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Cabbage stem flea beetle larval survey (2015)

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AHDB Cereals & Oilseeds is a division of the Agriculture and Horticulture Development Board (AHDB).

CONTENTS

1. Abstract

Cabbage stem flea beetle (CSFB) larval populations were monitored using plant dissection at sites in Bedfordshire, Cambridgeshire, Hampshire, Hertfordshire, Suffolk and Surrey. High and low risk sites (based on incidence of previous adult feeding damage) were assessed in each county. Sampling occurred in February and April, 2015. Presence of leaf-scarring on plants was also recorded. Data specific to the sampled field was collected, including insecticide use, yield at harvest and the field average five-year WOSR yield.

The overall aim of the project was to assess the impact of the 2014/15 infestations of CSFB larvae, and the measures used to control them, on the winter oilseed rape crop in selected areas of England. Specific objectives were:

1. To determine whether high autumn levels of crop damage from adult CSFB are associated with large CSFB larval populations.
2. To provide preliminary information on the impact of CSFB larval number on yield.
3. To determine whether the presence of larvae is always indicated by presence of leaf-scarring.

Larval populations above the treatment threshold (more than five larvae per plant in late October/early November) were found in all counties except Surrey, with the largest population in Cambridgeshire (27.8 larvae per plant). Larval populations were generally related to adult feeding damage during crop establishment (as reported by agronomists) with large differences between high and low risk sites in Bedfordshire, Cambridgeshire and Hampshire. Pest pressure was fairly uniform between high and low risk sites within Hertfordshire, Suffolk and Surrey. The majority of larvae were found in the petioles rather than the stems in both February and April. The presence or absence of leaf-scarring provided a reliable and easily identifiable indicator of larval infestation. The control of CSFB relied solely on the application of pyrethroid insecticides at the sites monitored. The effectiveness of these sprays against CSFB adults was mixed and at many sites they were unable to prevent the build-up of larval populations (although it is accepted that effectively controlling adults does not necessarily result in low numbers of CSFB larvae as eggs may be laid before adult beetles are killed and larvae may hatch when sprays are no longer effective).

At nine out of 12 sites for which historic yield data were available, the 2015 OSR yield was lower than the five year field average yield. The average yield reduction was 0.52 t/ha and the average yield across all sites was 3.5t/ha. The larval populations did not have a clear effect on yield, although a general trend for decreasing yield with increasing larval numbers was found. Few symptoms of turnip yellow virus (TuYV) were recorded in most counties.

This work highlights where CSFB larval pressure was greatest in the counties assessed in 2014/15, and that the treatments used provided inadequate control of the pest in some areas.

More information is needed to better understand how larval behaviour and numbers impact on crop physiology and yield.

2. Introduction

A restriction on the use of the neonicotinoids, clothianidin, imidacloprid and thiamethoxam, was enforced by the European Commission on 1 December 2013. The 2014 winter oilseed rape (WOSR) crop was the first for which neonicotinoid seed treatments were not available to protect plants during emergence and establishment.

Prior to the restriction, neonicotinoid seed treatments had been widely used to reduce damage during the establishment phase of the crop. A primary pest for which neonicotinoid seed treatments provided protection was cabbage stem flea beetle, *Psylliodes chrysocephala*, (CSFB). The beetles migrate into establishing WOSR and chew holes in cotyledons and early true leaves, causing 'shot-holing' symptoms. This results in stunting and poor plant vigour and occasionally total crop failure. The beetles lay eggs at the base of plants and hatching larvae bore into the leaf petioles from mid-October, where they feed throughout the winter, moving from the petioles to the stems. Larval feeding affects plant vigour, resulting in stunted plants with impaired stem elongation in the spring.

CSFB is estimated to affect around 67% of the total area of OSR (or 438,180 ha, based on the five-year average harvested area of 654,000 ha) (Clarke *et al*., 2009). In the 2009 Research Review (RR70) (Clarke *et al*., 2009) it was estimated that, in untreated crops, the average annual yield loss from CSFB would be 1%, or 15,336 t (based on 67% of the area affected and the five-year average annual yield of OSR of 3.5 t/ha). This equates to an annual loss of £5 million (using the July 2007 to mid-April 2013 average delivered Erith OSR price of £327.13 per tonne) or 0.7% of the total value of the crop (Nicholls, 2013).

The current recommended treatment threshold for CSFB larvae is five larvae per plant in late October/early November; however, it is unclear what impact such pest pressure has on yield. The threshold (previously two larvae per plant) was updated in 2015 to reflect changes in the economics of controlling the pest following the allowance of alternative control options through 120 day Emergency Use Authorisations and also the confirmation of resistance to pyrethroid insecticides.Assessing larval numbers can be done by plant dissection, usually in a laboratory with experienced staff, although this can be relatively expensive and time-consuming and can become uneconomic when insecticide treatments are inexpensive (Walters *et al*., 2001). Alternative thresholds for CSFB larvae are if the average number of beetles per yellow water trap caught from early September until the end of October exceeds 96, or if more than 50% of petioles exhibit entry and exit hole damage (leaf-scarring (Walters *et al*., 2001)).

In light of the neonicotinoid restriction, foliar-applied pyrethroids or a single autumn application of InSyst (acetamiprid) were the only alternatives to seed treatments in autumn 2014. However, in September 2014 (as part of AHDB Cereals & Oilseeds Project 214-0019), it was announced that knock-down resistance (kdr) (which confers reduced susceptibility to pyrethroids) was widespread in the UK, with pyrethroid-resistant beetles found in all samples tested and resistance genes occurring in 73% of individuals tested. A second mechanism, metabolic resistance, was also identified. It is likely that CSFB resistance to pyrethroids will cause problems controlling the pest.

The AHDB Cereals & Oilseeds-funded ‘Cabbage stem flea beetle snapshot assessment’ (PR546 – Extension) estimated that by the end of September 2014, 2.7% of the national area of winter OSR had been lost (mainly attributed to CSFB adult feeding damage). Regional variation in damage was also evident, with counties in the east and south east worst affected. In some regions, crop losses were estimated at 4.4%, with a further 46% of crop area exhibiting damage that exceeded the treatment thresholds (Wynn *et al.,* 2014). This is despite the majority of crops in these areas being treated with repeat applications of pyrethroid sprays. In some counties (e.g. Cambridgeshire, Hertfordshire and Suffolk) three or four applications by the end of September was typical (Wynn *et al*., 2014). By December, national total crop losses due to CSFB were estimated at 5% (AHDB Cereals & Oilseeds, 2015).

The aims of the project were to assess CSFB larval populations in selected areas of England, determine if high autumn levels of crop damage from adult CSFB are correlated with large CSFB larval populations, provide preliminary information on the impact of CSFB larval number on yield and to determine whether the presence of larvae is always indicated by presence of leaf-scarring. The project monitored CSFB larval populations in six of the counties appraised as worst affected by adult feeding during crop establishment (as identified in the ‘Cabbage stem flea beetle snapshot assessment’). These were Bedfordshire, Cambridgeshire, Hampshire, Hertfordshire, Suffolk and Surrey. In each county sampling occurred at two sites; one at high risk and one at low risk of CSFB larval pressures. Agronomists were asked to identify sites based on the level of adult feeding damage the field had suffered during establishment. At each site, data on larval numbers, presence of leaf-scarring, yield and other agronomic activities (e.g., insecticide applications) were collected.

3. Materials and methods

3.1. Experimental sites

Independent agronomists from the Association of Independent Crop Consultants (AICC) identified fourteen WOSR fields in six counties for the study. Two fields were sampled in each of Cambridgeshire, Hampshire, Hertfordshire, Suffolk and Surrey, and four fields were sampled in Bedfordshire. In each county, agronomists were asked to select fields which had suffered contrasting levels of damage from adult CSFB during the establishment phase of the crop, i.e. one field with high levels of adult CSFB feeding damage (‘high risk’) and one field with low levels of adult CSFB feeding damage (‘low risk’) (except for Bedfordshire where two high risk and two low risk sites were selected due to a misunderstanding over site locations).

3.2. Plant sampling

All sites were first sampled between 17 and 26 February. Within counties, the time between sampling different sites was as short as possible (up to four days). High risk sites in Bedfordshire, Cambridgeshire, Hampshire, Hertfordshire and Suffolk were sampled a second time between 23 and 28 April. On each occasion, 25 plants were collected at random from each site and sent by courier to ADAS laboratories.

3.3. Leaf-scarring

Plants were assessed for the presence of leaf-scarring in the laboratory. Leaf-scars are the entry and exit holes created by the larvae in the stems and petioles as they move in and out of the plant.

3.4. CSFB larval populations

All leaf petioles and stems of sampled OSR plants were dissected in the laboratory. The numbers of CSFB larvae and their location in the plant (petiole or stem) were recorded.

3.5. Site data

Data specific to the sampled field was collected by agronomists at all sites. This included drilling date, drilling method, seed rate, insecticide use (and estimated control provided), pest pressures, yield at harvest and the field average five-year WOSR yield. These data were collected to give context to yield and larval numbers. However, the relatively low number of sites monitored in the project meant that robust comparisons between these factors and larval population/yield could not be made.

3.6. Turnip yellows virus

Visual symptoms of turnip yellows virus (TuYV) were recorded in April as a percentage of plants affected.

3.7. Data analyses

Statistical analysis of the relationship between CSFB larval numbers and site factors (e.g. county, risk, position, date) was done using ANOVA. GenStat® was used to analyse correlations between CSFB larval numbers and yield.

4. Results

4.1. CSFB larval populations

4.1.1. February

Larval populations in February varied significantly between counties (df = 5, F = 56.49, p < 0.001) (Figures 1a and 1b). The largest population was found at the high risk site in Cambridgeshire (mean of 27.8 larvae per plant) and the lowest at the low risk site in Hampshire (mean of 0.2 larvae per plant).

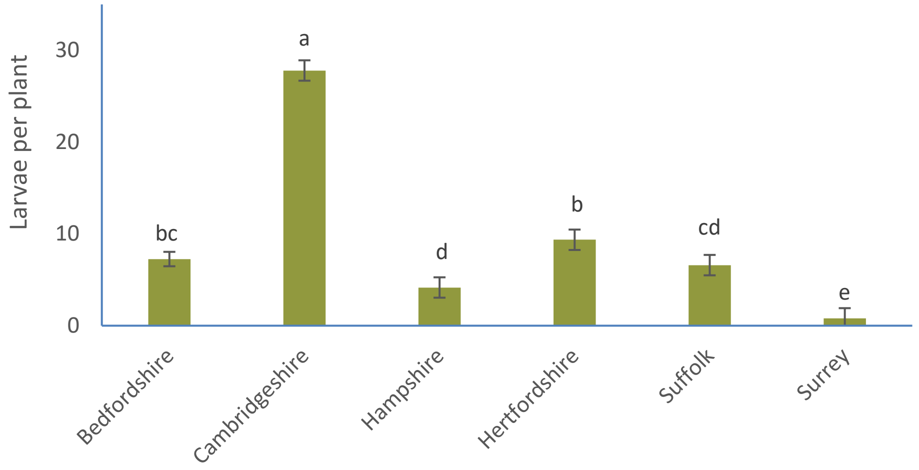

Figure 1a. Mean larvae per plant at high risk sites in each county in February. Bars indicate standard errors of the means. Bars followed by the same letter are not significantly different. Significant differences are identified using LSD.

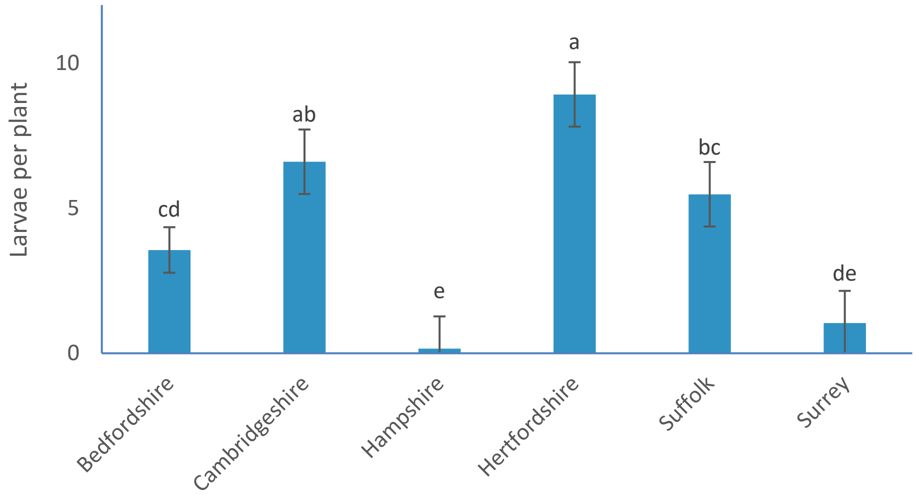

Figure 1b. Mean larvae per plant at low risk sites in each county in February. Bars indicate standard errors of the means. Bars followed by the same letter are not significantly different. Significant differences are identified using LSD.

Larval numbers were significantly higher at high risk sites than low risk sites (df = 1, F = 69.84, $p < 0.001$), indicating that there was a relationship between risk (based on the amount of adult feeding damage during establishment) and larval populations. However, an interaction with county was evident with significant differences in larval populations between high and low risk sites only in Bedfordshire, Cambridgeshire and Hampshire (df = 5, F = 26.79, $p < 0.001$).

The percentage of plants with more than five larvae (the autumn treatment threshold) was significantly different between counties (df = 5, F = 24.97, $p < 0.001$; Figures 2a and 2b) and within the same risk category between counties (df = 5, F = 5.01, $p < 0.001$). The highest percentage of plants with more than five larvae at the high risk sites was in Cambridgeshire (96%) and the lowest was in Surrey (4%). At the low risk sites, the highest percentage of plants with more than five larvae was in Hertfordshire (80%) and the lowest was in Hampshire (0%). The percentage of plants with more than five larvae was correlated with risk in most counties, being significantly higher at high risk sites than low risk sites in Bedfordshire, Cambridgeshire and Hampshire (df = 1, F = 5.01, $p < 0.001$)

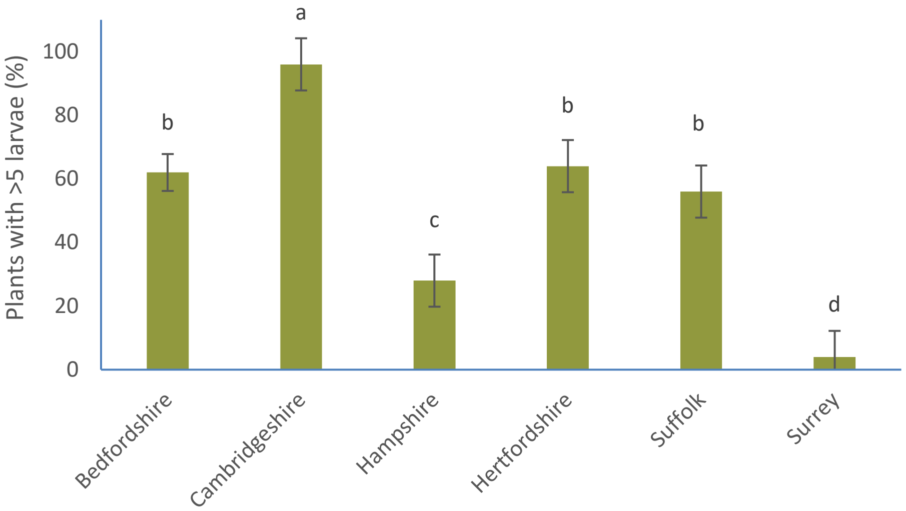

Figure 2a. Percentage of plants with more than five larvae at high risk sites in each county in February. Bars indicate standard errors of the means. Bars followed by the same letter are not significantly different. Significant differences are identified using LSD.

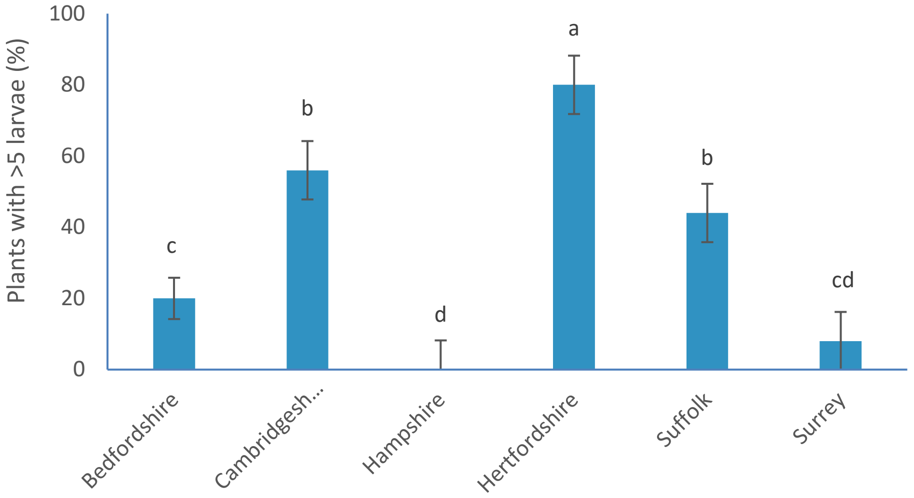

Figure 2b. Percentage of plants with more than five larvae at low risk sites in each county in February. Bars indicate standard errors of the means. Bars followed by the same letter are not significantly different. Significant differences are identified using LSD.

The percentage of plants with more than two larvae (the autumn threshold prior to 2015) was significantly different between counties (df = 5, F = 40.41, p < 0.001, Figure 3a and 3b). The highest percentage of plants with more than two larvae at the high risk sites was in Cambridgeshire (96%) and the lowest was in Surrey (12%). At the low risk sites, the highest percentage of plants with more than five larvae was in Hertfordshire (100%) and the lowest was in Hampshire (4%). The percentage of plants with more than two larvae was significantly higher at high risk sites than low risk sites in Bedfordshire and Hampshire (df = 1, F = 9.18, p < 0.001).

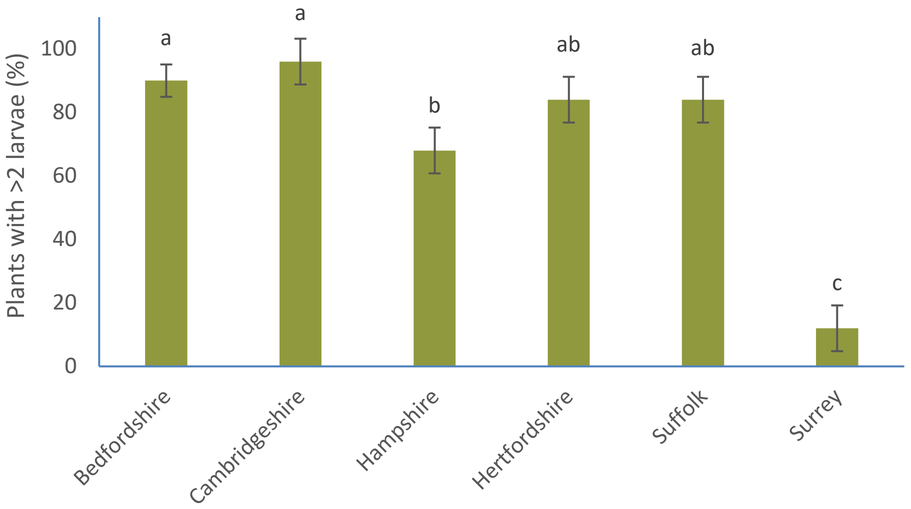

Figure 3a. Percentage of plants with more than two larvae at high risk sites in each county in February. Bars indicate standard errors of the means. Bars followed by the same letter are not significantly different. Significant differences are identified using LSD.

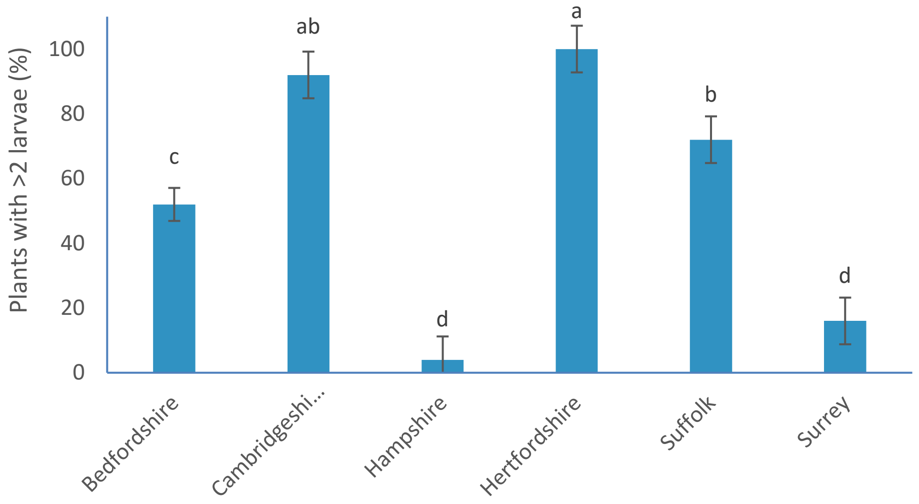

Figure 3b. Percentage of plants with more than two larvae at low risk sites in each county in February. Bars indicate standard errors of the means. Bars followed by the same letter are not significantly different. Significant differences are identified using LSD.

Significantly greater numbers of larvae were found in the petioles than the stems in February (df = 1, F = 416.17, $p < 0.001$), with an average of 94.7% of larvae in the petioles and 5.3% in the stem. An interaction of larval position with county and risk was found, with significantly more larvae found in the petiole than the stem at all high risk sites except Surrey (Figure 4a) and all low risk sites, except Hampshire and Surrey (Figure 4b) (df = 5, F = 20.15, $p < 0.001$).

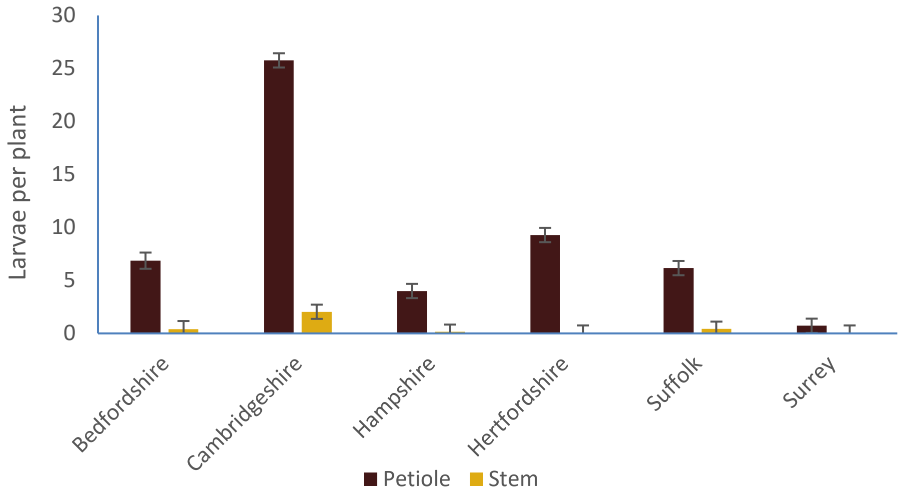

Figure 4a. Mean number of larvae in the petioles and stems at high risk sites in each county in February. Bars indicate standard errors of the means.

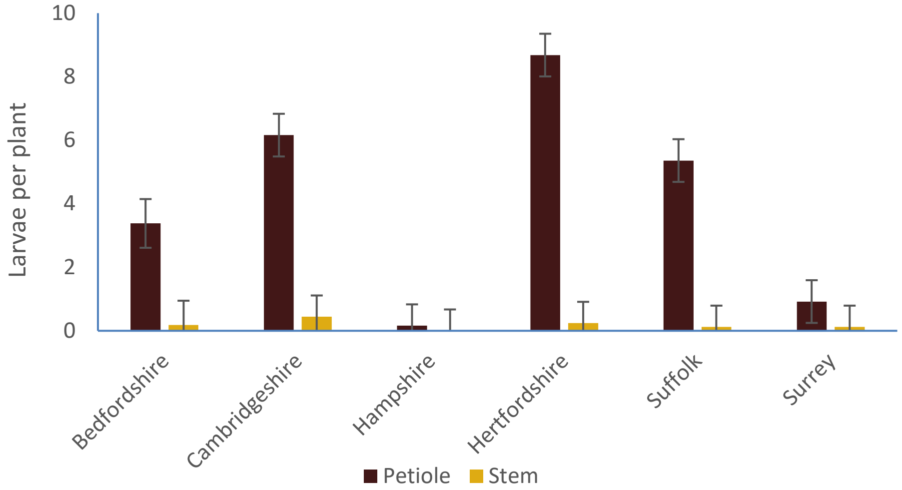

Figure 4b. Mean number of larvae in the petioles and stems at low risk sites in each county in February. Bars indicate standard errors of the means.

4.1.2. April

Larval populations in April varied significantly between counties (df = 4, F = 13.41, $p < 0.001$) (Figure 5). The smallest population was found in Suffolk (mean of 1.2 larvae per plant) and the largest population in Cambridge which had a significantly larger population than the other counties (mean of 5.8 larvae per plant).

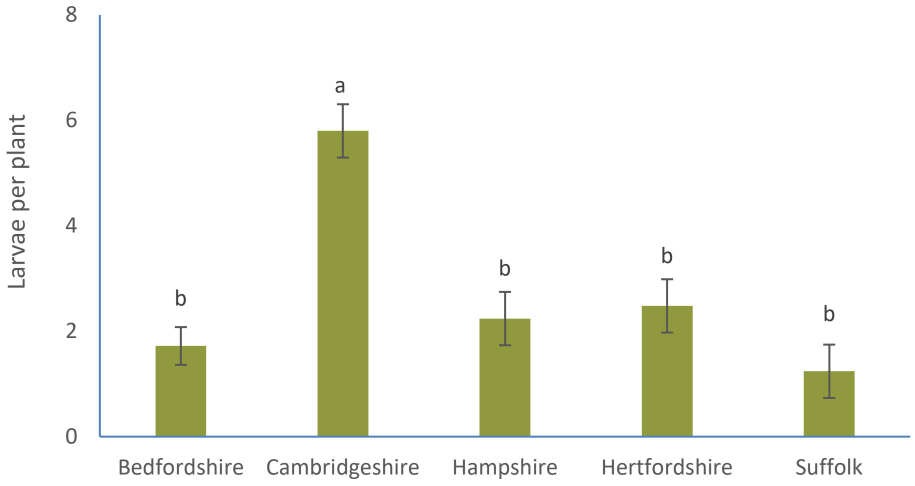

Figure 5. Mean larvae per plant at high risk sites in each county in April. Bars indicate standard errors of the means. Bars followed by the same letter are not significantly different. Significant differences are identified using LSD.

Between February and April, larval numbers decreased significantly (df = 1, F = 154.49, $p < 0.001$) in Bedfordshire, Cambridgeshire, Hertfordshire and Suffolk (Surrey was not sampled in April due to low larval numbers in February) (Figure 6). This is possibly because larvae were leaving the plant to pupate.

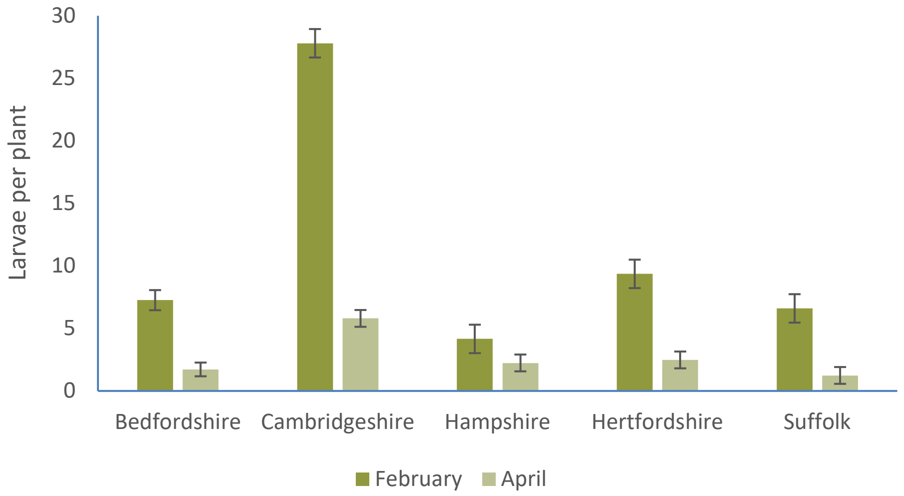

Figure 6. Mean larvae per plant at high risk sites in February and April. Bars indicate standard errors of the means.

Overall, larval numbers remained significantly higher in the petioles than the stems in April (df = 1, F = 18.14, p < 0.001). However, a significant interaction with county was found (df = 4, F = 2.81, p = 0.026) with larval numbers significantly higher in the petioles than the stems in all counties except Hertfordshire and Cambridgeshire (Figure 7).

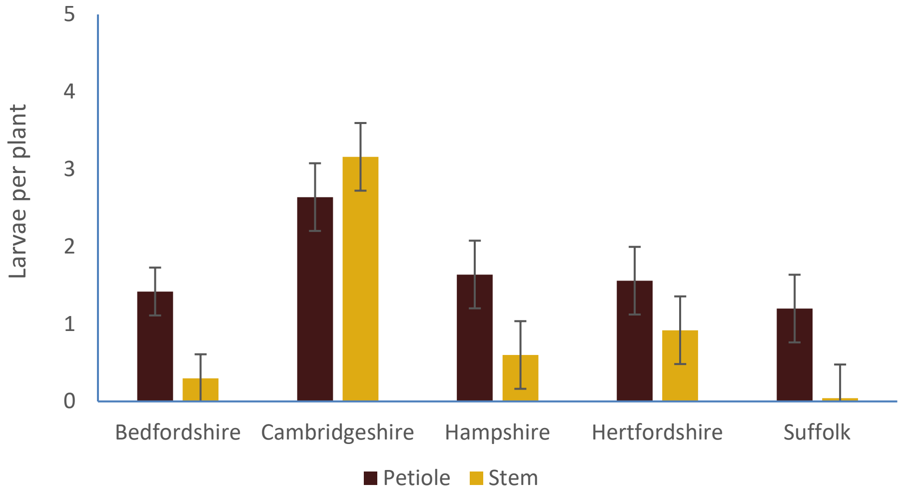

Figure 7. Mean number of larvae in the petioles and stems at high risk sites in each county in April. Bars indicate standard errors of the means.

Between February and April larval numbers at the high risk sites dropped significantly in the petioles but not the stems in all counties (df = 4, F = 32.81, p < 0.001). The proportion of the larvae in the petioles declined between February and April from 94.7% to 65%.

Summary data for larval counts can be found in the Appendix.

4.2. Leaf-scarring

Leaf-scarring was found on 316 plants (out of 350 sampled), of which 278 contained larvae. No leaf-scarring was found on 34 plants, of which one plant contained larvae. The presence of leaf-scarring was a correct indicator of the presence of larvae in 88% of cases (standard deviation = 1.8%). The absence of leaf-scarring was a correct indicator of the absence of larvae in 97.1% of cases (standard deviation = 2.9%). In summary, the present or absence of leaf-scarring was a correct indication of presence or absence of larvae in 88.9% of cases (311 out 350 cases).

4.3. Yield impacts

The yield of WOSR in the monitored fields was compared with the five-year average WOSR yields for the same fields (field average). It should be noted that the five-year field average yield was available for all but five sites (Table 1). Where possible at sites where the five year average was not available, average yield was based on fewer years; however, at two sites (Bedfordshire and Hampshire) no data on previous WOSR yields was available because WOSR had not been grown in the field during the farmer’s tenure. Interpretation of yield data must also be treated with some caution as only a single replicate site was studied for high and low risk crops in each county and because the yield could have also been affected by other factors, e.g. disease or season.

The 2015 average yield across the sites was 3.5 t/ha, 0.3 t/ha lower than the 2015 national average of (3.8 t/ha; Wynn *et al*., 2015) and the same as the five year (2010–14) national average (Defra, 2015). At nine out of 12 sites (five low risk and seven high risk) for which historic yield data was available, the 2015 OSR yield was lower than the field average yield (Table 1). Across both low and high risk sites the 2015 yield was on average 0.52 t/ha lower than the field average and the difference ranged between -2.55 t/ha and +0.85 t/ha. For low risk sites (five sites) the 2015 yield was, on average, 0.02 t/ha higher than the field average (range -0.31t/ha to +0.85 t/ha) and for high risk sites (seven sites) the 2015 yield was on average 0.9 t/ha lower than the field average (range -2.55 t/ha to +0.2t/ha).

Table 1. WOSR 2015 yield, the average field yield (based on one year**, two years*** or five year average yield where available) and yield difference for each site. (* = no historic yield data available).

County	Risk	2015 Yield (t/ha)	Average field yield (t/ha)	Difference (t/ha)
Bedfordshire	Low	3.99	4.30***	-0.31
Bedfordshire	Low	3.75	*	*
Bedfordshire	High	3.21	4.20	-0.99
Bedfordshire	High	3.12	3.50	-0.38
Cambridgeshire	Low	4.20	4.50	-0.30
Cambridgeshire	High	2.90	4.60	-1.70
Hampshire	Low	3.77	*	*
Hampshire	High	3.20	3.00	0.20
Hertfordshire	Low	4.75	3.90	0.85
Hertfordshire	High	0.85	3.40	-2.55
Suffolk	Low	4.15	4.27	-0.12
Suffolk	High	3.90	4.05	-0.15
Surrey	Low	3.46	3.46***	0
Surrey	High	3.46	4.20**	-0.74

It seems likely that CSFB larval pressure had an impact on crop yield. However, there was no significant correlation between larval numbers and the difference in yield between 2015 and the field average (Figure 8).

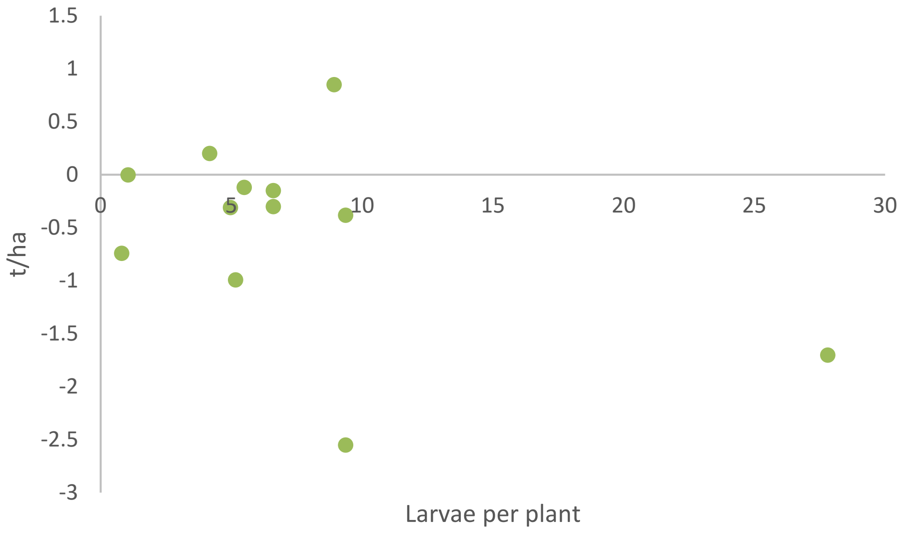

Figure 8. Mean number of larvae per plant plotted against the 2015 yield minus the field average yield.

Comparison of the data for Cambridgeshire and Hertfordshire illustrates the contrasting data for CSFB larval infestation and yield between sites. At high risk sites in Cambridgeshire and Hertfordshire there was a reduction in yield compared to the field average by 1.70 t/ha and 2.55 t/ha, respectively. In Cambridgeshire, the high risk site had about 28 larvae per plant and the low risk site seven larvae per plant. It is likely that this level of pest infestation at the high risk site would have an impact on crop yield. In Hertfordshire there were just over nine larvae per plant at the high risk site and yet the yield reduction, compared to the field average, was higher than recorded in Cambridgeshire. Interestingly, the low risk site in Hertfordshire had almost nine larvae per plant and yet the crop yield was 0.85 t/ha higher than the field average. This result illustrates the difficulty of interpreting the yield data and suggests that other factors (e.g. the growth stage of the crop at the time of larval invasion) could influence the relationship between the pest numbers and yield. It is also important to realise that the yield could have been affected by other factors, e.g. disease or season.

4.4. Insecticide use and other site data

Pyrethroids were used at every site for CSFB control in autumn 2014. The growers did not apply InSyst (acetamiprid), the only non-pyrethroid approved for CSFB control in 2014, at any site. The number of pyrethroids applications ranged from one at both sites in Surrey and the low risk sites in Cambridge and Hampshire to four at high risk sites in Bedfordshire, Cambridgeshire, Hertfordshire and Suffolk (Figure 9).

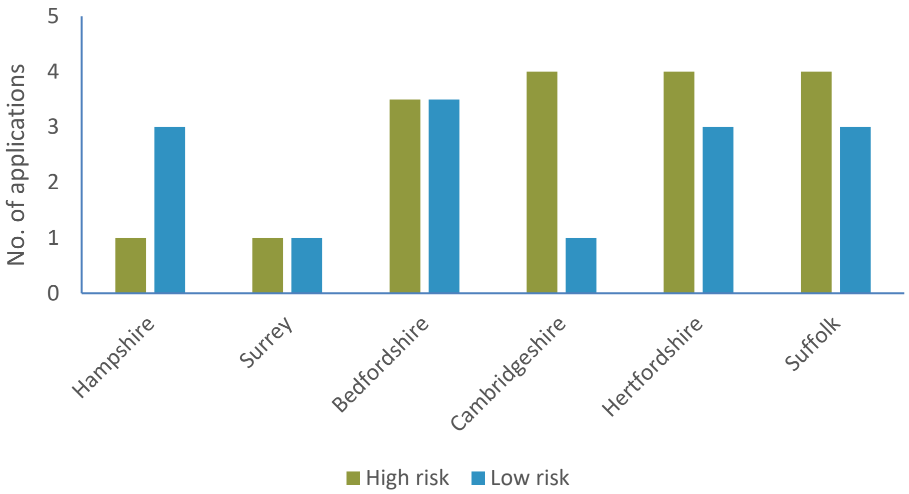

Figure 9. Number of pyrethroid sprays during autumn 2014 at each site (mean values for Bedfordshire sites shown).

Of the 39 pyrethroid applications made across the sites in the autumn, 87% (34 applications) were for CSFB control, with 31 targeting adults and three targeting larvae. Four of the treatments targeting CSFB were estimated by the agronomists to provide more than 50% control, while the rest either provided less than 50% of control (21 applications) or the level control could not be estimated (nine applications).

4.5. TuYV incidence

Visual symptoms of TuYV were reported to be low at all sites in April, except for Hampshire (Table 2).

Table 2. Percentage incidence of visual symptoms of TuYV in April.

County	TuYV symptoms (%)
Hertfordshire	0
Suffolk	1–2
Bedfordshire	1–2
Cambridgeshire	5
Hampshire	14

5. Discussion

There were large differences in CSFB larval populations between the counties at the sites monitored, with the largest numbers found in Cambridgeshire, Hertfordshire, Bedfordshire and Suffolk. These counties currently form part of Emergency Use Authorisations 1949 and 1950 of 2015, providing for limited sowing of neonicotinoid-treated WOSR seed. Low populations of larvae were found in Surrey (both sites) and one site in Hampshire. The high risk Cambridgeshire site was particularly badly affected with 96% of plants above the autumn treatment threshold (a single plant had 57 larvae). At this site, the 2015 crop yield was 1.7 t/ha lower than the field average for the same field.

Half of the sites sampled were above the current autumn treatment threshold (five larvae per plant). Had the previous treatment threshold (two larvae per plant) been in place, 11 of the 14 sites would have been above the threshold. It should be noted, however, that the current larval thresholds relate to plants sampled in late October/early November while the threshold comparisons here relate to plants sampled in February. Therefore it is likely that the number of larvae recorded here would be higher than would be found in late October/early November. The numbers of larvae had dropped significantly by April, suggesting that most had left the plants to pupate in the soil.

Risk based on the adult CSFB pressure in September was a good indicator of larval pressure, with high risk sites in Cambridgeshire, Bedfordshire and Hampshire having significantly more larvae than the low risk sites in these counties. Where risk was not a good indicator, this may have been due to either low CSFB pressures overall, which would make statistical differences between sites difficult to detect) (e.g. Surrey) or because of agronomists possibly choosing sites based on other risk factors, e.g. proximity and frequency of previous WOSR cropping.

The majority of larvae were found in the petioles in February (95% of total) and April (65% of total). CSFB eggs hatch when conditions are mild, with first egg hatch usually occurring in late

October/early November. The young larvae then bore into the petioles of nearby plants. It is generally thought that the larvae will feed in the petioles before moving to the stem as they grow at the end of the winter/beginning of spring. It is, therefore, surprising to find such low proportions of the larval populations in the stem, especially in April. It is possible that these observations are due to the timing of the assessments; the February assessment may have occurred slightly too early to find many larvae in the stem and the April assessment may have occurred after the majority of larvae had left the plant to pupate. Relatively mild conditions in December and January may also have prolonged the egg hatch period, resulting in higher numbers of young larvae in the petioles than would otherwise be expected.

The position of larvae within the plant may have an important effect on their impact on yield. Larvae feeding within the main stem of the plant are likely to have a greater impact on growth than those feeding within the leaf petioles. Therefore it might be expected that OSR plants can compensate better for the effect of larvae feeding within the leaf petioles than those feeding within the stem. Understanding the factors that influence the timing of larval movement around the plant is likely to be important for predicting risk and impact on yield. For example, at the high risk site in Cambridge the petioles contained an average of over 25 larvae per plant compared to just 2 in the stem, suggesting that larvae are able to tolerate high competition for space and that such conditions may not instigate movement to the stem.

Leaf-scarring provided a reliable and easily identifiable indicator of the presence of larvae (88% correct) and a lack of leaf-scarring provided a very good indicator of the absence of larvae (97% correct), which is important as treatment thresholds should avoid false negatives (i.e. where a threshold recommends not to treat when a treatment is required). This supports earlier work showing that monitoring leaf-scarring is an effective method of determining whether sprays for control of CSFB larvae are required (Green, 2008).

In the absence of neonicotinoid seed treatments, the growers in the study relied solely on pyrethroid sprays for chemical control of CSFB. The lowest number of applications occurred at low risk sites in Surrey, Hampshire and Cambridgeshire, which may reflect low CSFB pressures or effective treatments. At least three pyrethroid sprays were applied at all other sites with mixed results. These included three applications at the low risk site in Hampshire ostensibly for aphid control, although pyrethroids are unlikely to be effective against the primary autumn aphid pest of WOSR, *Myzus persicae,* due to resistance. At most sites, multiple pyrethroid applications targeted at adult CSFB did not appear to provide effective control with larval populations above five per plant at all sites. The exceptions being a low-risk site in Bedfordshire (four sprays) and the high risk site in Hampshire (three sprays) where larval populations were below five per plant. These responses to treatments may reflect geographic variations in resistance to pyrethroids, which has been detected in these areas as part of an AHDB Cereals & Oilseeds-funded project (214-0019).

At nine out of 12 sites for which data was available, the 2015 OSR yield at both low and high risk sites was lower than the field average yield. The average yield reduction was 0.52 t/ha. At high risk sites, the 2015 yield was, on average, 0.9 t/ha lower than the field average and at low risk sites there was on average little difference between the 2015 yield and the field average. It seems likely that CSFB had an impact on yield, however there was no simple relationship between larval numbers and yield. To illustrate the indeterminate impact of larval number on yield it is worth considering the yield response at sites in Bedfordshire, Cambridgeshire and Hertfordshire. At the high risk site in Cambridgeshire the crop had an average of 27.8 larvae per plant, which is almost six times the autumn threshold and therefore is highly likely to have contributed to the 1.7 t/ha yield reduction. In Hertfordshire, the high risk site had an average of 9.4 larvae per plant and a yield reduction of 2.55 t/ha. In contrast, larval populations of 9.4 and 8.9 larvae per plant, at one of the high risk sites in Bedfordshire and the low risk site in Hertfordshire respectively, appeared to have little impact on yield (-0.38 and +0.85 t/ha respectively). This is surprising both because these populations are almost twice the autumn threshold and because the yield responses vary so widely between them. These results suggest that a better understanding of the larval impact on yield are needed. It is important to realise that the yield may have also been affected by other factors such as disease or season.

The current larval threshold of five larvae per plant in late October/early November was originally developed by ADAS at least 25 years ago and validated by Purvis (1986). This threshold was adjusted to two larvae per plant in 2006 “to reflect favourable economics of control using pyrethroid sprays” (Green. 2008). AHDB project PR428 (Green, 2008) investigated the use of water-trapping as opposed to plant dissection to determine whether the threshold was exceeded and a spray was justified. This project also suggested that the threshold may need to be adjusted in response to market forces. As a result, the larval threshold was again increased upward to five larvae per plant in 2015.

It is not known whether modern OSR varieties differ in their response to larval feeding to those that were being grown when the five larvae per plant threshold was first proposed over 25 years ago. A better understanding of the developmental rate of larvae, activity periods (in terms of their movement in and out of the plant), the timing of movements between the leaf petioles and the stem, and the impact of larval feeding on crop yield would improve risk forecasting and targeting of insecticides.

With the uncertainty over the future of the current neonicotinoid restrictions and the poor control provided by pyrethroids where resistant populations are present, it is clear that an alternative integrated pest management strategy is needed for CSFB, which uses alternative control measures as well as chemicals. This could include cultural and biological control methods. The current neonicotinoid derogation (EUAs 1949 and 1950 of 2015) permits a limited use of neonicotinoid seed treatments. If this were to continue, methods of accurately predicting CSFB pressure would be valuable to allow better targeting of sites where neonicotinoid seed treatments are most needed.

6. References

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7. Appendix

Table 3. Mean larval numbers at high risk sites in February

County	Petiole	Stem	Total
Bedfordshire	6.8	0.4	7.3
Cambridgeshire	25.8	2.0	27.8
Hampshire	4.0	0.2	4.2
Hertfordshire	9.3	0.1	9.4
Suffolk	6.2	0.4	6.6
Surrey	0.7	0.1	0.8

Table 4. Mean larval numbers at low risk sites in February

County	Petiole	Stem	Total
Bedfordshire	3.4	0.2	3.6
Cambridgeshire	6.2	0.4	6.6
Hampshire	0.2	0.0	0.2
Hertfordshire	8.7	0.2	8.9
Suffolk	5.4	0.1	5.5
Surrey	0.9	0.1	1.0

Table 5. Mean larval numbers at high risk sites in April

County	Petiole	Stem	Total
Bedfordshire	1.4	0.3	1.7
Cambridgeshire	2.6	3.2	5.8
Hampshire	1.6	0.6	2.2
Hertfordshire	1.5	0.9	2.5
Suffolk	1.2	0.0	1.2