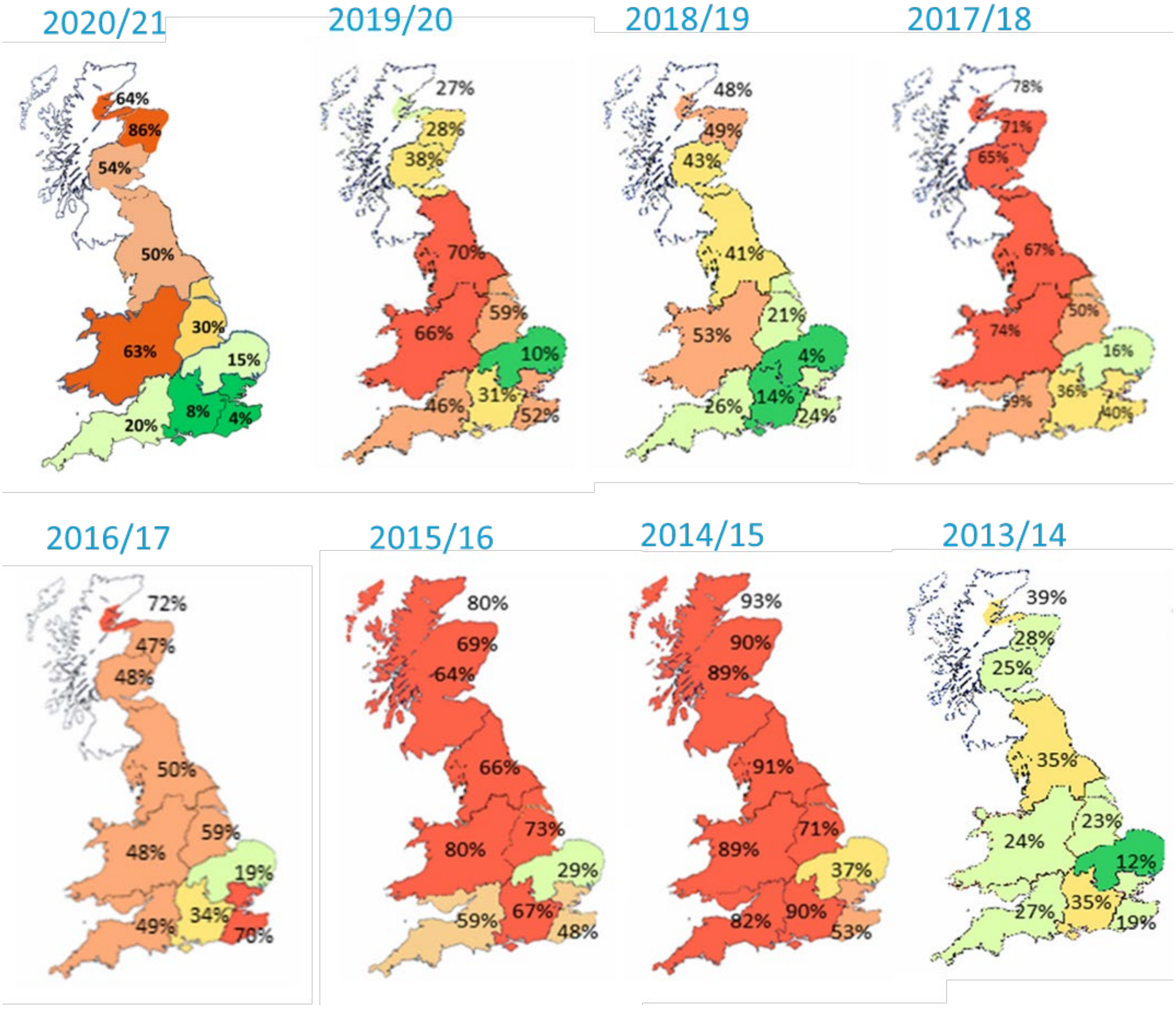

Figure 4. Final LLS forecasts for harvest seasons 2021 back to 2014 to illustrate regional trends and annual variation.

The variation shown in the predictions in Figure 4 show well-known regional trends for less LLS in the South-East and East-Anglia than in the North and West but in addition, there is a substantial range from year to year, for example with parts of Scotland ranging from 28% in 2019/20 to 90% in 2014/15; or East Anglia at 4% in 2018/19 and 37% in 2014/15. Although winter rainfall has a large effect on predicted LLS levels, there is a regional effect already used in the model and a build-up or paucity of inoculum the previous year, which can affect disease the following season is also accounted for in the model. Oilseed rape spring survey data from Cropmonitor (https://secure.fera.defra.gov.uk/cropmonitor/wosr/surveys/wosr.cfm) generally agrees with the final predictions – out of the four years of the project, 2017/18 was a fairly average year with more LLS in the north of Britain than the south, 2018/19 was the lowest LLS year since 2007, which was predicted, largely as a result of a drier winter than normal. The Cropmonitor spring 2020 survey recorded the highest LLS since 2015 (which in previous work shown in Figure 4, was also predicted to be a high LLS year), particularly high in the West but low in the East. Data for spring 2021 is not yet available to allow a comparison.

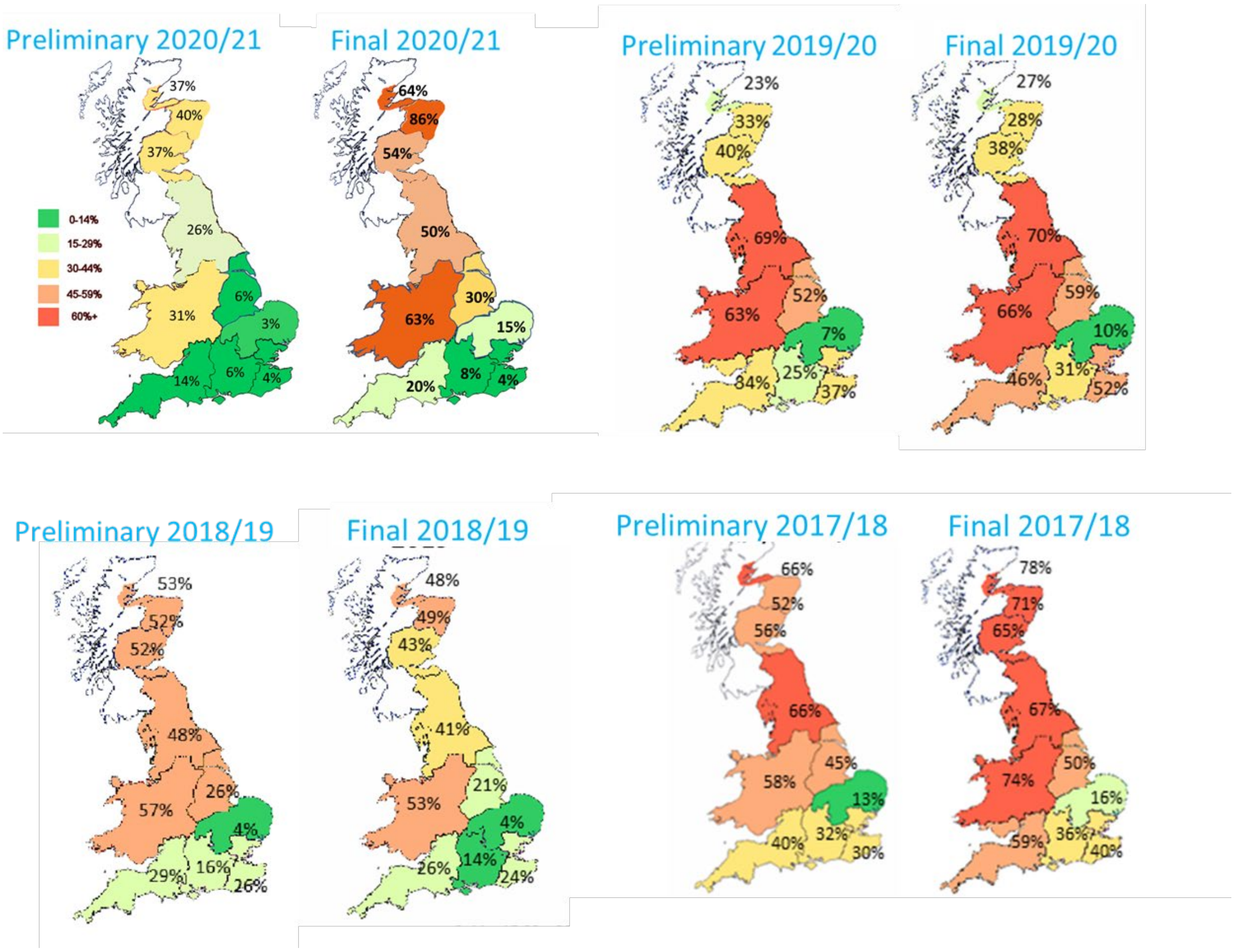

Figure 5. Examples of differences between the preliminary LLS forecast made in October and the final forecast, updated with actual winter rainfall data, made in March each year.

In the years of this project, generally there was higher winter rainfall than normal and so predictions increased in severity between the initial prediction and the final update made in spring, except in 2018/19 which had a drier winter than normal and was found from surveys in spring 2019 to be a low year for LLS.

4.2.2. LLS crop-specific forecasts

To present crop specific information in 2020/21 at a glance without needing to input variables into an online interactive portal, the table below was calculated to provide an illustration to growers of the effects of autumn fungicide use, sowing date, and increased cultivar resistance rating to LLS.

Location	Scenario 1: LLS prevalence based on resistance rating 5, sowing date of W/C 1st Sept, no autumn fungicide	Scenario 2: prevalence when autumn fungicide applied to scenario 1	Scenario 3: prevalence for scenario 1 when crop sown in mid-August	Scenario 4: prevalence for scenario 1 when crop sown in mid-September	Scenario 5: prevalence for scenario 1 when variety with a resistance rating of 8 sown
Grampian	37%	13%	42%	31%	15%
Aberdeenshire	40%	15%	45%	34%	16%
Fife	37%	13%	42%	31%	15%
North England	26%	7%	31%	21%	8%
West England & Wales	31%	10%	36%	25%	11%
East Anglia	6%	1%	10%	2%	3%
East	3%	1%	4%	1%	1%
South	6%	1%	10%	2%	3%
South-east	4%	1%	5%	1%	2%
South-west	14%	4%	18%	11%	4%

Table 1. Crop specific predictions of LLS levels by region, according to scenarios with fungicide use, altered sowing date and increased disease resistance.

Table 1 shows that applying an autumn fungicide (Scenario 2) causes a substantial reduction in the predicted LLS level (e.g. from 37% to 13%, or 6% to 1%) and a similar reduction is predicted by using a variety with a high level of disease resistance, rating 8 (Scenario 5) compared to a rating of 5 (Scenario 1). Table 1 also shows the effect of sowing date, in which sowing 2 weeks early (Scenario 3) leads to a slightly higher LLS level (e.g. 42% instead of 37%, or 10% instead of 6%), while a later sowing (Scenario 4) leads to a slight reduction on LLS level (e.g. 31% instead of 37%, or 2% instead of 6%).

4.3. Knowledge transfer

After each forecast or update, text was provided to the AHDB for potential use as a press release. The spring 2019 update suggested a reduction in the originally forecast LLS due to dry weather in January and February 2019. This contrasted with observations of visible disease which was accelerated in appearance by the dry and unusually warm weather (20°C in Feb 2019). Therefore, the text of the draft press release was carefully worded to indicate that the disease was more visible due to a period of warm, dry weather. Following the Autumn 2017 and 2018 PLS and LLS forecasts, an email alert was sent to registered users and a message sent on Twitter by Neal Evans. Further promotion of the forecasts was made by AHDB staff. Information was also disseminated by the Croprotect App.

Other dissemination activities included:

- Jon West attended the 19th International Reinhardsbrunn Symposium - Modern Fungicides and Antifungal Compounds 7-11 Apr 2019 and discussed disease surveillance and forecasting with key agrochemical industry representatives, including making a presentation in which AHDB was acknowledged.
- Jon West made an invited presentation at the 2nd Annual Congress on Plant Science and Biosecurity, 11-13 July 2019, London, which mentioned weather-based disease forecasts and acknowledged the AHDB.
- A presentation about the forecasts was made by Jon West at the Oilseed Rape Genetic Improvement Network stakeholder meeting on 24 November 2020 (slides available here: http://www.herts.ac.uk/oregin/files/OREGIN_Phoma-and-LLS-forecasts-2020.pdf), which was in place of a Covid19-cancelled exhibit at Cereals 2020.
- The forecasts were also promoted in an online presentation hosted by Rothamsted Research on Integrated Pest Management in February 2021.

5. Discussion

Anecdotal evidence, in the form of enquiries and comments by industry members, indicate that both the PLS and LLS forecasts are considered to be useful tools that are widely used. Both forecasts prompt the grower to increase vigilance at a key time and apply a fungicide treatment, if they consider it necessary.

The LLS predictions (Figure 4) generally agree quite well with spring survey results from Cropmonitor: https://secure.fera.defra.gov.uk/cropmonitor/wosr/surveys/wosr.cfm. For PLS, growers or extension specialists are advised to monitor crops around the prediction date to check for themselves. The forecasts encourage applications only when necessary, which is a key part of IPM. The crop-specific LLS forecast highlights the value of host resistance and fungicide use, allowing the grower to make a judgement on these factors early in the season. As part of IPM, the forecasts improve disease control, and increase the durability of varietal resistance and fungicide life-span. Previous work has shown that good crop protection may also help to reduce greenhouse gas (GHG) emissions associated with crop production (i.e. the carbon-cost per tonne of grain produced), by preventing yield losses that would otherwise waste a significant proportion of inputs, such as fertilisers that have relatively high associated GHG emissions (Mahmuti et al. 2009).

Through observation and consultation with industry members, the current PLS model predicts 10% PLS about two weeks earlier than it actually occurs. This itself is still useful in prompting a period of greater vigilance and may be due to the model having been developed on varieties and weather of the 1990s. In particular, intense rain events in the summer appear to bring the predicted date of PLS forward by more days than would realistically be expected by crop debris remaining moist to enable a period of fungal growth and development. Further rain in that period brings the forecast date forward further, which should be ignored if the model has already factored-in a period of fungal development based on earlier heavy rain wetting the debris.

The LLS forecast could also be improved in response to varietal resistance, and the current 30-year regional winter rainfall averages (currently 1961–1990). In addition, the LLS forecast could be augmented using spore trap data, due to the sporadic release of the ascospores that form the primary inoculum, which will provide an element of enhanced timing in addition to spray strategy. If a spore trap network were operated for several weeks from mid-September to late October, the cost of this is likely to vary from between £6K–14K per season, depending on whether reliable automated spore trap devices become available or whether samples from a network, of 5–10 locations, would be posted to a lab for analysis.

6. Acknowledgements

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7. References

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