September 2021

Annual Project Report No. 21510022

Autumn survey of wheat bulb fly incidence 2021

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This is the autumn 2021 report of a 27-month project (21510022) that started in August 2019. The work was funded by a contract for £32,000 from AHDB.

CONTENTS

1. Abstract

All cereals, except oats, can be attacked by wheat bulb fly (WBF). Eggs are laid in late summer in bare soil following fallows or early harvested crops, particularly if fields are cultivated between mid-July and mid-August. Fields cropped with root crops, such as sugar beet, potatoes and onions, are also favoured as egg-laying sites, as the pest can access bare soil between the rows. WBF is most prevalent in eastern England and north-eastern England.

The specific objectives of the project are (this report covers objectives 1 and 2):

1. To measure WBF incidence in autumn 2019–21.
2. To forecast the need for seed treatment in autumn 2019–21.
3. To test the Young and Cochrane model for prediction of WBF risk using historic met data and data from autumn 2019–21.
4. To investigate the potential for PCR analysis to predict WBF risk (2019 only).

In total, 30 fields were sampled for WBF eggs in September 2021 in areas prone to the pest, with 15 in eastern England and 15 in northern England. In autumn 2021, of the 30 fields sampled:

- One (3%) was very high risk (egg numbers >500/m²)
- Four (13%) were high risk (egg numbers 250–500/m²)
- Five (17%) were moderate risk (egg numbers 100–249/m²)
- 20 (67%) were low risk (egg numbers <100/m²)

For crops sown in September and October, the damage threshold (the egg population that might be expected to have an economic impact on yield) is 250 eggs/m² (2.5 million eggs/ha).

Overall risk has been relatively low for the last 10 years. Although the 2021 results make it one of the higher-risk years in this period, it is still below the long-term (1984–21) average. In 2021, 17% of sites were above the 250 eggs/m² threshold (the long-term average is 19%). It is possible that a delay to harvest, particularly in south and central England meant there was more time for saprophytic fungi to develop in cereal ears, which in turn meant more food for adult WBF females.

As in 2020, egg counts in eastern England were higher in organic than in mineral soil. The mean egg count from the organic soils was 236 eggs/m², in mineral soils it was 36 eggs/m². These results suggest that the potential for WBF damage in eastern England in organic soils is greater than in mineral soils.

Average egg numbers in eastern England (143 eggs/m²) were higher than northern England (95 eggs/m²). Across all sites, the highest risk was after beetroot with a mean of 582 eggs/m²,

although only one sites was sampled. The next highest risk was after potatoes with 240 eggs/m^2, again only one site was sampled.

Late-sown (November onwards) or slow developing crops are at greater risk from WBF than those that are early sown (September/October) due to slower tiller development. As a result, a lower threshold of 100 eggs/m^2 or 1 million eggs/ha is applicable for these crops. In eastern England, 40% of sites were above this level, in northern England it was 27%. All fields in the moderate category (or above) would benefit from a seed treatment if sown from November onwards.

For very late-sown crops (January), consider seed treatments irrespective of the population size (unless no eggs are present).

2. Introduction

All cereals except oats can be attacked by wheat bulb fly (WBF). Eggs are laid in late summer in bare soil following fallows or early harvested crops, such as vining peas, particularly if fields are cultivated between mid-July and mid-August. Fields cropped with root crops, such as sugar beet, potatoes and onions, are also favoured as egg-laying sites, as the pest is able to access bare soil between the rows (AHDB, 2016). The pest is most prevalent in eastern England and north-eastern England. In outbreak years, widespread damage can occur.

Eggs are laid in late July and August in England and up to mid-September in Scotland and remain dormant throughout late autumn and early winter. The larvae hatch between January and March. Soon after hatching, they invade shoots of cereal crops which wither or become yellow and stunted. These symptoms are known as 'deadhearts'.

The level of WBF risk each year fluctuates greatly, due mainly to July and August rainfall (Young & Cochrane, 1993) and the harvest dates of the previous wheat crops. The longer crops remain in the ground, the longer adult flies have to feed on saprophytic fungi within the cereal ears and mature their eggs. Incidence generally increases following a wet harvest period, such as in 2004, and is lowest after a hot, dry summer, such as in 1995. The proportion of fields having an egg count greater than the 250 eggs/m² damage threshold (the egg population that might be expected to have an economic impact on yield) ranged from 3% to 44% in the period 1984–1999 (Oakley & Young, 2000) and from 0% to 50% between 2000 and 2021 (Figure 1).

Wheat harvest 2021 was slow to start. Crops were slow to ripen, and then a period of unsettled wet weather though out much of the early part of August resulted in delays especially to the harvest of earlier ripening crops in southern and central England. Many crops in these regions were ripe by mid-August, but not harvested until conditions improved in the last week of August first week of September. With improving weather conditions steady progress was made to the harvest of wheat in the south. Further north where wheat harvest is normally later and often affected by unsettled weather later in the season harvest progressed rapidly during early September, with Scottish wheat harvest being ahead of normal. Wheat harvest was all but complete by the end of week beginning 14 September. The delay to harvest, particularly in the south, suggested an increased risk from wheat bulb fly. The survey will help determine if this is the case and provide valuable information on the potential risk from the pest for the 2021/22 season.

The overall objective of the autumn survey of wheat bulb fly incidence is to establish the annual incidence of WBF in autumn 2019-2021 and the risk of subsequent damage and to validate the Young and Cochrane model of WBF risk prediction.

Specific objectives are:

1. To measure the incidence of WBF in autumn 2019-2021 in the east and north east of England.
2. To forecast the need for seed treatment in autumn 2019-2021.
3. To test the Young and Cochrane model for prediction of WBF risk using historic met data and that for autumn 2019-21.
4. To investigate the potential for PCR analysis to predict WBF risk (2019 only)

This report covers objectives 1 and 2.

Egg numbers can be estimated by soil sampling and related to damage threshold levels of 250 eggs/m² (2.5 million eggs/ha) for crops sown in September or October, or 100 eggs/m² (1.0 million eggs/ha) for crops sown from November onwards. At lower infestation levels, economic damage is less likely, although winter cereal crops sown from November onwards or those sown in spring before the end of March can be particularly vulnerable. Larvae attack shoots of wheat, barley and rye from January to April, with yield loss depending on tiller density at the time of attack. Crops still at the single shoot stage in February are most vulnerable and may be completely destroyed (Young, 2000). Yield losses of up to about 4 t/ha have been recorded following severe damage (Young & Ellis, 1996).

The options for control of WBF have been reduced by pesticide reviews and withdrawals and are currently limited to a cypermethrin seed treatment (Signal 300 ES).

Seed treatment is the most effective option for late-sown crops, for example those at risk following potatoes, sugar beet, onions or red beet. Young (1992) demonstrated that November and December drillings of winter wheat were more vulnerable to WBF damage than earlier sowings and are, therefore, more likely to benefit from the use of a preventive insecticidal seed treatment.

3. Materials and methods

A total of 30 fields were sampled in September 2021 in areas prone to WBF, with 15 in eastern England and 15 in northern England (Table 1). The survey was stratified to represent some of the main preceding crops (Table 2) leading to a risk of wheat bulb fly damage in each area.

For each field sampled, 32 cores each of 7.2 cm diameter or 20 cores each of 10 cm diameter were taken to cultivation depth. Fields were sampled in a standard W sampling pattern. WBF eggs were extracted following soil washing and flotation in saturated magnesium sulphate. Egg numbers were expressed as number of eggs per m².

Table 1. Location of sampling sites, by region and county.

Region	County	Number of fields sampled
Eastern England	Cambridgeshire	6
	Norfolk	8
	Lincolnshire	1
	Total	15
Northern England	East Yorkshire	12
	North Yorkshire	3
	Total	15

Table 2. Preceding crop for sampled fields.

Preceding crop	Eastern England	Northern England
Beetroot	1	0
Dwarf beans	2	0
Fallow	0	1
Linseed	1	0
Maize	2	0
Onions	2	0
Potatoes	1	0
Seed potatoes	0	5
Sugar beet	6	0
Vining peas	0	9
Total	15	15

4. Results

In autumn 2021, one of the sampled fields was considered at very high risk (egg numbers >500/m²), four at high risk (egg numbers 250-500/m^2), five at moderate risk (egg numbers 100-249/m^2 and 20 at low risk (egg numbers <100/m^2). This was equivalent to 3%, 13%, 17% and 67% of fields in the very high, high, moderate and low risk infestation categories respectively. A total of 17% of sites had egg numbers above the 250 eggs/m^2 threshold for crops sown in September and October (Figure 1). The overall risk in 2021 is the equal highest it has been since 2012 (2015 also had 17% of sites over the 250 eggs/m^2 threshold) but still just below the average of 19% of sites above the 250 eggs/m^2 threshold for monitoring since 1984. Since 1984 the overall risk has been equal to or higher than 2021 on 19 occasions and lower than 2021 on 17 occasions. It is possible that a delay to harvest, particularly in south and central England meant there was more time for saprophytic fungi to develop in cereal ears, which in turn meant more food for adult WBF females. As a result, egg numbers were the equal highest they have been since 2012.

Average egg numbers in the east of England were 143/m^2 which is higher than in the north of England where 95/m^2 were recorded (Figure 2). Over all sites, the highest risk was after beetroot with a mean of 582 eggs/m^{2}although only one site was sampled. The next highest risk was after potatoes with 240 eggs/m^2 although again only one site was sampled. The highest individual count was 582 eggs/m^2 after beetroot followed by 370 eggs/m^2 after sugar beet. Both sites were in organic soils with the beetroot in Norfolk and the potatoes in Cambridgeshire.

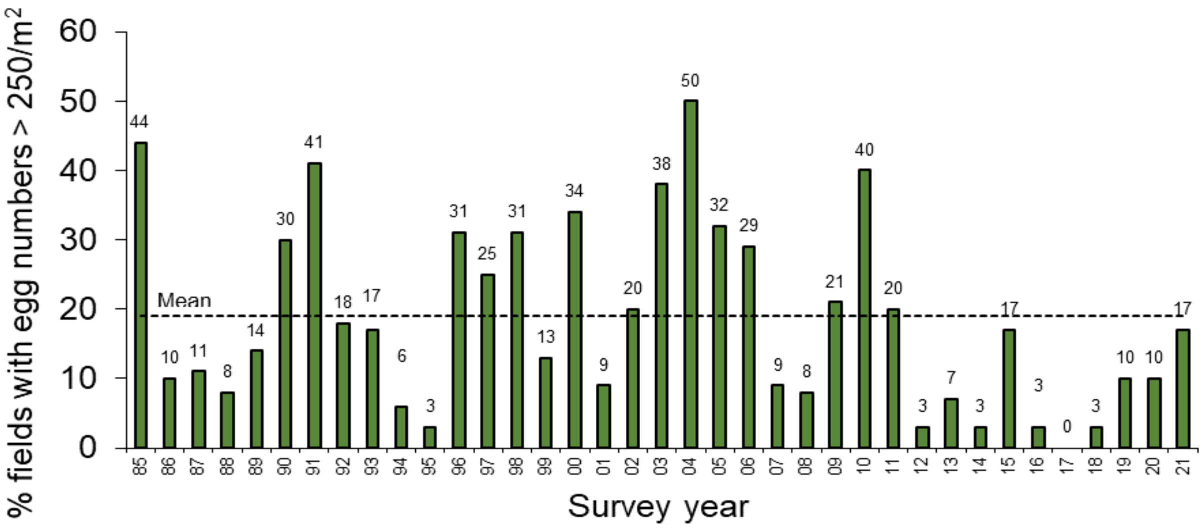

Figure 1. Wheat bulb fly annual risk levels 1984–2021 and overall mean (dashed line). Fields at risk have >250 eggs/m^2

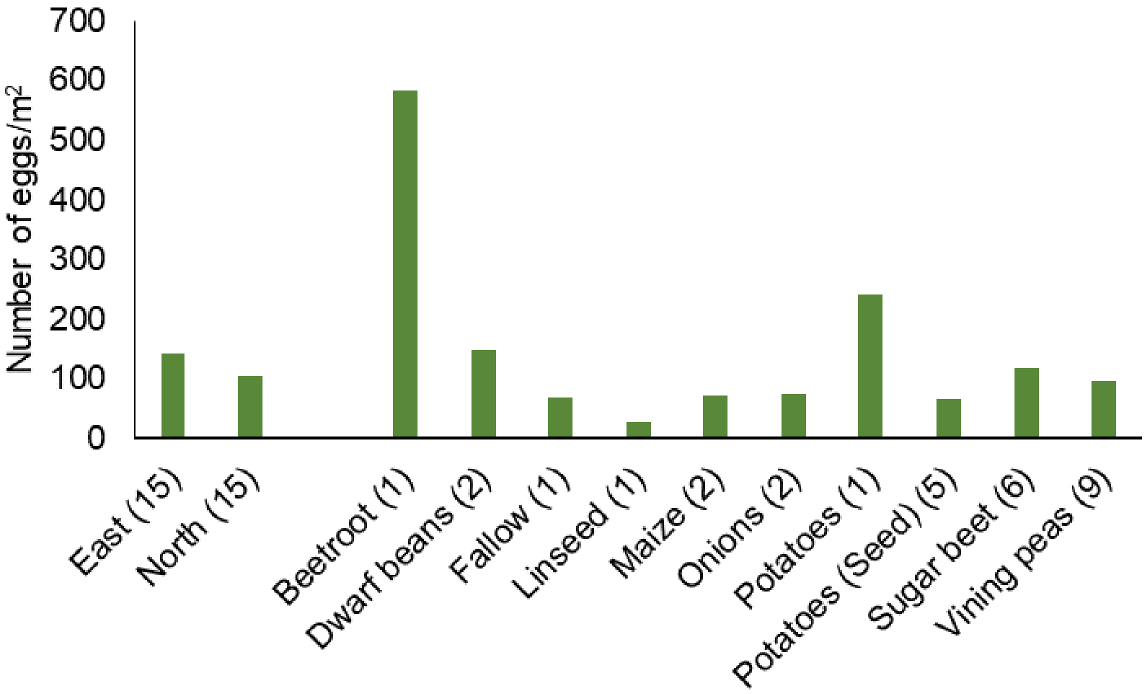

Figure 2. Average egg counts by region and previous crop in autumn 2021 (number of sites in brackets).

4.1. Eastern England

The mean egg number was 143 eggs/m² for sites sampled in eastern England. This is lower than in 2020 (173 eggs/m^2) although this figure was heavily influenced by two very two very high counts of 1000 and 850 eggs/m^2. In general counts from individual sites in the east of England in 2021 were higher in than in 2020 with nine sites in the low category in 2021 and 12 in 2020. As in 2020 it was interesting that the eight samples taken from organic soils had a much higher mean egg count (236/m^2) than the seven samples from mineral soils (31/m^2). All egg counts over 100/m^2 (six sites) were recorded in organic soils. Therefore, the potential for WBF damage in eastern England in organic soils is greater than in mineral soils.

Overall, four sites (27%) had egg numbers above the 250 eggs/m^2 threshold for crops sown at the conventional timing (before November). The equivalent figure for 2020 was 20%. However, late-sown crops (November onwards) which are likely to have few tillers at the time of egg hatch, could still be at risk from lower egg numbers.

The highest egg counts of 582 eggs/m^2 was after beetroot in Norfolk, the second highest of 370 eggs/m^2 was after sugar beet in Cambridgeshire and the third highest of 260 eggs/m^2 was after sugar beet in Norfolk. In total 9 of the 15 sites sampled (60%) had egg numbers lower than 100 eggs/m^2. Beetroot had the highest mean number of eggs of all crops sampled (582 eggs/m^2, Table 3) but only one site was sampled. Potatoes had the next highest count of 240 eggs/m^2 but again only one site was sampled.

Table 3. Mean eggs/m² and preceding crops in eastern England in autumn 2021 (range in brackets).

Preceding crop	Number of fields sampled	Mean number of eggs per m²
Beetroot	1	582
Dwarf beans	2	148
Linseed	1	27
Maize	2	72
Onions	2	75
Potatoes	1	240
Sugar beet	6	118
Mean egg count		143 (7–582)

In eastern England, one of the sampled fields was in the very high risk category (7%), three in the high risk category (20%) two in the moderate category (13%) and nine in the low category (60%, Table 4). Overall, six fields (40%) were in risk categories of moderate or above.

Table 4. Infestation categories and preceding crops in eastern England in autumn 2021.

Preceding crop	Number of fields by rotation and risk category			
	Low (<100 eggs/m²)	Moderate (100–249 eggs/m²)	High (250–499 eggs/m²)	Very high (>500 eggs/m²)
Beetroot	0	0	0	1
Dwarf beans	1	0	1	0
Linseed	1	0	0	0
Maize	2	0	0	0
Onions	1	1	0	0
Potatoes	0	1	0	0
Sugar beet	4	0	2	0
Total	9	2	3	1
% of fields by infestation category	60	13	20	7

4.2. Northern England

The mean egg number was 95 eggs/m² for northern England (Table 5). The highest egg population of 253 eggs/m² was recorded in North Yorkshire after vining peas. The highest overall risk was also after vining peas with an average of 97 eggs/m^2 followed by fallow with 68 eggs/m^2 although only one site was sampled. Seed potatoes were the only other crop sampled and had a mean of 65 eggs/m^2.

Table 5. Numbers of eggs/m² and preceding crops in northern England in autumn 2021 (range in brackets).

Preceding crop	Number of fields sampled	Mean number of eggs per m²
Fallow	1	68
Seed potatoes	5	65
Vining peas	9	97
Mean egg count		95 (49–253)

In northern England none of the sampled fields was in the very high risk category, one (7%) was in the high risk category, three were in the moderate category (20%) and 11 in the low risk category (73%, Table 6).

Overall, four fields (27%) were in risk categories of moderate or above, which is the same as recorded in 2020 and lower than recorded in 2018 (33%), 2015: (87%), 2014: (53%), 2013: (40%), 2011: (60%), 2010: (60%) and 2009: (47%). This represents a low risk to crops sown after November.

Table 6. Infestation categories and preceding crops in northern England in autumn 2021.

Preceding crop	Number of fields by rotation and infestation category			
	Low (0–100 eggs/m²)	Moderate (100–250 eggs/m²)	High (250–500 eggs/m²)	Very high (>500 eggs/m²)
Fallow	1	0	0	0
Seed potatoes	4	1	0	0
Vining peas	6	2	1	0
Total	11	3	1	0
% of fields by infestation category	73	20	7	0

5. Discussion

Egg populations above 250 eggs/m² present a risk of economic damage to winter wheat crops drilled in September and October. Egg numbers above 100 eggs/m² justify the use of seed treatment on the late-drilled crops of winter wheat or barley sown from November onwards.

5.1. Early sown crops (September/October)

In 2021, five of the fields sampled (17%) were over the 250 eggs/m^2 threshold (2.5 million eggs/ha) for crops sown in September or October). The overall risk in 2021 is the equal highest it has been since 2012 (2015 also had 17% of sites over the 250 eggs/m^2 threshold) but still just below the average of 19% of sites above the 250 eggs/m^2 threshold for monitoring since 1984. Since 1984 the overall risk has been equal to or higher than 2021 on 19 occasions and lower than 2021 on 17 occasions. It is believed that the level of saprophytic fungi in the wheat ears has an influence on wheat bulb fly egg numbers. The fungi provide a food source for wheat bulb fly adults so when levels are high more eggs are laid. In 2021 the wheat harvest was slow to start as crops were slow to ripen and further delays followed a period of unsettled wet weather in the early part of August. This was particularly the case in southern and central England. In contrast further north where wheat harvest is normally later and often affected by unsettled weather progress was relatively rapid. It is possible that this could account for the differences in WBF egg numbers between the east and north of England. Mean egg numbers in the east were 143 eggs/m^2 in the north they were 95 eggs/m^2.

5.2. Late-sown crops (November onwards)

Late-sown (November onwards) or slow developing crops are at greater risk from WBF attack than those that are early sown (September/October) due to slower tiller development. As a result, a lower threshold of 100 eggs/m^2 or 1 million eggs/ha is applicable for these crops. In the east of England 40% of monitored fields were above this level and in the north 27% of fields were above this level. All fields in the moderate infestation category or above would benefit from a seed treatment if sown after November. Where egg numbers are high or very high then some WBF damage might be expected. A summary of control strategies for WBF in relation to egg numbers and sowing date is given in Table 7.

Table 7. Wheat bulb fly egg numbers that would justify a seed treatment in crops sown between September and March.

Risk category	Sowing date		
	Sep–Oct	Nov–Dec	Jan–Mar*
Low (<100 eggs/m^2)	Economic damage unlikely; no treatment	Economic damage unlikely; no treatment	Seed treatment
Moderate (100–249 eggs/m^2)	Economic damage unlikely; no treatment	Seed treatment	Seed treatment
High (250–500 eggs/m^2)	No available treatment	Seed treatment	Seed treatment
Very high (>500 eggs/m^2)	No available treatment	Seed treatment	Seed treatment

*Treated seed must not be sown after 31 January, as this is defined as the end of the winter period by CRD.

5.3. Chemical control

Seed treatment (Cypermethrin, Signal 300 ES) is effective on late-sown crops (November onwards) and is the recommended treatment for late autumn or winter sowings of wheat and barley made before the end of egg hatch in areas and rotations at risk from WBF. The label treatment claim for this product is for a ‘reduction of wheat bulb fly’. Treated seed should be drilled at a recommended maximum depth of 4 cm in a firm, even seedbed. It is important to note that seed treatments may not be sufficiently persistent to fully protect crops sown in September or October.

If plants are well-tillered by the time that WBF larvae hatch between January and March, it is possible that they will be able to tolerate some pest attack.

5.4. Non-chemical control

With the loss of chlorpyrifos egg hatch sprays non-chemical control of WBF is becoming increasingly important, particularly for those crops sown before November for which seed treatments will have limited efficacy. Seed treatment is the only chemical control option currently available for WBF and these are most effective for crops sown after November. As only a small proportion of wheat crops are sown after this date alternative control strategies are urgently required for this pest.

The impact of WBF can be reduced by sowing early and increasing the seed rate. This is likely to result in a more robust crop which is well tillered before the start of WBF egg hatch and so can tolerate and compensate for larval invasion. Taking account of crop tolerance is fundamental to improving pest risk assessment and achieving a rational approach to pesticide use which is cost effective and minimises the impact on the environment and the potential for the development of resistance (Ellis *et al*., 2009). This approach was the subject of an AHDB Cereals & Oilseeds funded project entitled 'Crop management guidelines for minimising wheat yield losses from wheat bulb fly' (21120032) (Storer et al, 2018). A WBF threshold scheme was developed that used information from the autumn survey of WBF incidence in September, egg viability, the maximum shoot number the crop could achieve by late winter, and the number of shoots that a single WBF larva could destroy. This model showed that typical variation in the maximum shoot number had a large effect on the chance of yield loss because well grown crops produce excess shoots which can be sacrificed without affecting yield. A model of shoot production was developed based on thermal time and plant population that was embedded within the WBF threshold scheme. This was done to allow a prediction of yield loss from WBF to be made in time for decisions about sowing date and seed rate. A review of literature showed that most WBF mortality occurs in the larval stage between egg hatch and plant invasion. The lowest level of mortality recorded was 56% and this value was used to help calculate the numbers of shoots likely to be lost to the pest. The literature also suggested that the number of shoots destroyed by an individual WBF larva was typically four. Independent tests showed the shoot production model performed reasonably well, but it should be recognised that it does not deal with site specific factors that may limit tillering (e.g. soil capping). The project has developed prototype guidelines summarising how sowing date and plant population should be adjusted, and insecticide seed treatments targeted, for different WBF risk situations.

In order for the threshold scheme described above to be adopted, a more reliable and up-to-date estimate of the minimum final ear number required for high yielding wheat crops was considered necessary. This was the subject of a desk study (Storer et. al, 2019) which investigated whether the minimum final ear number changes in different regions and under different environmental conditions. A positive association between yield and final ear number was identified for UK wheat crops. For crops expected to yield up to 11 t/ha, a target final ear number of 500 ears/m^2 was deemed a conservative default value. For crops expected to exceed 11 t/ha, a higher target final ear number of 600 ears/m^2 was deemed appropriate. Although there was evidence that the ear number associated with specific yields may vary between varieties and geographic regions, it was not strong enough to recommend its inclusion in the threshold scheme. Before the scheme can be adopted, further research is necessary. In particular, it is important to quantify varietal differences in relation to shoot number at growth stage 31 and final ear number. Despite this significant steps have been made in developing a control strategy to help combat WBF in the absence of chemical control.

The primary method for risk determination for WBF is soil sampling, egg extraction, and egg counting. This process is labour-intensive and requires the use of bulky extraction equipment and taxonomic expertise for egg identification, and so can only be undertaken by a specialised laboratory. Soil sampling is effective but laborious and often too late to influence decisions for winter wheat crops. Objective 3 of the current project is ‘To test the Young and Cochrane model for prediction of WBF risk using historic met data and that for autumn 2019-21’

The WBF risk prediction model was developed by Young & Cochrane in 1993. This model uses January air temperature, January soil temperature, July air temperature, and rainfall during the preceding October to predict wheat bulb fly egg density, with a reported predictive power (accuracy) of 59%. In objective 3 of the current study, the effectiveness of the Young & Cochrane model was tested by using it to predict WBF risk from 2005 – 2019. Model predictions were then compared with the results of the 2005 – 2019 AHDB WBF surveys. Following this, an updated risk prediction model was developed by combining the 2005 – 2019 data with the original 1952 – 1991 data included in the Young & Cochrane model and by incorporating a wider range of meteorological parameters. This updated model has a predictive power of 70% (Leybourne *et al.*, 2021), an 11% increase when compared with the original Young & Cochrane model and uses the following meteorological parameters to predict wheat bulb fly risk: preceding September sun days, preceding October rain days, January mean temperature, January frost, April maximum temperature, May maximum temperature, April rainfall, and July minimum temperature. Improving the predictive power of decision support models is likely to increase the confidence in their findings, and therefore uptake by farmers and agronomists. This updated risk prediction model will provide an additional component to a potential IPM strategy for the pest.

The potential to estimate WBF prevalence using water trapping, rather than laborious egg counts from soil samples, was assessed by reviewing literature and testing at 12 sites (Storer et al., 2018). The literature on this topic demonstrated that this approach should work, however the field tests were inconclusive due to low WBF egg levels in the seasons of testing.

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Appendix A

Egg populations ranked in descending order for 15 fields sampled in eastern England in autumn 2021

County	Previous crop	Number of eggs (number/m^2)	Soil type	Risk category
Norfolk	Beetroot	582	Organic	Very high
Cambridgeshire	Sugar beet	370	Organic	High
Norfolk	Sugar beet	260	Organic	High
Norfolk	Dwarf beans	254	Organic	High
Norfolk	Potatoes	240	Organic	Moderate
Cambridgeshire	Onions	116	Organic	Moderate
Cambridgeshire	Maize	82	Mineral	Low
Cambridgeshire	Maize	62	Mineral	Low
Cambridgeshire	Dwarf beans	41	Organic	Low
Lincolnshire	Onions	34	Mineral	Low
Norfolk	Sugar beet	34	Mineral	Low
Cambridgeshire	Linseed	27	Organic	Low
Norfolk	Sugar beet	21	Mineral	Low
Norfolk	Sugar beet	14	Mineral	Low
Norfolk	Sugar beet	7	Mineral	Low
Mean		143		

Appendix B

Egg populations ranked in descending order for 15 fields sampled in northern England in autumn 2021. All fields are mineral soil types.

County	Previous crop	Number of eggs (number/m²)	Risk category
North Yorkshire	Vining peas	253	High
East Yorkshire	Vining peas	130	Moderate
East Yorkshire	Seed potatoes	111	Moderate
North Yorkshire	Vining peas	105	Moderate
East Yorkshire	Seed potatoes	99	Low
East Yorkshire	Seed potatoes	93	Low
East Yorkshire	Vining peas	93	Low
North Yorkshire	Vining peas	93	Low
East Yorkshire	Vining peas	86	Low
East Yorkshire	Seed potatoes	74	Low
East Yorkshire	Fallow	68	Low
East Yorkshire	Vining peas	62	Low
East Yorkshire	Vining peas	56	Low
East Yorkshire	Seed potatoes	49	Low
East Yorkshire	Vining peas	49	Low
Mean		95	