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# Project Report No. 546

## Maximising control of cabbage stem flea beetles (CSFB) without neonicotinoid seed treatments


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# 1. Abstract

Cabbage stem flea beetles (CSFB, *Psylliodes chrysocephala*) migrate into establishing oilseed rape (OSR) 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 2013/14 cropping season was the last before the suspension of use of neonicotinoid seed treatments in oilseed rape took effect. The aim of this project was to conduct a one year study to investigate establishing oilseed rape without neonicotinoids and to identify topics for further research. The main objectives of this project were to:

1. Identify levels of CSFB control achievable without the use of neonicotinoids
2. Assess tolerance of oilseed rape seedlings to simulated 'shot hole' damage at a range of growth stages

A field experiment was established at Settrington, North Yorkshire on a site with a previous history of CSFB damage. There were eight replicates of three experimental treatments, untreated seed, Cruiser OSR (fludioxinil, metalaxyl-M, thiamethoxam) treated seed and untreated seed plus a spray of Hallmark (lamda-cyhalothrin) at the 1–2 leaf stage. Numbers of adult CSFB were monitored with yellow water traps. Plant populations, numbers of shot holes and yield were also assessed. A pot experiment located in a glasshouse at ADAS High Mowthorpe also investigated the impact of defoliation to the cotyledons, leaf 1 and leaf 2 on green leaf area and dry matter yield. A total of sixteen treatments were compared in which between 0 and 100% of leaf area was removed. A hole punch was used to simulate shot holing by CSFB and scissors were used to remove entire leaves.

Numbers of CSFB in the field experiment were relatively low. Cruiser-treated seed improved plant populations compared with the untreated control but all treatments had sufficient plants to achieve potential yield. Cruiser and Hallmark both reduced the numbers of shot holes but levels of damage were less than the 25% leaf area lost at the 1–2 leaf stage to justify insecticide treatment. There was no statistically significant effect of treatment on crop yield.

In the pot experiment, there was surprisingly little impact of defoliation on green area or dry matter yield. In 13 out of 15 defoliation treatments there was no significant difference in green area between defoliated plants and the untreated control and in the remaining two treatments (including removal of both cotyledons) green leaf area was significantly increased. Overall, only three of 15 defoliation treatments significantly reduced dry matter yield compared with the untreated control, nine had no effect and, where both cotyledons were removed, dry matter yield was increased.

In summary, results of glasshouse studies under ideal growing conditions showed that once above ground oilseed rape has significant inherent ability to compensate for loss of leaf area. These

results now require further validation in the field. Crop damage does not necessarily equate to loss of yield and results from the pot experiment suggest that defoliation thresholds may be too conservative. Tolerance to loss of green area has the potential to limit unnecessary applications of insecticides. Recommendations are provided for further research to help improve our understanding of the interaction between CSFB and oilseed rape and contribute to the development of a rational approach to pest control minimising reliance on insecticide sprays.

## 2. Introduction

Cabbage stem flea beetles (CSFB, *Psylliodes chrysocephala*) migrate into establishing oilseed rape (OSR) 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. Larvae affect plant vigour by boring into the leaf petioles and, later, into the stems. The damage they cause can also result in stunted plants in the spring with impaired stem elongation.

Around 67% of the total area of OSR in the UK is affected by CSFB. This area may vary from year to year, depending upon climatic conditions. Based on 67% area affected and the 5-year average harvested area (654,000 ha), it is estimated that 438,180 ha is affected by CSFB annually. In 2009, AHDB Cereals & Oilseeds Research Review 70 (RR70) estimated that the average annual yield loss of from CSFB in untreated crops was 1%. Based on this 1%, the area affected (67%) and the 5-year average annual yield of OSR (3.5 t/ha), it is estimated that 15,336 tonnes could be lost each year. This amounts to over £5 million in losses due to CSFB if untreated, based on the July 2007 to mid-April 2013 average delivered Erith OSR price of £327.13 per tonne. This is 0.7% of the total value of the crop (Nicholls, 2013).

The 2013/14 cropping season was the last before the suspension of use of neonicotinoid seed treatments in oilseed rape took effect. The aim of this project was to conduct a one-year study to investigate establishing the crop without neonicotinoids and to identify topics for further research. In the absence of neonicotinoid insecticides, growers only have foliar sprays of pyrethroid insecticides to combat CSFB. Overuse of these products could select for insecticide resistance. Therefore, work was also done to determine to what extent oilseed rape seedlings can tolerate loss of leaf area due to shot-holing to help improve risk assessment for the pest.

An AHDB Cereals & Oilseeds-funded project (214-0019) has already confirmed that knock-down resistance (kdr) is widespread in the UK. Rational pyrethroid usage must, therefore, be based on the risk of pest damage and failure to do so could result in further and more severe control problems in future years. It is vital that further spread of resistance and the proportion of beetles tolerant to insecticide sprays is minimised. Work is, therefore, urgently required to assess the efficacy of pyrethroids against CSFB and this was a primary objective of this project.

In order to develop improved risk assessment for CSFB, better data on the impact of the pest on crop yield are required. The 1% yield loss reported in RR70 is not robust, as it is based on consultations rather than sound research. There is a lack of empirical research confirming the relationship between damage caused by adult CSFB or larvae and subsequent loss of yield. There is no research that reports average yield losses caused by adult CSFB or its larva. There is also a lack of accurate information on the maximum yield losses, although there have been reports of total crop loss from adult CSFB infestations coinciding with crop establishment, and whether other factors, such as slug damage were involved. An accurate assessment of the average yield loss due to this pest is vital in order to develop future integrated pest management (IPM) strategies; an understanding of the frequency and distribution of extreme infestations which could result in crop loss is also required. Pivotal to the development of IPM for CSFB are robust thresholds for both adult and larval feeding damage. This project concentrated on feeding by adult beetles.

An assessment of the loss of leaf area due to shot-holing can be used to determine the need for control. The current advice is to consider treatment if adults have eaten over 25% of leaf area at the cotyledon–2 leaf growth stage; or if adults have eaten over 50% of the leaf area at the 3–4 true leaf stage; or if the crop is growing more slowly than it is being destroyed. Unfortunately, these thresholds are not robust as their origin is unknown. Work is, therefore, required to assess impact of loss of leaf area on crop growth and yield and this was the second major objective of this project.

The main objectives of this project were to:

1. Identify levels of CSFB control achievable without the use of neonicotinoids
2. Assess tolerance of oilseed rape seedlings to simulated shot hole damage at a range of growth stages

# 3. Materials and methods

## 3.1. Field experiment to investigate levels of CSFB control achievable without the use of neonicotinoids

### 3.1.1. Experiment site

The experiment was located in a field of oilseed rape at Settrington in North Yorkshire (grid ref: SE815710). The soil type was a sandy loam and the field had a previous history of CSFB damage.

### 3.1.2. Treatments and drilling

There were three experimental treatments (Table 1) replicated eight times to give 24 plots in total. Plots were 12 m long x 2 m wide and sown with an Oyjard small plot drill. The previous crop was spring barley. The stubble was ploughed and power harrowed to create a seedbed. The variety of OSR was PR46W21, sown to achieve a plant population of 70 seeds/m$^2$ on 9 September 2013. The seed rate for the untreated seed (treatment 1) and untreated seed plus Hallmark spray (treatment 3) was 3.5 kg/ha. The seed rate for the Cruiser-treated seed was 4.5 kg/ha in view of a higher 1,000 seed weight, due the presence of the seed treatment.

**Table 1.** Treatment list for field experiment to investigate levels of CSFB control achievable without the use of neonicotinoids

| Treatment number | Treatment |
|---|---|
| 1 | Untreated seed |
| 2 | Cruiser OSR treated seed (fludioxinil, metalaxyl-M, thiamethoxam, Syngenta) |
| 3 | Untreated seed + Hallmark (lamda-cyhalothrin, Syngenta) @ 50ml/ha in 200l water/ha |

The foliar spray of Hallmark was applied at the one to two leaf stage on 15 October 2013. The spray was applied with an Oxford Precision Sprayer using flat fan nozzles (LD02F110) to achieve medium spray quality at the equivalent of 200 L water/ha.

The plots received the same inputs as the field crop and these were applied by the host farmer. Plants were assessed for the presence of pollen beetle and seed weevil in spring/summer 2014 but no further insecticide sprays were applied as numbers of both pests were below threshold.

### 3.1.3. Assessments

***Plant counts and adult CSFB damage***

Five 0.5 m lengths of row were marked in each plot at full emergence and the number of plants and the number of shot holes per plant counted at weekly intervals until early November. By using marked areas of row it was possible to determine if pest damage worsened over the duration of the experiment.

***Numbers of adult CSFB in water traps***

One yellow water trap (fishing bait box: 15 cm diameter x 10 cm deep) was placed in the centre of each plot in blocks 2, 4, 6 and 8. There were 12 traps in total with four replicate traps for each treatment. These were emptied weekly at the same time as assessing plant number and CSFB damage. The contents of each trap were tipped into a piece of muslin within a kitchen sieve. The muslin was then folded to contain the catch and put into sealable container and returned to the laboratory for examination. The contents of the muslin were washed into a tray and the numbers of adult CSFB present counted.

***Numbers of CSFB larvae***

On 21 November 2013, 20 plants were randomly sampled per plot. These were returned to the laboratory and all stems and leaf petioles dissected with a sharp scalpel. Numbers of CSFB larvae were recorded.

***Crop yield***

On 28 July 2014, a single cut was taken down each plot with a plot combine. Crop yield at 91% dry matter was assessed.

### 3.1.4. Statistical analysis

The field experiment used a fully randomised block design with three treatments, including an untreated control replicated three times. Data were analysed using the parametric analysis of variance or, if this was not appropriate, another parametric or non-parametric technique.

## 3.2. Glasshouse experiment to measure the tolerance of oilseed rape seedlings to loss of leaf area by simulating adult CSFB damage

### 3.2.1. Experimental site

The pot experiment was located in a glasshouse at ADAS High Mowthorpe. This was maintained at 15°C and 16 hours daylight to mimic conditions in late summer/early autumn. Pots were watered as necessary. On 14 March 2014, pots were moved to a poly tunnel because temperatures were regularly exceeding 16°C and were causing plants to become stressed.

### 3.2.2. Treatments and sowing

There were 16 defoliation treatments in total (Table 2) replicated six times to give 96 pots in total. A total of three oilseed rape seeds (cv PR46W21) were sown per plot and thinned after emergence to leave one seedling per pot.

Thirteen of the treatments started with moderate defoliation of the cotyledons and then varied the amount of defoliation applied to leaves 1 and 2. Treatment 1 was the control: no defoliation. Treatment 2 represented slight defoliation of the cotyledons, after which it was assumed that plants would recover, so there was no further defoliation. Treatment 3 applied severe defoliation to the cotyledons, which it was assumed would probably kill oilseed rape seedlings and so, again, there was no further defoliation.

**Table 2.** Treatment list for glasshouse experiment to measure the tolerance of oilseed rape seedlings to loss of leaf area by simulating CSFB adult damage.

| Treatment | Both cotyledons | Leaf 1 | Leaf 2 |
|---|---|---|---|
| 1 | No defoliation | No defoliation | No defoliation |
| 2 | Slight (20% defoliation) | No defoliation | No defoliation |
| 3 | Severe (100% defoliation) | No defoliation | No defoliation |
| 4 | Moderate (50% defoliation) | No defoliation | No defoliation |
| 5 | Moderate (50% defoliation) | Slight (20% defoliation) | No defoliation |
| 6 | Moderate (50% defoliation) | Moderate (50% defoliation) | No defoliation |
| 7 | Moderate (50% defoliation) | Severe | No defoliation |
| 8 | Moderate (50% defoliation) | Slight (20% defoliation) | Slight (20% defoliation) |
| 9 | Moderate (50% defoliation) | Slight (20% defoliation) | Moderate (50% defoliation) |
| 10 | Moderate (50% defoliation) | Slight (20% defoliation) | Severe (100% defoliation) |
| 11 | Moderate (50% defoliation) | Moderate (50% defoliation) | Slight (20% defoliation) |
| 12 | Moderate (50% defoliation) | Moderate (50% defoliation) | Moderate (50% defoliation) |
| 13 | Moderate (50% defoliation) | Moderate (50% defoliation) | Severe (100% defoliation) |
| 14 | Moderate (50% defoliation) | Severe (100% defoliation) | Slight (20% defoliation) |
| 15 | Moderate (50% defoliation) | Severe (100% defoliation) | Moderate (50% defoliation) |
| 16 | Moderate (50% defoliation) | Severe (100% defoliation) | Severe (100% defoliation) |

The method of simulating adult CSFB feeding damage is illustrated in Figures 1–3.


**Figure 1.** A hole punch was used to create simulated shot holes in cotyledons. A larger diameter punch was used to create holes in the true leaves.

**Figure 2.** Seedling with slight damage (20% cotyledon area removed, left) and seedling with severe damage (both cotyledons removed, right)

**Figure 3.** Seedling with slight damage to the cotyledons and moderate damage to leaf 1 (50% leaf area removed).

### 3.2.3. Assessments

***Crop tolerance***

Crop tolerance was assessed at the six leaf stage. The number of surviving plants, green leaf area and dry weight were all measured in each pot. Green leaf area was assessed using a moving belt leaf area meter (Licor Model 3100, Delta T Devices).

***Dry matter yield***

Plants were washed clean of any soil then oven dried at 80°C for 24 hours. Dry matter yield was then assessed.

### 3.2.4. Statistical analysis

The glasshouse experiment used a fully randomised block design with 16 treatments including an untreated control replicated six times. Data were analysed using the analysis of variance or, if this was not appropriate, another parametric or non-parametric technique.

# 4. Results

## 4.1. Field experiment to investigate levels of CSFB control achievable without the use of neonicotinoids

Data for plant populations (number/$m^2$), number of shot holes per plant, numbers of adult CSFB caught in water traps per trap per seven days and crop yield were subjected to the analysis of variance.

### 4.1.1. Number of adult CSFB caught in water traps

Numbers of adult CSFB in water traps were relatively low during October and November (Table 3). There was only a significant difference (P<0.05) in catches between treatments on 17 October when most beetles were caught in the Cruiser-treated plots. There was no obvious trend in water trap catches between treatments.

**Table 3.** Mean number of adult CSFB caught in water traps in plots sown with untreated seed, Cruiser treated seed or untreated seed plus Hallmark spray over seven days at Settrington, North Yorkshire in October and November 2013

| | **Date water traps emptied** | | | | | | |
|---|---|---|---|---|---|---|---|
| **Treatment** | 3 Oct | 10 Oct | 17 Oct | 25 Oct | 31 Oct | 6 Nov | 15 Nov |
| Untreated | 0.3 | 0.8 | 0.3 | 1.3 | 1.8 | 0 | 1.4 |
| Cruiser | 0.3 | 1.0 | 2.5 | 1.1 | 1.8 | 0.3 | 0.2 |
| Untreated + Hallmark | 1.3 | 1.0 | 0.5 | 1.3 | 1.5 | 0 | 0.7 |
| **F prob P** | **0.125** | **0.824** | **0.014** | **0.939** | **0.919** | **0.422** | **0.465** |
| **SED (6df)** | **1.15** | **0.46** | **0.57** | **0.71** | **0.81** | **0.20** | **1.14** |

### 4.1.2. Plant counts

Plant counts differed significantly between treatments on each assessment date (P<0.05 in each case, Table 4). Cruiser treated plots consistently had the highest plant numbers followed by plots sown with untreated seed plus Hallmark and those sown with untreated seed alone. There was a trend for plant numbers to decline over the period of study. By 21 November numbers of plants in untreated plots, Cruiser plots and untreated plus Hallmark plots had declined by 14%, 17% and 16%, respectively when compared with numbers in the same treatment on 10 October.

**Table 4.** Mean number of plants (number/$m^2$) in plots sown with untreated seed, Cruiser treated seed or untreated seed plus Hallmark spray at Settrington, North Yorkshire in October and November 2013

| | **Plant number/$m^2$** | | | | | | |
|---|---|---|---|---|---|---|---|
| **Treatment** | 10 Oct | 17 Oct | 25 Oct | 31 Oct | 6 Nov | 15 Nov | 21 Nov |
| Untreated | 68.8 | 68.8 | 67.1 | 65.4 | 65.4 | 60.0 | 59.2 |
| Cruiser | 90.0 | 91.7 | 87.9 | 80.4 | 80.4 | 75.0 | 74.6 |
| Untreated + Hallmark | 80.4 | 80.8 | 78.3 | 69.2 | 69.2 | 66.2 | 67.5 |
| **F prob P** | **<0.05** | **<0.05** | **<0.05** | **<0.05** | **<0.05** | **<0.05** | **<0.05** |
| **SED (6df)** | **7.07** | **7.16** | **6.49** | **4.93** | **4.93** | **4.83** | **9.53** |

### 4.1.3. Numbers of shot holes per plant

Numbers of shot holes per plant differed significantly between treatments at all assessment dates from 25 October until 21 November (Table 5). On all these dates, Cruiser-treated plants consistently had the lowest numbers of shot holes followed by untreated seed plus Hallmark and the untreated control.

As expected, shot hole numbers increased throughout the study although the rate of increase varied between treatments. Where Cruiser-treated seed was sown, numbers of shot holes per plant remained relatively constant between 17 October and 6 November. Where untreated seed was sown and a spray of Hallmark applied on 15 October, shot hole numbers were similar on 17 and 25 October, after which numbers increased. In the untreated control, shot hole numbers tended to increase at each assessment date with the exception of between 25 and 31 October. The level of defoliation due to shot holing was well below the threshold level of 25% loss of leaf area up to the two leaf stage.

**Table 5.** Mean number of shot holes per plant in plots sown with untreated seed, Cruiser treated seed or untreated seed plus Hallmark spray at Settrington, North Yorkshire in October and November 2013

| | **Shot holes/plant** | | | | | | |
|---|---|---|---|---|---|---|---|
| **Treatment** | 10 Oct | 17 Oct | 25 Oct | 31 Oct | 6 Nov | 15 Nov | 21 Nov |
| Untreated | 1.6 | 2.2 | 2.8 | 2.8 | 2.9 | 3.4 | 3.7 |
| Cruiser | 1.1 | 1.7 | 1.7 | 1.8 | 1.7 | 2.1 | 2.4 |
| Untreated + Hallmark | 1.1 | 2.1 | 2.0 | 2.6 | 2.5 | 2.9 | 3.2 |
| **F prob P** | **0.094** | **0.469** | **<0.05** | **<0.05** | **<0.05** | **<0.01** | **<0.01** |
| **SED (6df)** | **0.26** | **0.37** | **0.35** | **0.23** | **0.33** | **0.31** | **0.31** |

### 4.1.4. Numbers of CSFB larvae per plant

Numbers were assessed on 21 November 2013 by randomly sampling 20 plants per plot and dissecting all the stems and leaf petioles on each plant. No larvae were found in any of the plots.

### 4.1.5. Crop yield

Plots were harvested on 28 July 2014 with a plot combine. Yields were calculated at 91% dry matter. There was no significant difference in yield between treatments. The highest yield was in the Cruiser-treated plots followed by untreated seed with Hallmark and the untreated control (Table 6)

**Table 6.** Mean crop yield of oilseed rape (t/ha @ 91% dry matter) at Settrington, North Yorkshire on 28 July 2014.

| **Treatment** | **Yield** |
|---|---|
| Untreated | 1.98 |
| Cruiser | 2.26 |
| Untreated + Hallmark | 2.24 |
| **F prob P** | **0.321** |
| **SED (14df)** | **0.203** |

## 4.2. Glasshouse experiment to measure the tolerance of oilseed rape seedlings to loss of leaf area by simulating adult CSFB damage

For both green leaf area and dry matter yield, the data were analysed in two ways. Firstly, an analysis of variance was done on all six blocks of sixteen treatments (96 pots). Secondly, treatments 1–4 were omitted and treatments 5–16 were analysed as a 3 x 4 factorial treatment structure to compare the impact of three levels of defoliation on leaf 1 (slight, moderate or severe) and four levels of defoliation on leaf 2 (no defoliation, slight, moderate or severe). This provided information on the impact of defoliating leaf 1 irrespective of leaf 2, the impact of defoliation of leaf 2 irrespective of leaf 1, and also whether the level of defoliation of leaf 1 had any effect on the impact of the level of defoliation of leaf 2.

### 4.2.1. Green leaf area

Although green leaf area differed significantly between treatments ($P<0.001$, Figure 4), there were surprisingly few differences between individual treatments despite some severe levels of defoliation of oilseed rape seedlings. The statistically significant F test was probably primarily due to seedlings with both cotyledons removed (treatment 3) having a higher green leaf area than all other treatments ($P<0.05$) and seedlings with moderate defoliation of the cotyledons, leaf 1 and leaf 2 (treatment 12) having a higher green leaf area than those with moderate defoliation of the cotyledons and severe defoliation of both leaves 1 and 2 (treatment 16, P<0.05). The result for treatment 3, in which both cotyledons were removed, was unexpected as after defoliation only the stem of the seedling remained.

Surprisingly, there was little difference in green leaf area between all other treatments. In 13 out of the 15 defoliation treatments, there was no significant difference in green area between defoliated plants and the untreated control (treatment 1). In the remaining two defoliation treatments (treatments 3 and 12), green leaf area was, surprisingly, significantly increased after defoliation.

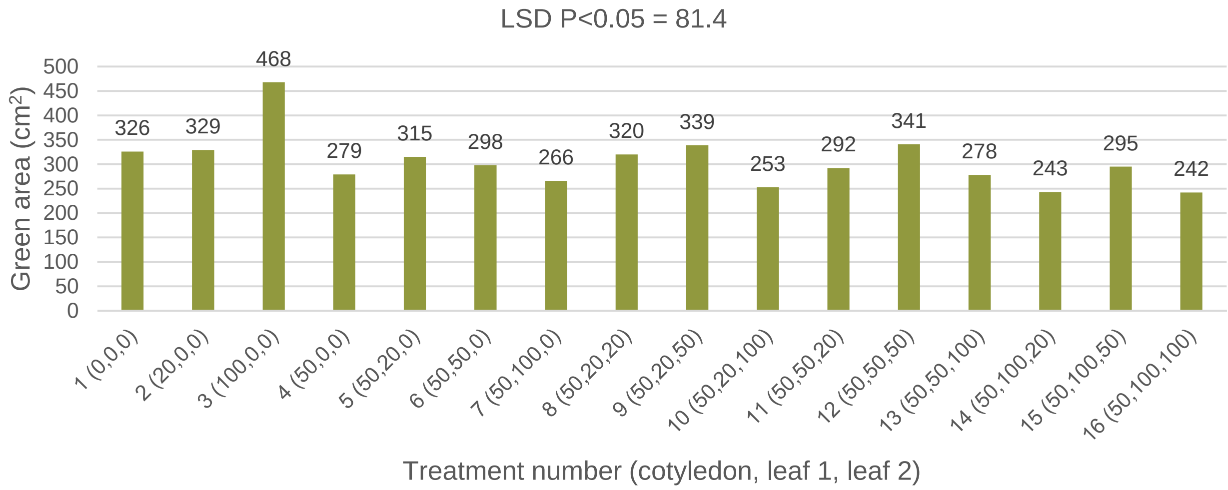


**Figure 4.** Green leaf area ($cm^2$) of oilseed rape seedlings subjected to a range of defoliation treatments ten weeks (six true leaves) after pruning. Numbers in brackets indicate the % leaf or cotyledon removed.

Analysis of the factorial treatment structure showed no statistically significant difference in green leaf area between levels of defoliation of leaf 1, leaf 2 or their interaction (Table 7). However, there was a trend for the severe level of defoliation to have the lowest level of green leaf area on leaf 1 (P=0.065) and leaf 2 (P=0.057).

**Table 7.** Mean green leaf area of oilseed rape seedlings ($cm^2$) at the 6 leaf growth stage after being subjected to a range of defoliation treatments of both leaves 1 and 2.

| | **Defoliation of leaf 2** | | | | |
|---|---|---|---|---|---|
| **Defoliation of leaf 1** | No defoliation | Slight | Moderate | Severe | Mean |
| Slight | 315.4 | 320.0 | 339.4 | 252.9 | 306.9 |
| Moderate | 298.1 | 291.8 | 341.1 | 277.7 | 302.2 |
| Severe | 266.0 | 243.4 | 294.5 | 242.1 | 261.5 |
| Mean | 293.1 | 285.1 | 325.0 | 257.5 | |
| F prob for comparisons of leaf 1 means P = 0.065, SED (55 df) = 20.83 | | | | | |
| F prob for comparison of leaf 2 means P = 0.057, SED (55 df) = 24.06 | | | | | |
| F prob for comparison of means in the body of the table P = 0.955, SED (55df) = 41.66 | | | | | |

#### 4.2.2. Dry matter yield

Dry matter yield differed significantly between treatments (P<0.001). Where both cotyledons were removed (treatment 3), dry matter yield was higher than in all other treatments (P<0.05).

Overall, only three of the 15 defoliation treatments significantly reduced dry matter yield compared with the untreated control (treatments 10, 14 and 16, P<0.05), eleven had no effect on dry matter yield (treatments 2, 4, 5, 6, 8, 9, 11, 12, 13 and 15) and one increased dry matter yield (treatment 3, P<0.05).

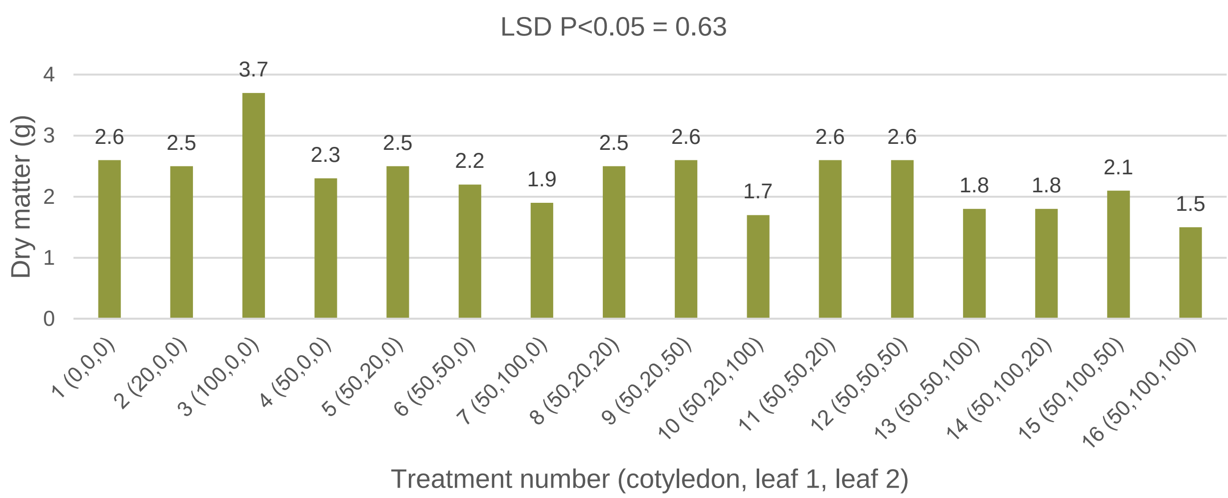


**Figure 5.** Dry matter yield (g) of oilseed rape seedlings subjected to a range of defoliation treatments ten weeks (six true leaves) after pruning. Numbers in brackets indicate the % leaf or cotyledon removed.

Analysis of the factorial treatment structure showed a significant difference in dry matter yield between levels of defoliation of leaf 1 (P<0.01) and leaf 2 (P<0.001, Table 8) but no significant interaction.

**Table 8.** Mean dry matter yield of oilseed rape seedlings (g) at the 6 leaf growth stage after being subjected to a range of defoliation treatments of both leaves 1 and 2.

| | **Defoliation of leaf 2** | | | | |
|---|---|---|---|---|---|
| **Defoliation of leaf 1** | No defoliation | Slight | Moderate | Severe | Mean |
| Slight | 2.5 | 2.5 | 2.6 | 1.7 | 2.3 |
| Moderate | 2.2 | 2.2 | 2.6 | 1.9 | 2.2 |
| Severe | 1.9 | 1.8 | 2.1 | 1.5 | 1.8 |
| Mean | 2.2 | 2.2 | 2.5 | 1.7 | |
| F prob for comparison of leaf 1 means P = <0.01, SED (55 df) = 0.15 | | | | | |
| F prob for comparison of leaf 2 means P = <0.001, SED (55 df) = 0.17 | | | | | |
| F prob for comparison of means within the body of the table P = 0.896, SED (55df) = 0.29 | | | | | |

Yield was lowest following severe defoliation of both leaves 1 and 2. However, the yield of leaf 2 was unaffected by the severity of defoliation of leaf 1.

# 5. Discussion

## 5.1. Field experiment to investigate levels of CSFB control achievable without the use of neonicotinoids

Water trapping was effective at indicating the presence of CSFB at the experimental site although numbers of the pest were relatively low. Numbers of adults caught never exceeded 3/trap/seven days. Water trapping is a relatively simple monitoring method that could be used by farmers and agronomists, provided they are given photographs to enable them to distinguish CSFB from other insects trapped. Water trapping can also be used to indicate the need for control of CSFB larvae. As reported in Project Report 428 (PR428), a catch of 35 beetles/trap between crop emergence and the end of October is considered sufficient to justify treatment, as this has been shown to be equivalent to the two larvae per plant threshold. Total catches of beetles at the site did not exceed 17 in any of the water traps so, according to the threshold, this crop would not have needed an insecticide to control CSFB larvae. This was confirmed by plant dissection, which revealed no larvae. This result is surprising as, although number of adult beetles were low, it would have been expected that some larvae would have invaded plants. CSFB larvae can hatch and invade plants anytime from October until early April so it is possible that this occurred after plants were sampled on 21 November 2013.

Plant populations differed significantly between treatments on all assessment dates and this was probably due to higher numbers in plots grown from Cruiser-treated seed in comparison with those grown from untreated seed. Hallmark also improved plant populations but was not as effective as Cruiser. However, sufficient plants established in all plots to exceed the guideline threshold for oilseed rape to achieve potential yield (25–35 plants/m$^2$, Berry *et al*, 2012). In plots drilled with Cruiser-treated seed and plots drilled with untreated seed and sprayed with Hallmark, initial plant populations were greater than the target 70 plants/m$^2$. This was probably due to volunteer oilseed rape, as the field has grown this crop in a number of previous years.

Both Cruiser and Hallmark reduced the number of shot holes in comparison with the untreated control. Differences were statistically significant from 25 October until the end of the study. On 25 October this was probably due to lower numbers of shot holes in the Cruiser-treated plots than in the untreated control but at subsequent assessments both Cruiser and Hallmark treated plots had lower numbers of shot holes than the control.

As expected, shot hole numbers increased throughout the study, although the rate of increase varied between treatments. Cruiser is thought to give protection against CSFB for 6–8 weeks so, as the crop was sown on 9 September, efficacy would be expected to decline from about 21 October to 4 November. Shot hole numbers remained relatively constant between 17 October and 6 November but damage increased on the last two assessment dates when the seed treatment would be predicted to be less effective. Hallmark might be expected to persist for about two weeks, so this would probably explain why, after its application on 15 October, shot hole numbers were similar on 17 and 25 October, after which they increased. Overall, the level of defoliation due to shot holing was well below the threshold level of 25% loss of leaf area up to the two leaf stage needed to justify an insecticide spray.

The apparent efficacy of Hallmark is, to an extent, unexpected as AHDB Cereals & Oilseeds-funded project 214-0019 confirmed that there was a resistant population in Yorkshire. To date, only two samples had been tested, so it is possible that beetles at the Settrington site were susceptible to pyrethroids. Unfortunately, as numbers were low, it was not possible to collect a sample for resistance testing. It could also be possible that beetles were resistant to insecticide sprays but were deterred from feeding on treated plants while the product persisted on the foliage.

As predicted by low levels of CSFB adult damage and an absence of larvae, there was no significant difference in yield between the three treatments, although both Cruiser-treated seed and the application of a Hallmark spray did increase yield by about 0.26–0.28 t/ha. As well as thiamethoxam, Cruiser also contains fludioxinil and metalaxyl-M for the control of downy mildew, damping-off, phoma and alternaria. It is possible that the control of these diseases rather than CSFB resulted in the yield response. Hallmark, however, has no activity against oilseed rape diseases, so the yield response to this product may just result from variability in the data. Yield data was very variable with no consistent ranking between treatments within individual replicates. It is possible that this variability also contributed to the differences in yield between treatments. Such experimental variability suggests that the yield data for this experiment should be treated with caution as numbers of CSFB adults and the degree of loss of leaf area produced by their feeding were well below threshold levels expected to influence yield.

### 5.2. Glasshouse experiment to measure the tolerance of oilseed rape seedlings to loss of leaf area by simulating adult CSFB damage

A hole punch and scissors were used to simulate adult feeding damage by CSFB, producing a range of defoliation treatments of between 20% and 100% of leaf area lost. Despite some severe levels of defoliation, there was surprisingly little difference in the green area and dry matter yield between treatments (Table 9). No plants were killed by any defoliation treatment and, where both cotyledons were removed, both green area and dry matter yield were higher than in all other treatments.

**Table 9.** Summary of results of analyses of variance on green leaf area and dry matter yield data of oilseed rape seedlings at the 6 leaf growth stage after being subjected to a range of defoliation treatments of both leaves 1 and 2. All significant differences are at P<0.05

| Treatment | | | | Results of analyses of variance | |
|---|---|---|---|---|---|
| # | Cotyledons | Leaf 1 | Leaf 2 | Green area | Dry matter yield |
| 2 | Slight | None | None | No significant difference | No significant difference |
| 3 | Severe | None | None | Significant increase | Significant increase |
| 4 | Moderate | None | None | No significant difference | No significant difference |
| 5 | Moderate | Slight | None | No significant difference | No significant difference |
| 6 | Moderate | Moderate | None | No significant difference | No significant difference |
| 7 | Moderate | Severe | None | No significant difference | No significant difference |
| 8 | Moderate | Slight | Slight | No significant difference | No significant difference |
| 9 | Moderate | Slight | Moderate | No significant difference | No significant difference |
| 10 | Moderate | Slight | Severe | No significant difference | Significant decrease |
| 11 | Moderate | Moderate | Slight | No significant difference | No significant difference |
| 12 | Moderate | Moderate | Moderate | Significant increase | No significant difference |
| 13 | Moderate | Moderate | Severe | No significant difference | No significant difference |
| 14 | Moderate | Severe | Slight | No significant difference | Significant decrease |
| 15 | Moderate | Severe | Moderate | No significant difference | No significant difference |
| 16 | Moderate | Severe | Severe | No significant difference | Significant decrease |

In 13 out of the 15 defoliation treatments, there was no significant difference in green area between defoliated plants and the untreated control. In the two remaining treatments, (treatments 3 and 12) defoliation significantly increased green leaf area. Overall, only three of the 15 defoliation treatments significantly reduced dry matter yield compared with the untreated control (treatments 10, 14 and 16), nine had no effect on dry matter yield (treatments 2, 4, 5, 6, 8, 9, 11, 12, 13 and 15) and one significantly increased dry matter yield (treatment 3).

These results are supported by previous work (Ellis *et al*, 2014, in prep CRD Project PS2820). In that project, green leaf area of oilseed rape was only significantly reduced (P<0.05) where leaves 1, 2 and 3 or 1, 2, 3, and 4 were removed, in comparison with the untreated control, which had no leaves removed. There was no effect on green area for the equivalent treatments in which half of each leaf was removed. In 11 out of 21 treatments, green area was higher where leaves were pruned than where there was no pruning. Similarly, there was limited impact of loss of leaf area on dry matter. Only where leaves 1, 2 and 3 or leaves 1, 2, 3 and 4 were removed as the next leaf was emerging was dry matter significantly less than in the untreated control (P<0.05). Thirteen of 21 pruning treatments had a higher dry matter than in the unpruned control.

The pot experiment was done in a glasshouse/poly tunnel, where conditions would have been more favourable for crop growth than in the field. Therefore, it is likely that the pot study has better demonstrated the inherent capacity of oilseed rape to tolerate loss of leaf area. This inherent tolerance will be modified by environmental conditions, so predicting which crops can compensate for loss of leaf area will be crucial if tolerance is to become an important component of integrated pest control strategies. However, it is difficult to predict future weather so field experimentation under different environmental conditions and possibly a range of sowing dates may be needed to help predict the likely extent of compensatory growth in a particular season.

For oilseed rape, the majority of the resources required for seed yield must be captured after flowering (Berry and Spink, 2006) and compensatory branching occurs after the onset of stem extension in the spring. Defoliation of oilseed rape by mowing the crop in winter has been shown to increase seed yield in some crops (Spink *et al*., 1992; Lunn *et a*l., 2001). Yield increases were greater for early sown crops which had developed large canopies, but late sown crops with small canopies lost yield after defoliation. This indicates there is a minimum canopy size that the crop must achieve to realise yield potential. Previous work has shown that pruning may increase net assimilation rate in rice (Kupkanchanakul & Vergara, 1991). They suggested that if part of the green tissue is removed, the photosynthetic rate of that remaining increases to compensate for the loss. The same mechanism could occur in oilseed rape. Therefore, it is clear that reductions in green leaf area before the start of stem extension often do not lead to reductions in seed yield.

Litsinger (2009) suggests that damage simulation is one of the most controversial of the crop loss damage assessment methods. In the studies he describes, as in the current experiment, damage is imposed on the plant in the absence of natural pest populations. The main advantage of this technique is that it allows the researcher to precisely control the degree of damage and to assess crop losses. The main criticism of this approach is that the imposed damage is not representative of an equivalent level of damage produced by the pest. Wells (1975) compared the relationship between the effects of the adult mustard leaf beetle (*Phaedon cochlearia*) and artificial defoliation, on yields of white mustard (*Sinapis alba*). Results showed that the yield responses of mustard when defoliated by beetles or by artificial means were similar. Whilst this does not necessarily mean that the response of oilseed rape to artificial defoliation is the same as that to cabbage stem flea beetle (or slugs), it does suggest that the technique has some merit. A simple study to investigate whether defoliation by slugs or cabbage stem flea beetle could be easily done to investigate the relationship between artificial defoliation and that imposed by pests. Also, the ability of oilseed rape to compensate for some of the severe levels of artificial defoliation imposed in this experiment suggests that the crop would be able to grow away from lesser damage imposed by pests in the field. This is backed up by anecdotal data from farmers and agronomists who have commented on the resilience of oilseed rape to pest attack.

Defoliation treatments in the pot experiment were designed to remove up to 100% of leaf area. Current guideline thresholds for control of cabbage stem flea beetle in oilseed rape suggest that a spray is justified if 25% of leaf area is lost at the cotyledon–2 true leaf growth stages. Results from the current study suggest that this threshold could be increased to 50% without impacting on crop growth. Oilseed rape seedlings appear to have significant tolerance to defoliation once above ground level, assuming sufficient soil moisture is available to stimulate crop growth. If seedlings are attacked as they are emerging, the potential to compensate for pest damage is likely to be significantly reduced. In this situation, seed treatments provide the best option for control of CSFB adults and are also environmentally beneficial as they minimise the quantity of active ingredient required and consequently limit impacts on non-target species. In the absence of seed treatments, attention to establishment is key to minimising risk from CSFB adults because a rapidly growing crop is the best way of combatting the pest.

### 5.3. Recommendations for the industry

- Water traps are an effective way of monitoring CSFB populations.

- Focus on establishing a rapidly growing crop to minimise the risk of adult CSFB damage. Results of glasshouse studies under ideal growing conditions showed that once above ground the crop has significant inherent ability to compensate for loss of leaf area.

- Remember that crop damage does not necessarily equate to loss of yield. In the field experiment shot holing by CSFB adults was well below current threshold levels and had no effect on crop yield. The pot experiment confirmed the ability of the crop to tolerate defoliation and it is vital that thresholds are used to rationalize insecticide use to minimise the spread of resistance.

- Continue to use current thresholds for loss of leaf area to justify sprays against adult CSFB and water trapping to justify sprays against the larvae. Results from the pot experiment suggest that defoliation thresholds may be too conservative.

- Tolerance to loss of green leaf area and plants has the potential to limit unnecessary applications of insecticides. However, methods of predicting which crops can tolerate leaf damage and plant loss will be required before this can be used by farmers and agronomists.

## 5.4. Recommendations for future research

There are a number of areas of further research worthy of investigation, which would lead to a greater understanding of the interaction between CSFB and oilseed rape and contribute to the development of a rational approach to pest control minimising reliance on insecticide sprays.

***Determining indicators of crop tolerance***

Predicting which crops can compensate for loss of leaf area and plants will be crucial if tolerance is to become an important component of integrated pest control strategies. However, it is difficult to predict future weather, so field experimentation under different environmental conditions and a range of sowing dates and seedbed conditions will be needed to help predict the likely extent of compensatory growth in a particular season. For example, understanding the relationship between loss of leaf area and ultimate yield might help to decide on the need for insecticide treatment. An investigation of potential indicators of crop tolerance is worthy of further research.

***Assessing the impact of the distribution of damage on the potential for crop tolerance***

Farmers and agronomists frequently point out that pest damage is rarely uniformly distributed within a field and is more likely to be aggregated. The distribution of pest infestations on and between plants affects the ability of a crop to make compensatory growth (Bardner and Fletcher, 1974). Litsinger (2009) suggested that compensation is less effective if killed or injured plants are aggregated. The potential to design field experiments to measure how the aggregation of pest damage influences the compensatory ability of the crop should be investigated. It may be possible to simulate loss of leaf area or plant number by developing the methods used in the current study.

***Re-assessing flea beetle defoliation thresholds***

Pot experiments under ideal growing conditions have indicated the inherent tolerance of oilseed rape plants to loss of leaf area. These results should now be validated under field conditions using the same techniques to simulate pest attack. This work could be combined with that suggested to re-assess larval thresholds, using a factorial treatment design.

***Re-assessing flea beetle larval thresholds***

Currently, treatment is recommended if there is an average of two CSFB larvae per plant in late October/early November. However, by this stage many crops may have five or six true leaves. It is difficult to imagine that the growth of such a robust crop would be significantly affected by two CSFB larvae. Also, many of the leaves invaded by larvae are lost over winter. If larvae have not moved into the central stem before these leaves are lost, they will no longer be able to have an impact on crop growth. Further information is required to determine when, and under what conditions, larvae move from the leaf petioles into the central stem.

***Investigating how feeding by CSFB larvae affects crop yield***

There is little information on the impact of CSFB larvae on crop yield. These data are vital if new robust, sustainable thresholds are to be developed against the pest which take account of the inherent tolerance of the crop.

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