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Autumn survey of wheat bulb fly incidence 2022

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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:

1. To measure the incidence of WBF in autumn 2022 in eastern and north eastern England.
2. To forecast the need for seed treatment in autumn 2022.
3. To test the model for prediction of WBF risk.

Thirty fields were sampled for WBF eggs in September 2022 in areas prone to the pest, with 15 in eastern England and 15 in north eastern England. The sites were chosen to represent some of the main preceding crops leading to a risk of WBF damage. For crops sown in September and October, the damage threshold (the egg population having an economic impact on yield) is 250 eggs/m² (2.5 million eggs/ha). In autumn 2022, one field was considered at high risk (250-500 eggs/m^2), eight at moderate risk (100-249 eggs/m^2) and 21 at low risk (<100 eggs/m^2). This was equivalent to 3%, 27% and 70% of fields in the high, moderate and low risk infestation categories, respectively. The overall risk in 2022 is the second lowest since 2012. This may have been due to the dry summer and rapid harvest in 2022.

As in 2021 and 2020, it was noted that the 10 samples from organic soils had a higher mean egg count (81/m^2) than the five samples from mineral soils (23/m^2). This suggests that WBF damage in eastern England in organic soils may be greater than in mineral soils. Average egg numbers were higher in the north east than in the east, with 100 eggs/m^2 in the north and 62 eggs/m^2 in the east. Over all sites, the highest risk was after red beet with a mean of 151 eggs/m^2, followed by seed potatoes with 142 eggs/m^2. The model for predicting WBF risk showed that mean predicted egg counts over all 30 sites sampled correlated well with soil counts. Counts for individual regions were, however, very different from soil counts for the same areas. The model predicts much higher counts for the east than was the case, and much lower counts for the north east.

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 north east of England, 40% of sites were above this level and in the east, it was 13%. All fields in the moderate category or above 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 the bare soil following fallows or early harvested crops, such as vining peas. If fields are cultivated between mid-July and mid-August they are particularly attractive. 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 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. Eggs will remain dormant throughout late autumn and early winter until 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, mainly because of 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 can 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 exceeding 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).

Cereal harvest in the UK in 2022 progressed relatively unhindered since its start in early July and was completed early for most growers. An estimated 95% of crops were harvested by the 23rd of August 2022, which was faster than the five-year average. Winter wheat harvest got off to an early start in the last week of July and progress continued well throughout July and August. Peak harvest occurred in the week ending the 9th of August with almost 650,000ha cleared in a single week. Mild, dry weather meant that crops were easy to harvest, and straw was baled in good condition almost immediately after harvest.

The survey will help determine if this is the case and provide valuable information on the potential risk from the pest for the 2022/23 season.

The overall objective of the autumn survey of WBF incidence is to establish the annual incidence of WBF in autumn 2022, the risk of subsequent damage and to test the model for prediction of WBF risk.

The specific objectives of the project are:
1. To measure the incidence of WBF in autumn 2022 in the east and north east of England.
2. To forecast the need for seed treatment in autumn 2022.
3. To test the model for prediction of WBF risk.

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 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 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.

Data from soil sampling were also used to test a model developed to predict WBF numbers. The model uses a range of meteorological parameters and is described by Leybourne et al, (2022). Mean counts from soil sampling for the east, north east and the two areas combined were compared with model predictions.

3. Materials and methods

A total of 30 fields were sampled in September 2022 in areas prone to WBF, with 15 in the east of England and 15 in the north east of England (Table 1). The survey was stratified to represent some of the main preceding crops (Table 2) leading to a risk of WBF damage in each area.

For each field sampled, 32 cores of 7.2 cm diameter, or 20 cores 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 (Salt & Hollick, 1944). Egg numbers were expressed as number of eggs per m². The total number of WBF eggs recovered from area of soil comprising 32, 7.2cm or 20 10cm diameter cores was used to calculate egg numbers per m^2 and per ha.

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

Region	County	Number of fields sampled
Eastern England	Cambridgeshire	10
	Norfolk	5
	Total	15
North eastern England	East Yorkshire	11
	North Yorkshire	4
	Total	15

Table 2. Preceding crop for sampled fields.

Preceding crop	Eastern England	Northern England
Green beans	1	0
Maize	2	0
Onions	3	0
Potatoes	4	0
Potatoes (seed)	0	1
Red beet	1	0
Sugar beet	4	0
Vining peas	0	13
Winter beans	0	1
Total	15	15

4. Results

In autumn 2022, one of the sampled fields was considered at high risk (egg numbers 250-500/m^2), eight at moderate risk (egg numbers 100-249/m^2 and 21 at low risk (egg numbers <100/m^2). This was equivalent to 3%, 27% and 70% of fields in the high, moderate and low risk infestation categories, respectively. A total of 3% 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 2022 is the second lowest it has been since 2012 (2017 had 0% of sites over the 250 eggs/m^2 threshold) and well below the average of 18% of sites above the 250 eggs/m^2 threshold for monitoring since 1984. Since 1984 the overall risk has been higher than 2022 on 32 occasions and lower than 2022 on one occasion and equal to 2022 on five occasions. This was possibly t due to the dry summer and rapid harvest in 2022 which meant that there was little time for saprophytic fungi to develop in cereal ears, which resulted in limited food for adult WBF females, coupled with low numbers of eggs being laid.

Average egg numbers in the north east of England were 100/m^2 which is higher than in the east of England where 62/m^2 were recorded (Figure 2). Over all sites, the highest risk was after red beet with a mean of 151 eggs/m^2, followed by seed potatoes with 142 eggs/m^2. Though in both cases one site was sampled. The highest individual count was 274 eggs/m^2 after potatoes followed by 199 eggs/m^2 after onions. Both sites were in organic soils in Cambridgeshire.

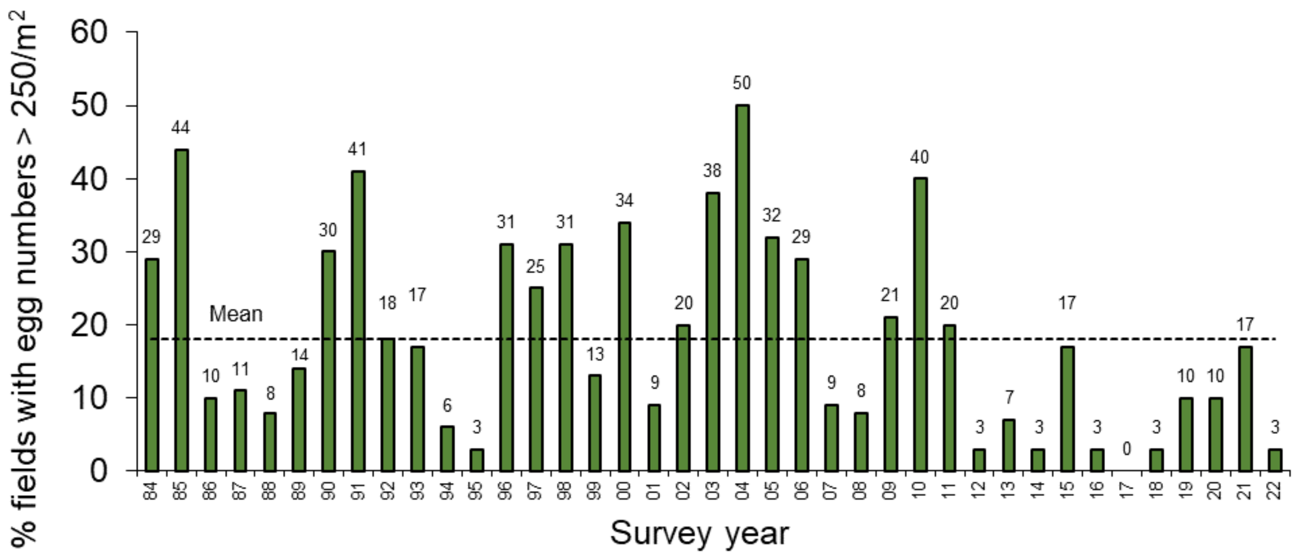

Figure 1. Wheat bulb fly annual risk levels 1984–2022 and overall mean (dashed line). Fields at risk have >250 eggs/m^2

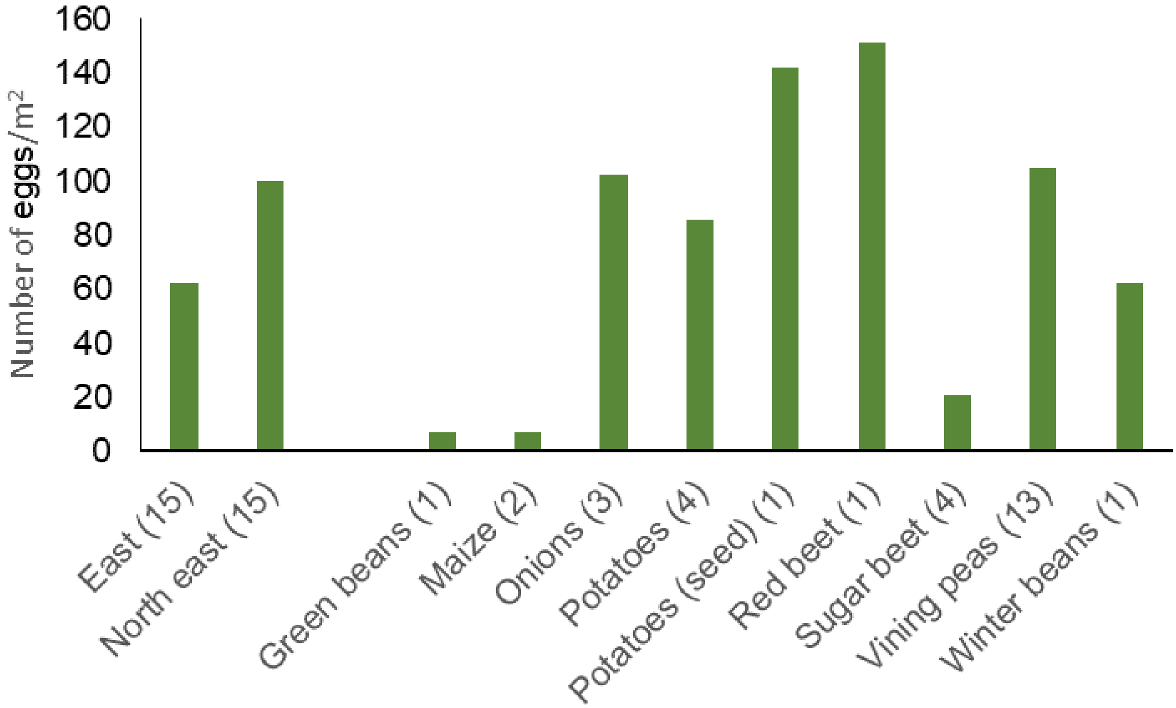

Figure 2. Average egg counts by region and previous crop in autumn 2022 (number of sites in brackets).

4.1. Eastern England

The mean egg number was 62 eggs/m² for sites sampled in eastern England. This is lower than in 2021 (143 eggs/m^2). In general, counts from individual sites in the east of England in 2022 were lower than in 2021 with 12 sites in the low category in 2022 and nine in 2021. As in 2021 and 2020, it was interesting that the 10 samples taken from organic soils had a higher mean egg count (81/m^2) than the five samples from mineral soils (23/m^2). All egg counts over 100/m^2 (three sites) were recorded in organic soils. Therefore, the potential for WBF damage in eastern England in organic soils may be greater than in mineral soils.

Overall, one site (7%) had egg numbers above the 250 eggs/m^2 threshold for crops sown at the conventional timing (before November). The equivalent figure for 2021 was 27%, and for 2020 it 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 274 eggs/m^2 was after potatoes, the second highest of 199 eggs/m^2 was after onions and the third highest of 151 eggs/m^2 was after red beet. Each of these sites was located in Cambridgeshire. In total, 12 of the 15 sites sampled (67%) had egg numbers lower than 100 eggs/m^2. Red beet had the highest mean number of eggs of all crops sampled (151 eggs/m^2, Table 3) but only one site was sampled. Onions had the next highest count of 103 eggs/m^2.

Table 3. Mean eggs/m² and preceding crops in eastern England in autumn 2022 (range in brackets).

Preceding crop	Number of fields sampled	Mean number of eggs per m²
Green beans	1	7
Maize	2	7
Onions	3	103
Potatoes	4	86
Red beet	1	151
Sugar beet	4	21
Mean egg count		62 (0–274)

In eastern England, one of the sampled fields was in the high-risk category (7%), two in the moderate category (13%) and twelve in the low category (80%, Table 4). Overall, three fields (20%) were in risk categories of moderate or above.

Table 4. Infestation categories and preceding crops in eastern England in autumn 2022.

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)
Green beans	1	0	0	0
Maize	2	0	0	0
Onions	2	1	0	0
Potatoes	3	0	1	0
Red beet	0	1	0	0
Sugar beet	4	0	0	0
Total	12	2	1	0
% of fields by infestation category	80	13	7	0

4.2. North eastern England

The mean egg number was 100 eggs/m² for north eastern England (Table 5). The highest egg population of 173 eggs/m² was recorded in North Yorkshire after vining peas. The highest overall risk predicted was after seed potatoes with an average of 142 eggs/m^2, although only one site was sampled. This was followed by vining peas with 105 eggs/m^2. Winter beans were the only other crop sampled and had a mean of 62 eggs/m^2.

Table 5. Numbers of eggs/m² and preceding crops in north eastern England in autumn 2022 (range in brackets).

Preceding crop	Number of fields sampled	Mean number of eggs per m²
Potatoes (seed)	1	142
Vining peas	13	105
Winter beans	1	62
Mean egg count		100 (62–173)

In north eastern England, there were no sampled fields in the very high- or high-risk category. Six were in the moderate category (40%) and nine in the low-risk category (60%, Table 6).

Overall, six fields (40%) were in risk categories of moderate or above, which is higher than in 2020 (27%) and 2018 (33%), and the same as in 2013. This represents a moderate risk to crops sown after November.

Table 6. Infestation categories and preceding crops in north eastern 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)
Potatoes (seed)	0	1	0	0
Vining peas	8	5	0	0
Winter beans	1	0	0	0
Total	9	6	0	0
% of fields by infestation category	60	40	0	0

4.3. Testing the model for prediction of WBF risk

The model was applied to samples from both the east and northeast of England, and results compared with egg numbers from soil counts for both areas. The results are given in Table 7. Mean predicted egg counts over all 30 sites sampled show a good correlation with soil counts. The revised model is just 1% above the soil counts and the Young and Cochrane (1993) model 7% lower than soil counts. Counts for individual regions are, however, very different from soil counts for the same areas. The revised model predicts much higher counts for the east than was the case, and much lower counts for the north.

Table 7. Comparison of WBF egg counts (number/m^2) from soil sampling and those from predictive models in 2022.

	East	North east	Mean
Egg counts from soil sampling	62	100	81
Predicted egg counts from Young & Cochrane (1993)	111	38	75
Predicted egg counts from revised model	118	45	82

5. Discussion

Egg populations above 250 eggs/m^2 present a risk of economic damage to winter wheat crops drilled in September and October. Egg numbers above 100 eggs/m^2 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 2022, only one of the fields sampled (3%) was over the 250 eggs/m^2 threshold (2.5 million eggs/ha) for crops sown in September or October. The overall risk in 2022 is the second lowest it has been since 2012 (2017 had 0% of sites over the 250 eggs/m^2 threshold) and well below the average of 18% of sites above the 250 eggs/m^2 threshold for monitoring since 1984. Since 1984 the overall risk has been higher than 2022 on 32 occasions, lower than 2022 on one occasion and equal to 2022 on five 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. It is possible that the dry summer and rapid harvest in 2022 meant that there was little time for saprophytic fungi to develop in cereal ears, which resulted in limited food for adult WBF females and low numbers of eggs being laid.

Mean egg numbers in the north were 100 eggs/m^2 in the east they were 62 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 north of England 40% of monitored fields were above this level and in the east 13% 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.

A summary of control strategies for WBF in relation to egg numbers and sowing date is given in Table 8.

Table 8. Wheat bulb fly thresholds (egg numbers/m^2) that 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 (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 the only available option for those crops sown before November as seed treatments are insufficiently persistent.

The impact of WBF can be reduced by sowing early and increasing 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 using 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 larvae was typically four. Independent tests showed that 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.

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.

A revised WBF risk prediction model was developed based on the Young & Cochrane model (Young & Cochrane 1993). The Young & Cochrane model used January air temperature, January soil temperature, July air temperature, and rainfall during the preceding October to predict WBF egg density and had a reported predictive power (accuracy) of 59%. The updated risk prediction model incorporated a wider range of meteorological parameters (preceding September sunshine days, preceding October rain days, January mean temperature, January frost days, April maximum temperature, April rainfall, May maximum temperature, July minimum temperature) and has a predictive power of 70% (Leybourne *et al.*, 2022), an 11% increase when compared with the original Young & Cochrane model. This model was run using meteorological data for 2021/22 and results compared with those from soil sampling.

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 revised predictive model was very accurate when compared to mean soil counts over all 30 sites sampled but far less accurate in its predictions of egg counts for both the east and north east regions. Egg numbers in the east were overestimated and numbers in the north were underestimated. These results are difficult to explain. In 2020, the revised model predicted 107 eggs/m^2 for the north compared with an actual count of 111 eggs/m^2 and 60 eggs/m^2 for the east compared with an actual count of 173 eggs/m^2. However, the eastern soil count was driven by three high egg counts of 100, 850 and 404 eggs/m^2 from three sites on organic soils. Further development and refinement by inclusion of model moderators such as soil type and possibly previous crop would allow the production of a more robust and dynamic model (Leybourne *et al*., 2022). That the highest egg counts in 2020 in the east were all in organic soil suggests that soil type may influence the egg laying preferences of WBF. In 2021 and 2022, it was also noticeable that in the east, the highest egg counts were recorded in organic soil. Previous crop in the rotation also affects WBF egg laying so including soil type and previous crop in subsequent model improvements represents the next logical step in model development.

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 2022

County	Previous crop	Number of eggs (number/m^2)	Soil type	Risk category
Cambridgeshire	Potatoes	274	Organic	High
Cambridgeshire	Onions	199	Organic	Moderate
Cambridgeshire	Red beet	151	Organic	Moderate
Cambridgeshire	Onions	75	Organic	Low
Cambridgeshire	Potatoes	48	Organic	Low
Norfolk	Onions	34	Mineral	Low
Norfolk	Sugar beet	34	Mineral	Low
Norfolk	Sugar beet	34	Mineral	Low
Cambridgeshire	Potatoes	21	Organic	Low
Cambridgeshire	Sugar beet	21	Organic	Low
Cambridgeshire	Maize	14	Organic	Low
Norfolk	Sugar beet	14	Mineral	Low
Cambridgeshire	Green beans	7	Organic	Low
Cambridgeshire	Maize	0	Organic	Low
Norfolk	Sugar beet	0	Mineral	Low
Mean		**62**		

Appendix B

Egg populations ranked in descending order for 15 fields sampled in north easternEngland in autumn 2022. All fields are mineral soil types.

County	Previous crop	Number of eggs (number/m²)	Risk category
North Yorkshire	Vining peas	173	Moderate
East Yorkshire	Seed potatoes	142	Moderate
North Yorkshire	Vining peas	130	Moderate
North Yorkshire	Vining peas	123	Moderate
East Yorkshire	Vining peas	117	Moderate
North Yorkshire	Vining peas	105	Moderate
East Yorkshire	Vining peas	99	Low
East Yorkshire	Vining peas	93	Low
East Yorkshire	Vining peas	93	Low
East Yorkshire	Vining peas	86	Low
East Yorkshire	Vining peas	74	Low
East Yorkshire	Vining peas	74	Low
East Yorkshire	Vining peas	68	Low
East Yorkshire	Vining peas	62	Low
East Yorkshire	Winter beans	62	Low
Mean		**100**	