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Feature

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A COMPREHENSIVE SUGAR BEET VIRUS YELLOWS MODEL

BBRO recently funded a four-year project titled 'A Comprehensive Sugar Beet Virus Yellows Model' that is scheduled to complete its objectives on 31st August 2023. The need for the project arose because sugar beet yields faced a potentially increased threat from virus yellows (VY) following the EU ban of systemic use of neonicotinoid seed treatments in 2018. As many growers will be well aware, control of the aphid vector *Myzus persicae*, commonly known as the peach-potato aphid, is critical for effective VY management. As a result, the project, led by scientists at Rothamsted Research, is tasked with enhancing a decision support system which uses aphid data from the Rothamsted Insect Survey and a statistical model to produce a forecast of potential infection levels due to VY that is issued on the 1st March each year.

In September 2019, the Rothamsted team began updating the model, aiming to include the latest incoming aphid information within the model. An older version of the model had been in operation since the late-1990s (Werker et al. 1998) but since that time, climate change has had a profound impact on the system and has advanced the first flight of aphids. Indeed, since the Rothamsted Insect Survey began recording aphids in a systematic way, aphids have advanced the start of the flight season by more than 30 days in 50 years (Bell et al. 2015). Thus, the project first statistically scrutinised previous model assumptions about the relationship between first flight, cumulative abundance and temperature (Fig. 1. Regressions and 1/5/10/20th plot below), in an attempt to obtain better predictions about the threat of virus yellows.

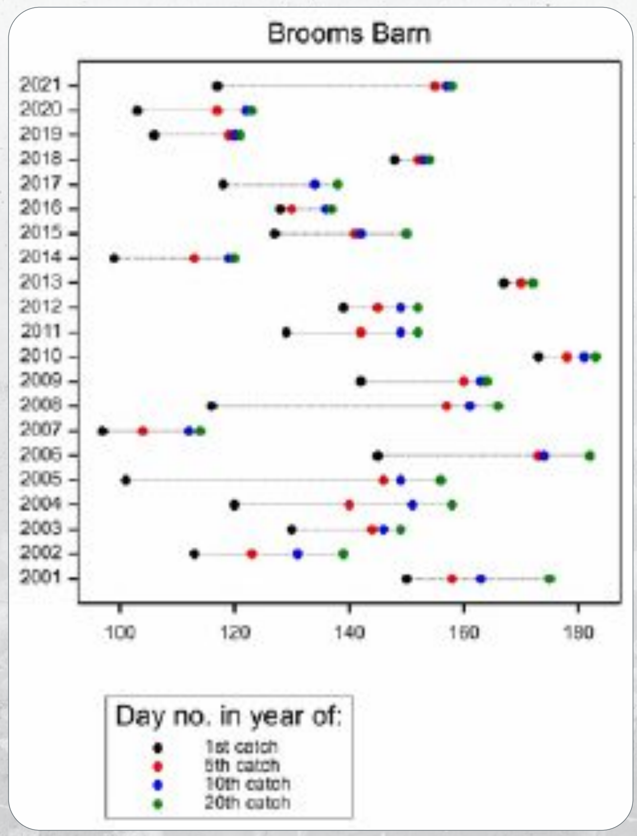

Fig. 1a. Timing (day number in year from 1st January) of the first (black dot), fifth (red dot), tenth (blue dot) and twentieth (green dot) catches of *Myzus persicae* in the Rothamsted Insect Survey's Brooms Barn suction trap (see Fig. 3) from 2001 to 2021.

Winged and wingless
Myzus Persicae

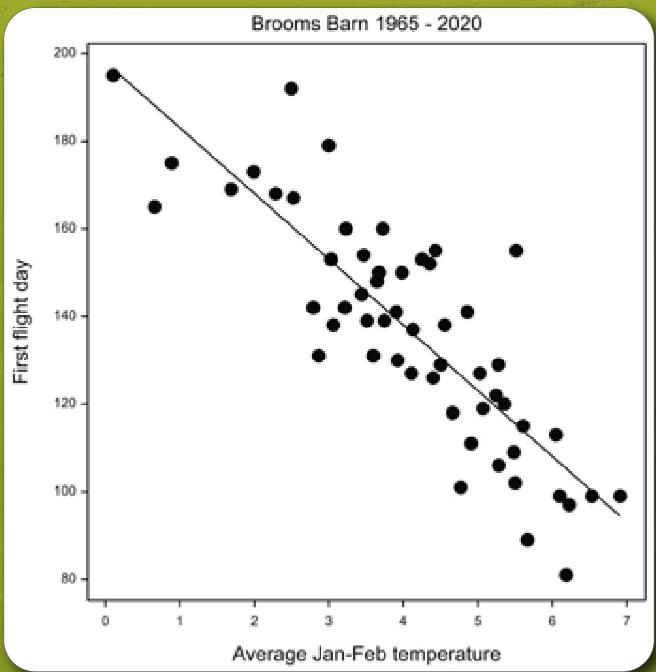

Fig. 1b. Fitted linear regression relationship between first flight day of *Myzus persicae* and average daily mean temperature (°C) over the period 1st January to 28th February at the Brooms Barn suction trap. Points show the observed values for each year between 1965 and 2020.

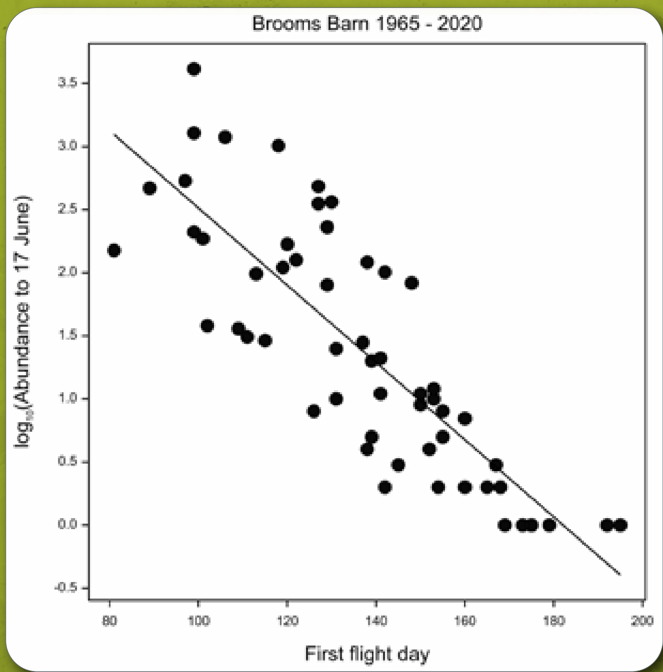

Fig. 1c. Fitted linear regression relationship between the total count of *Myzus persicae* at the Brooms Barn suction trap from 1st January to 17th June (log base 10 transformed after adding an offset of 1) and first flight day. Points show the observed values for each year between 1965 and 2020.

Some argued that following the decision to ban neonicotinoid seed treatments, the industry would be in a similar position to the 1970s when yield loss due to VY was estimated at about 40%, but the first season without the seed treatment did not yield large impacts on the crop. However, in 2020 when the warm winter promoted the early migration of the vector, VY frequency in individual crops rose to unprecedented levels, routinely exceeding 40%, and often approaching 100%, on the fens of Cambridgeshire as well as other locations in Norfolk, Suffolk and South Lincolnshire (Stevens & Bowen 2021). This outbreak motivated British Sugar and the NFU, guided by the BBRO, to apply for an emergency derogation to use Cruiser SB in 2021 if the 'Rothamsted Model' predicted >9% virus yellows nationally. It was then that the project came to the fore because our 1st March forecast predicted that 8.37 % of the national sugar beet crop would be affected by virus yellows by the end of August 2021. A statement, issued by Defra with HSE and interpreted by the BBRO for the industry, clearly indicated that no seed treatment would be used in 2021 because the conditions for the trigger had not been met. It is at this point that growers will be wondering how that figure of 8.37% arose.

The 'Rothamsted Model' is a semi-mechanistic epidemiological model first described by Werker et al. (1998) and presented in a simplified way in this article (Fig. 2. The model). The model has several interconnected parts with VY infection simulated to start after the predicted first aphid flight and the predicted cumulative numbers of aphids to the 17th June influencing the scale of infection. These predictions are derived from simple regression models relating historical aphid catch data from both the Broom's Barn and Kirton 12.2m suction traps to average winter temperatures (Fig 3. Broom's Barn ST). These predictions drive the development of primary and secondary inoculation events (green box – (Fig 2)), which have different trajectories over time but can largely be described as 'S' shaped curves that may reach saturation, depending on conditions. The predicted cumulative proportion of plants receiving either primary or secondary infection over the growing season produces the forecast of overall VY infection.

Each year, the timing of aphid flight and hence virus infection changes and we only need to look at the recent past to see that. For example, compare 2020 when aphids started their migrations at Broom's Barn (9th April) and Kirton (16 April) early in the season compared to 2021 when their migration was much later (27 April and 5 June respectively). Thus, we know when the season starts, but we also know that the rate of virus infection declines through the growing season. Due to an inherent plant trait known as mature plant resistance that decreases the susceptibility of sugar beet to virus yellows with age, we know that aphids increasingly struggle to feed on sugar beet from mid-June onwards. This is caused by a black sticky substance produced by sugar beet that blocks the aphids' feeding tubes (stylets) (Kift et al. 1996) and is the focus of current studies (Schop 2021). This aspect is included in the model as a decay rate over time which captures the decreasing susceptibility of the crop to feeding and thus virus infection.

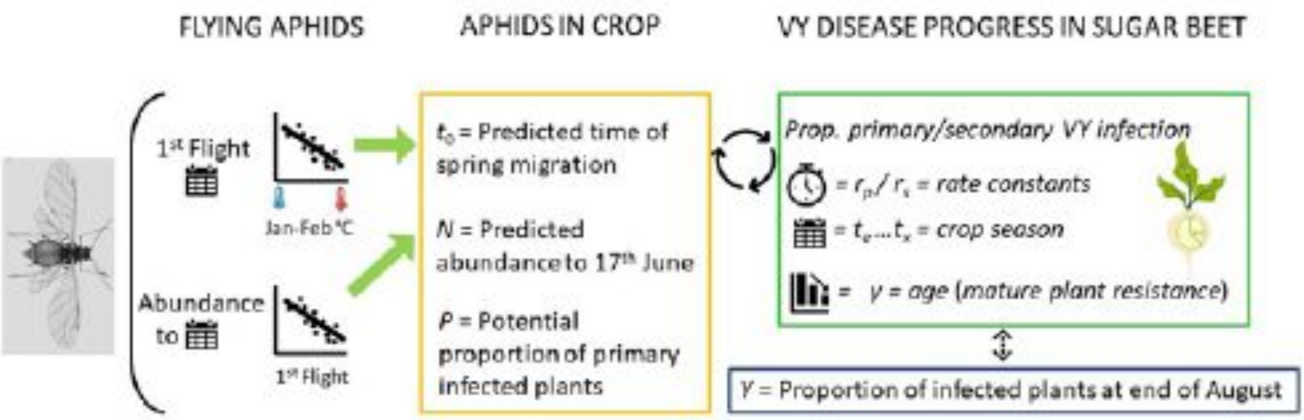

Fig. 2. Schematic representation of the sugar beet virus yellows forecast model.

One of the greatest challenges in biological forecasting is predicting insect population size. It's perhaps worth reminding ourselves that the Met Office communicate 'medium-range weather forecasts' that extend to 10 days for the UK. The Rothamsted team are really extending their biological and statistical knowledge to give an estimate of the total numbers of aphids four months into the future! In this noisy biological system, there's plenty of opportunity to produce a poor estimate, especially considering how rapidly biological, physical and environment variables are changing. Science does not yet know how these variables impact population growth rates precisely, but we have the world's best resource providing the richest aphid datasets to help guide us.

It's important to note that this is the first time a derogation decision has been based on a statistical model and, by all accounts, the forecasts have turned out to be accurate for the 2021 season. However, this is no time to rest on our laurels as there still is a great deal of work to do to incorporate more detailed plant and aphid biology. The biological background is important because the peach-potato aphid has a diverse diet of over 50 host plant families, some of which may also act as virus reservoirs. **If conditions are right, the aphid acquires the virus within five minutes of feeding on an infected host and then is primed to transmit the virus to neighbouring sugar beet.** The original source of that virus may come from nearby beet clamps, root remnants, weeds and fodder beet or further afield. Even so, it is therefore vital that growers remain vigilant to the virus threats to sugar beet and maintain high levels of crop hygiene to minimise risk.

If predicting a national virus figure more than five months ahead of the sugar beet harvest was a challenge, then predicting which fields will be impacted across the 100,000 hectares of arable land is an even greater one. We have been analysing field data on aphid numbers from BBRO and British Sugar to potentially provide estimates at a more local level. That is proving hard to resolve because each individual yellow water trap is contributing unique knowledge regarding the level of the pest threat. In some circumstances, one trap may report large numbers and nearby another will catch very few. If all the traps within a local area reported similar data, then it would be much easier to produce postcode-based forecasts, but because they don't that remains a future aspiration rather than a reality. Here, growers can help because we now know the importance of yellow water traps in providing information about geographical variability - sustaining the effort and building on that network of traps can only ever be a good thing for sugar beet growers for the future.

Fig. 3. The Rothamsted Insect Survey 12.2m suction trap at Brooms Barn, Suffolk

References

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