October 2019

# Project Report No. No. 21120003

## Autumn survey of wheat bulb fly incidence 2019


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

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## 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:

1. To measure the incidence of wheat bulb fly 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.

A total of 30 fields were sampled for WBF eggs in September 2019 in areas prone to the pest, with 15 in eastern England and 15 in northern England. The sites were chosen to represent some of the main preceding crops, leading to a risk of WBF damage in each area.

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). In autumn 2019, two of the sampled fields were considered at very high risk (egg numbers >500/m²), one at high risk (egg numbers 250-500/m$^2$), four at moderate risk (egg numbers 100-249/m$^2$ and 23 at low risk (egg numbers <100/m$^2$). This was equivalent to 7%, 3%, 13% and 77% of fields in the very high, high, moderate and low risk infestation categories respectively. A total of 10% of sites had egg numbers above the 250 eggs/m$^2$ threshold for crops sown in September and October. This represents a relatively low risk, as in recent years. WBF adults feed on saprophytic fungi in wheat ears. It is possible that good progress with the wheat harvest in 2019 meant there was less time for these fungi to develop, which in turn meant less food for adult WBF females and, as a result, they produced fewer eggs. Interestingly, in the east of England, egg counts in organic soil were higher than in mineral soil. The mean egg count from the organic soils was 278 eggs/m$^2$, whereas from the mineral soils it was 34 eggs/m$^2$. Although the mean in organic soils was heavily influenced by two very high counts after sugar beet, results suggest that the potential for WBF damage in eastern England in organic soils is greater than in mineral soils. Average egg numbers in the East were about twice as high in the North, with 131 eggs/m$^2$ in the North and 66 eggs/m$^2$ in the East. The counts in the East were heavily influenced by the two very high counts after sugar beet. Over

all sites, the highest risk was after sugar beet with a mean of 186 eggs/$m^2$. The next highest risk was after spring beans with 123 eggs/$m^2$, although 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 the east of England, 27% of sites were above this level and 20% were above this level in the North. All fields in the moderate category would benefit from a seed treatment if sown from November onwards. Crops sown between January and March would benefit from a seed treatment if any WBF eggs are found.

## 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 and the attacked shoots 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/$m^2$ 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 2019 (Figure 1).

Harvest of wheat was completed by week ending 17 September in England, with small areas harvested in Scotland during week ending 24 September. The 2019 wheat harvest was for the most part relatively straightforward. It started in the first week of August (week ending 6 August) and progressed steadily for two weeks as crops gradually ripened in the south. The week ending 20 August saw a period of heavy and persistent rain affecting the whole country which brought wheat harvest to a virtual halt. However, a significant improvement in the weather for the last week of August (week ending 27 August) resulted in record areas of wheat being harvested and brought progress back in line with the early harvests of recent years. There were just small areas of late ripening wheat (mostly feed wheat) left to harvest in the northern counties of England and Scotland during September. This suggested that the risk from wheat bulb fly would be low again as in the last two years and this survey will help determine if this is the case and provide valuable information on the potential risk from the pest for the 2019/20 season.

The overall objective of the autumn survey of wheat bulb fly incidence is to establish the annual incidence of wheat bulb fly 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 wheat bulb fly 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 only 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 tefluthrin + fludioxinil seed treatment (Austral Plus) and a cypermethrin seed treatment (Signal 300 ES). In 2016 uses of chlorpyrifos-ethyl or products containing chlorpyrifos-ethyl were lost due to a non-dietary risk review of current uses, as a result of the reduction of the toxicological reference values recommended by EFSA. Consequently, chlorpyrifos can no longer be used as an egg hatch spray against wheat bulb fly larvae.

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 2019 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 $m^2$.

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

| Region | County | Number of fields sampled |
| --- | --- | --- |
| Eastern England | Cambridgeshire | 10 |
| | Norfolk | 5 |
| | Total | 15 |
| Northern England | East Yorkshire | 10 |
| | North Yorkshire | 5 |
| | Total | 15 |

**Table 2.** Preceding crop for sampled fields.

| Preceding crop | Eastern England | Northern England |
| --- | --- | --- |
| Linseed | 1 | 0 |
| Maize | 1 | 0 |
| Onions | 2 | 0 |
| Peas (combining) | 0 | |
| Peas (vining) | 0 | 9 |
| Potatoes | 2 | 4 |
| Spring beans | 1 | 2 |
| Sugar beet | 8 | |
| Winter oilseed rape | 0 | 0 |
| Total | 15 | 15 |

# 4. Results

In autumn 2019, two of the 30 surveyed fields (7%) were considered at very high risk (egg numbers>500/m$^2$, Figure 1) and only one (3%) at high risk (egg numbers between 250/m$^2$ and 500/m$^2$). A total of four fields (13%) were considered at moderate risk, containing egg numbers between 100/m$^2$ and 249/m$^2$ and 23 fields (77%) were considered at low risk, containing egg numbers less than 100/m$^2$. A total of 10% of sites had egg numbers above the 250 eggs/m$^2$ threshold for crops sown in September and October. The overall risk in 2019 is equal to or lower than 13 other years since monitoring began in 1984 and well below the average of 20% of sites above the 250 eggs/m$^2$ threshold for monitoring since 1984. As in recent years it is possible that the rapid winter wheat harvest meant there was little time for saprophytic fungi to develop in cereal ears, which in turn meant less food for adult WBF females. As a result they produced less eggs than in a wetter season their fungal food source is more plentiful.

Average egg numbers in the east of England were 131/m$^2$ which is almost twice as high as in the north of England where 66/m$^2$ were recorded. Over all sites, the highest risk was after sugar beet (Figure 2), with a mean of 186 eggs/m$^2$. The next highest risk was after spring beans, with 123 eggs/m$^2$ although only one site was sampled. The highest individual count was 726 eggs/m$^2$ followed by 507 eggs/m$^2$ both after sugar beet in Cambridgeshire.

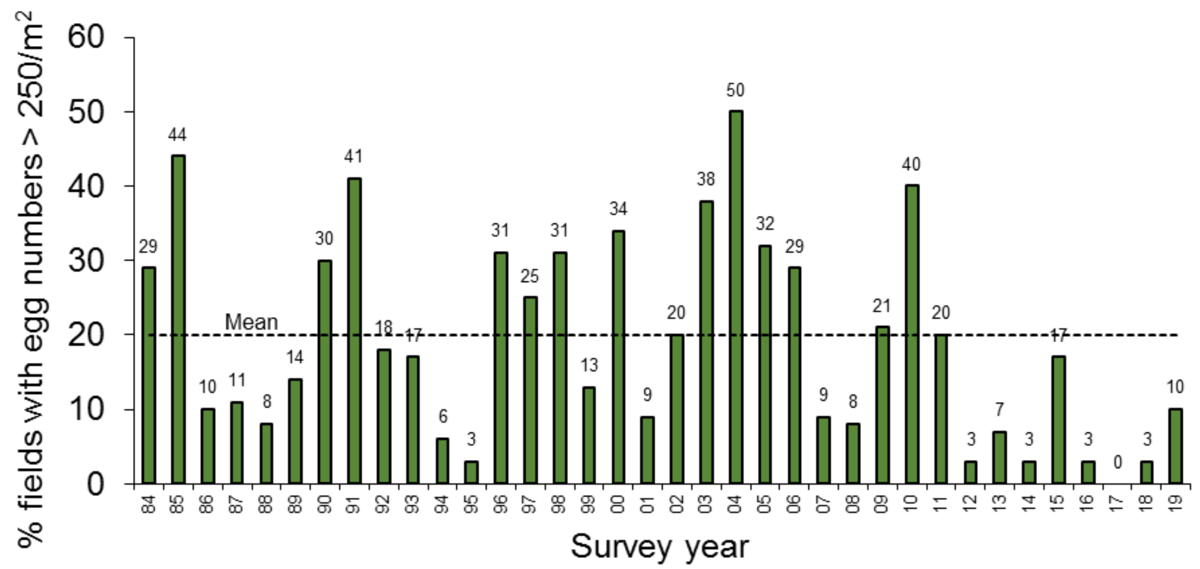


**Figure 1.** Wheat bulb fly annual risk levels 1984–2019 and overall mean (dashed line). Fields at risk have >250 eggs/m$^2$

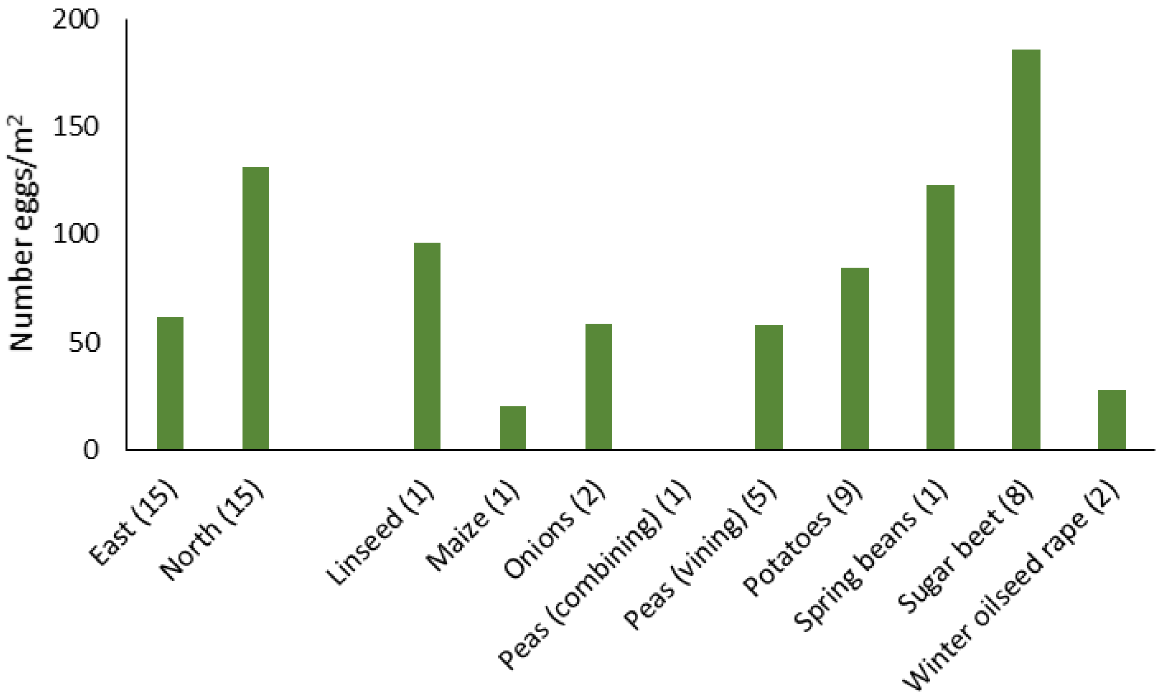


**Figure 2.** Average egg counts by region and previous crop in autumn 2019 (number of sites in brackets).

### 4.1. Eastern England

The mean egg number was 131 eggs/m² for sites sampled in eastern England. This is the third highest count since 2010 with higher numbers of eggs recorded in 2011 (179/$m^2$) and 2010 (309/$m^2$). However it should be noted that this result is heavily influenced by two very high counts of 726 and 507 eggs/$m^2$ in Cambridgeshire. All the remaining thirteen sites had counts of less than 123 eggs/$m^2$. It was also interesting that the six samples taken from organic soils had higher egg counts than any of those taken from mineral soils. The mean egg count from the six organic soils was 278 eggs/$m^2$ whereas from the mineral soils it was 34 eggs/$m^2$. Therefore, the potential for WBF damage in eastern England is organic soils is greater than in mineral soils although the two very high counts again have a significant impact on the mean egg count for organic soils.

Overall the risk to crops sown at a conventional timing (before November) is still relatively low with only two sites (13%) with egg numbers above the 250 eggs/$m^2$ threshold. 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 two highest egg counts of 726 eggs/$m^2$ and 507 eggs/$m^2$ were both after sugar beet in Cambridgeshire. In total 11 of the 15 sites sampled had egg numbers lower than 100 eggs/$m^2$. Sugar beet had the highest mean number of eggs of all crops sampled (186 eggs/$m^2$, Table 3). This value was heavily influenced by the very high counts discussed above. .

**Table 3.** Mean eggs/m² and preceding crops in eastern England in autumn 2019 (range in brackets).

| Preceding crop | Number of fields sampled | Mean number of eggs per m² |
|---|---|---|
| Linseed | 1 | 96 |
| Maize | 1 | 21 |
| Onions | 2 | 58 |
| Potatoes | 2 | 62 |
| Spring beans | 1 | 123 |
| Sugar beet | 8 | 186 |
| Mean egg count | | 131 (0–726) |

In eastern England, two of the sampled fields were in the very high risk category (13%) and none in the high risk category (Table 4). Of the remaining 13 sites two were in the moderate category(13%) and 11 in the low category (74%).

**Table 4.** Infestation categories and preceding crops in eastern England in autumn 2019.

| 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) |
| Linseed | 1 | 0 | 0 | 0 |
| Maize | 1 | 0 | 0 | 0 |
| Onions | 1 | 1 | 0 | 0 |
| Potatoes | 2 | 0 | 0 | 0 |
| Spring beans | 0 | 1 | 0 | 0 |
| Sugar beet | 6 | 0 | 0 | 2 |
| Total | 11 | 2 | 0 | 2 |
| % of fields by infestation category | 74 | 13 | 0 | 13 |

## 4.2. Northern England

The mean egg number was 66 eggs/m² for northern England (Table 5). This is the lowest count since 2010. The highest egg population of 270 eggs/m² was recorded in East Yorkshire after potatoes. The highest overall risk was also after potatoes with 92 eggs/m$^2$. In northern England none of the sampled fields was in the very high risk category, one was in the high risk category (7%), two were in the moderate category (13%) and 12 in the low risk category (80%) (Table 5).

**Table 5.** Numbers of eggs/m² and preceding crops in northern England in autumn 2019 (range in brackets).

| Preceding crop | Number of fields sampled | Mean number of eggs per m² |
|---|---|---|
| Peas (combining) | 1 | 0 |
| Peas (vining) | 5 | 58 |
| Potatoes | 7 | 92 |
| Winter oilseed rape | 2 | 28 |
| Mean egg count | | 66 (0–270) |

Overall, three fields (20%) were in risk categories of moderate or above, which is the lowest recorded since 2009 (2018 33%, 2017 27%, 2016: 27%, 2015: 87%, 2014: 53%, 2013: 40%, 2012: 27%, 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 2019.

| 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) |
| Peas (combining) | 1 | 0 | 0 | 0 |
| Peas (vining) | 4 | 1 | 0 | 0 |
| Potatoes | 5 | 1 | 1 | |
| Winter oilseed rape | 2 | 0 | 0 | 0 |
| Total | 12 | 2 | 1 | 0 |
| % of fields by infestation category | 80 | 13 | 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 2019, only three of the fields sampled (10%) were over the 250 eggs/$m^2$ threshold (2.5 million eggs/ha) for crops sown in September or October. The overall risk has been equal to or lower than this in 13 other years since monitoring began in 1984. As in recent years it is possible that this is due to a low level of saprophytic fungi in the wheat ears which provide food for wheat bulb fly adults. The levels of fungi in the ears is likely to be influenced by whether the harvest was early or late. If wet weather delays the harvest this would provide the environmental conditions and the time necessary for the development of saprophytic fungi. The 2019 wheat harvest was for the most part relatively straightforward and progress was in line with the early harvests of recent years. As a result there was little time and insufficient moisture for fungal development in wheat ears. With a limited food supply WBF adults will produce fewer eggs than in a season in which their food is plentiful.

Mean egg numbers in the east were almost twice as high as in the north with 131 eggs/m$^2$ in the north and 66 eggs/m$^2$ in the north. This result was heavily influenced by two very high counts of 726 eggs/m$^2$ and 507 eggs/m$^2$ after sugar beet in the east of England.

### 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 27% of monitored fields were above this level and in the north 20% of fields were above this level. All fields in the moderate infestation category would benefit from a seed treatment if sown after November.

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 |

## 5.3. Chemical control

Seed treatment (tefluthrin + fludioxinil, Austral Plus or 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. 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 treatments are the only chemical control option currently available for WBF and these are only 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’ (RD 2140047118). This project has developed a threshold scheme for the pest which is reliant on manipulating sowing date and/or target plant population (through seed rate) in order to produce a crop which is sufficiently robust to tolerate pest attack. This approach takes advantage of the fact that wheat crops often produce more shoots than are required to achieve potential yield. Consequently these excess shoots can be sacrificed to pests without affecting yield. It should be stressed that the threshold model used to predict sow dates and changes in target plant population is a prototype and is likely to go through further iterations of testing and development before it is finalised. Nonetheless it is an important step in the sustainable management of WBF and follows on from the work to re-evaluate thresholds for pollen beetle in oilseed rape which also took advantage of the fact that this crop produces more buds than it needs to achieve potential yield.

Being able to predict sowing date and target plant population to produce crops that are tolerant of WBF attack effectively provides another control method for this pest. It is conceivable that manipulation of sowing date and/or plant population could be used instead of seed treatments for late sown crops although the relative economics of these control options will need to be evaluated. In those situations where cropping decisions are made too late for application of seed treatments the current threshold model will at least provide the opportunity to assess the likely cost of manipulating seed rate so that it could be compared with potential options for spring cropping.

Predicting the annual risk of WBF attack is crucial to making early decisions on WBF control, whether this be to use a seed treatment for late sown crops or manipulate sowing date and/or seed rate for those sown at a more conventional timing. Soil sampling is effective but laborious and often too late to influence decisions for winter wheat crops. Risk prediction for WBF is an important area for future research and is another objective of the current project. Young and Cochrane (1993) used stepwise regression analysis to identify the most important relationships of meteorological variables with mean annual egg numbers or the proportion of fields sampled with egg numbers in excess of the action threshold of 2.5 million eggs/ha. This resulted in a regression equation using departures from average of July temperature, August rain days and the percentage of October (preceding year) rainfall. Up to 59% of the variation in the annual proportion of fields above threshold was accounted for and estimated mean annual egg populations and the proportion of fields above threshold showed a good fit with observed values. Historic data from the autumn survey of WBF incidence going back to 2005 will be used to help test the Young and Cochrane model with more recent met data. The model will be run to predict the WBF risk for each of the survey years and this will be compared with the overall average egg counts for those years. If met data is available for individual sites this could also be used to generate a risk prediction for that site.

The AHDB Cereals and oilseeds funded PhD ‘Enhancing management of wheat bulb fly via the use of lure and kill and assessment of egg numbers RD-2007-3361’ developed a real time PCR assay to determine WBF risk as an alternative to large scale soil sampling. The technique uses a much smaller soil sample than is required for traditional egg counts and was able to show good correlation between mean quantity of WBF DNA and WBF eggs/m$^2$ ($R^2$ =0.997). A reduction in soil sample size shows a significant advantage over the current soil sampling methodology. The final objective of this project (initially in 2019 only) will be to validate PCR methodology on English soil samples taken from those sites selected for the autumn survey of WBF incidence. Additional small soil samples (approx. 400g) have been taken alongside those collected for egg counting in the east and north of England to provide material that will be subjected to PCR analysis. The dataset could be enhanced further by inclusion of PCR analysis of soil samples taken as part of the annual Scottish survey of WBF incidence. This work is collaborative with SRUC in Scotland.

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## Appendix A

### Egg populations ranked in descending order for 15 fields sampled in eastern England in autumn 2019

| County | Previous crop | Number of eggs (number/m$^2$) | Soil type | Risk category |
|---|---|---|---|---|
| Cambridgeshire | Sugar beet | 726 | Organic | Very high |
| Cambridgeshire | Sugar beet | 507 | Organic | Very high |
| Cambridgeshire | Spring beans | 123 | Organic | Moderate |
| Cambridgeshire | Onions | 116 | Organic | Moderate |
| Cambridgeshire | Linseed | 96 | Organic | Low |
| Cambridgeshire | Potatoes | 96 | Organic | Low |
| Norfolk | Sugar beet | 82 | Mineral | Low |
| Camridgeshire | Sugar beet | 69 | Mineral | Low |
| Norfolk | Sugar beet | 48 | Mineral | Low |
| Norfolk | Sugar beet | 34 | Mineral | Low |
| Cambridgeshire | Potatoes | 27 | Mineral | Low |
| Cambridgeshire | Maize | 21 | Mineral | Low |
| Norfolk | Sugar beet | 14 | Mineral | Low |
| Norfolk | Sugar beet | 7 | Mineral | Low |
| Cambridgeshire | Onions | 0 | Mineral | Low |
| Mean | | 131 | | |

## Appendix B

## Egg populations ranked in descending order for 15 fields sampled in northern England in autumn 2018

| County | Previous crop | Number of eggs (number/m²) | Risk category |
|---|---|---|---|
| East Yorkshire | Potatoes | 270 | High |
| North Yorkshire | Vining peas | 136 | Moderate |
| North Yorkshire | Potatoes | 105 | Moderate |
| North Yorkshire | Potatoes | 74 | Low |
| East Yorkshire | Potatoes | 62 | Low |
| East Yorkshire | Potatoes | 56 | Low |
| East Yorkshire | Vining peas | 56 | Low |
| East Yorkshire | Potatoes | 49 | Low |
| East Yorkshire | Vining peas | 43 | Low |
| East Yorkshire | Vining peas | 37 | Low |
| East Yorkshire | WOSR | 31 | Low |
| East Yorkshire | Potatoes | 25 | Low |
| East Yorkshire | WOSR | 25 | Low |
| East Yorkshire | Vining peas | 19 | Low |
| North Yorkshire | Combining peas | 0 | Low |
| Mean | | 66 | |