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Scottish Winter Oilseed Rape Cultivation 2015/16: Impact of the second year of Neonicotinoid Seed Treatment Restrictions

Scottish Winter Oilseed Rape Cultivation 2015/16: Impact of the Second Year of Neonicotinoid Seed Treatment Restrictions

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Executive summary

This is the second of two consecutive surveys, conducted to inform the Scottish Government, about the impact of the current neonicotinoid restrictions on Scottish winter oilseed rape (WOSR) cultivation. Data were collected from a representative sample of Scottish growers collectively accounting for 18 per cent of the 2016 WOSR crop area.

2016 was a difficult year for Scottish WOSR cultivation. There was a 14 per cent decrease in Scottish crop area and a 20 per cent reduction in yield; both of which were primarily attributed to adverse weather conditions. However, autumn insect pest populations, which were formerly controlled by neonicotinoid seed treatments, were also significantly lower than in the previous year. As a consequence, insect damage levels, primarily from Cabbage Stem Flea Beetle (CSFB) grazing, were significantly reduced and, unlike autumn 2014, no CSFB-related crop loss was reported. The proportion of crops with symptoms of Turnips Yellow Virus (TuYV), which is transmitted by aphids, also continued to be low in 2016.

In response to reduced pest and damage levels, significantly fewer insecticidal sprays were applied by Scottish growers in autumn 2015 than in the previous year; and the number of foliar applications was similar to pre-restriction levels. As in the previous survey, the insecticides used were almost exclusively pyrethroid compounds, targeted at CSFB control, and few growers reported issues with the efficacy of their pest control strategies.

Despite it being a sub-optimal year for Scottish WOSR production, this survey corroborates the findings of the previous survey. The neonicotinoid restrictions have introduced additional challenges for some Scottish WOSR growers. Despite low damage levels, more than a third of growers still felt that the lack of an insecticidal seed treatment had led to greater crop damage, and a small proportion of growers stated that the restrictions will reduce the likelihood of their growing WOSR in future. However, other growers appear to be relatively unaffected and it is clear that the impact of the restrictions is less severe in Scotland than in other regions of the UK.

This reduced comparative impact is influenced by lower pest pressure and resistance levels to the approved foliar insecticides available; both of which may change in future. However, in the interim, it appears that Scottish growers can, on the whole, continue to successfully cultivate WOSR during the moratorium on neonicotinoid use. At a UK level, new research and guidance about alternative control strategies is being formulated. This will determine which actions are best adopted in future integrated pest management (IPM) strategies for oilseed rape.

No follow up surveys on Scottish WOSR crop cultivation are scheduled. However, this position will be reassessed if evidence suggests further monitoring is necessary.

Introduction

This is the second of two surveys conducted by Science and Advice for Scottish Agriculture (SASA). These surveys are designed to inform the Scottish Government about the impact of the EU restrictions of neonicotinoid use on Scottish winter oilseed rape (WOSR) cultivation.

In December 2013, the European Commission amended the approval conditions for three neonicotinoid insecticides; clothianidin, imidacloprid and thiamethoxam(1). These restrictions were imposed in response to a series of scientific reviews by the European Food Safety Authority (EFSA), which concluded that there was insufficient information to fully describe the risk to pollinators resulting from exposure to these compounds(2)(3)(4). The EFSA reviews are being updated to reflect new scientific information, and this work is scheduled to be finalised in autumn 2017. This will inform the European Commission position on the future approval of these compounds.

In the UK, the main impact of these restrictions is the loss of insecticidal seed treatments for oilseed rape. In Scotland, oilseed rape crops currently consist mainly of winter sown varieties, with spring crops accounting for around two per cent of crop area(5)(6). WOSR is Scotland's principal break crop in arable rotations, providing an alternative cropping system to help suppress the build-up of weeds, disease and insect pests associated with cereals and potatoes. It is also an important component of Scotland's agricultural economy. The Scottish oilseed rape crop had a market value of £37.1 million in 2015(7).

As discussed in the first report in this series, WOSR is host to a wide range of insect pests and this is reflected in greater foliar insecticide input than other combinable crops(8)(9). In addition to sprays, use of insecticidal seed treatments, to protect crops from insect damage during emergence and establishment, has previously been an integral component of oilseed rape production. Neonicotinoid seed treatments have been approved on UK WOSR crops since 2000 and around 80 per cent of Scottish crops were grown from treated seed before the onset of the current restrictions(9). Prior to the advent of neonicotinoid seed treatments, Scottish crops were treated with lindane (Gamma-HCH), an organochlorine insecticide which lost approval in 2001(9).

In Scotland, the main autumn insect pests of WOSR are cabbage stem flea beetle (CSFB, *Psylliodes chrysocephala*), the peach potato aphid (*Myzus persicae*) which transmits turnips yellow virus (TuYV) and, to a lesser extent, *Phyllotreta* spp. flea beetles (*Phyllotreta cruciferae* and *Phyllotreta nigripes*). In the absence of an insecticidal seed treatment, control of these pests is reliant on foliar insecticide application. The other main autumn pest is the rape winter stem weevil (*Ceutorhynchus picitarsis*), which invades the crop later in the season, after the period in which neonicotinoid seed treatments provide protection from phytophagous insects.

There are operational limitations associated with foliar use of insecticides[8], and control options are also limited by the development of resistance by the target pests to many of the approved insecticides[10][11]. These issues have been recognised by the UK regulatory authority and emergency and extension of use authorisations have been made to allow some alternative foliar insecticides to be available for autumn use. In addition, an emergency authorisation was granted to allow the use of two neonicotinoid seed treatments (thiamethoxam and clothianidin) on a limited area of oilseed rape in autumn 2015. This authorisation was approved for those areas at highest risk of crop loss (ca. 30,000 ha, five per cent of England's oilseed rape crop)[12]. No emergency authorisation application was made for use of neonicotinoid seed treatments in Scotland.

During the first year of the restrictions, SASA conducted a survey to gather information about the initial impact on Scottish WOSR cultivation[8]. The results indicated that the absence of neonicotinoid seed treatments made the control of autumn insect pests more challenging for some growers but the overall impact of the restrictions was less severe in Scotland than was reported in Southern and Eastern England. A second season of data collection was undertaken to assess the impact of the restrictions under different, potentially more challenging, conditions. This report describes the results of this second survey.

Results and comparison with previous survey

Survey sample

One hundred and four growers participated in this survey. The sample consisted of 50 participants from the original 2014/15 survey and 54 new recruits drawn from a sample of Scottish WOSR growers(13). These growers collectively sowed 5,553 hectares (ha) of WOSR on 131 farms. This sample represents18 per cent of the 2016 Scottish crop area(6). The areas sampled in each region reflect the geographic distribution of Scottish oilseed rape cultivation, accounting for between 13 and 22 per cent of the crop grown in the main WOSR producing regions (Table 1).

The total area of WOSR sown in Scotland decreased by 14 per cent between 2014 and 2015 (35,198 and 30,141 ha, respectively)(6). The 2015/16 crop area is 9 per cent lower than the ten year average of 33,263 ha (2007 to 2016) reported in the Scottish agricultural census(6). There were also reductions in areas of winter cereals sown in 2015 and these declines in winter crops were in part attributed to the late harvest in 2015, followed by a period of very wet weather, which made planting autumn-sown crops problematical(14). These difficulties were encountered by several farmers who were contacted in relation to the survey. Four potential participants, who had collectively intended to sow over 800 ha of WOSR in autumn 2015, stated that they were unable to do so due to the late harvest or wet weather at sowing.

The number of participants, and crop area, surveyed were similar to the previous survey in which 96 growers, collectively growing 5,465 ha, were surveyed, representing 14 per cent of the 2015 WOSR crop.

Drilling date and seed rate

All WOSR encountered in this survey was sown between August and September 2015. The majority of crops were sown in August (83 per cent of growers and 84 per cent of the crop area) with most of the crop drilled in the last two weeks of the month (81 per cent of growers and crop area) (Table 2).

As discussed in the previous section it has been reported that the late 2015 harvest delayed, and in some cases prevented, sowing of winter crops in Scotland. This delay in sowing was reflected in our survey data for the two consecutive seasons (Figure 1).

The median seed rate was 2.5 kg/ha (range 1.4 to 5.0 kg/ha). Hybrid WOSR varieties were drilled at lower rates than conventional varieties. The median seed rate recorded in the previous survey was 3 kg/ha (range 1.2 to 6 kg/ha). This reduction in seed rate may have been influenced by fewer of the growers in this survey increasing their seed rate as mitigation for CSFB damage. In the previous survey 11 per cent of growers adapted seed spacing and rate in autumn 2014, compared to four per cent in autumn 2015 (refer to following operational changes section).

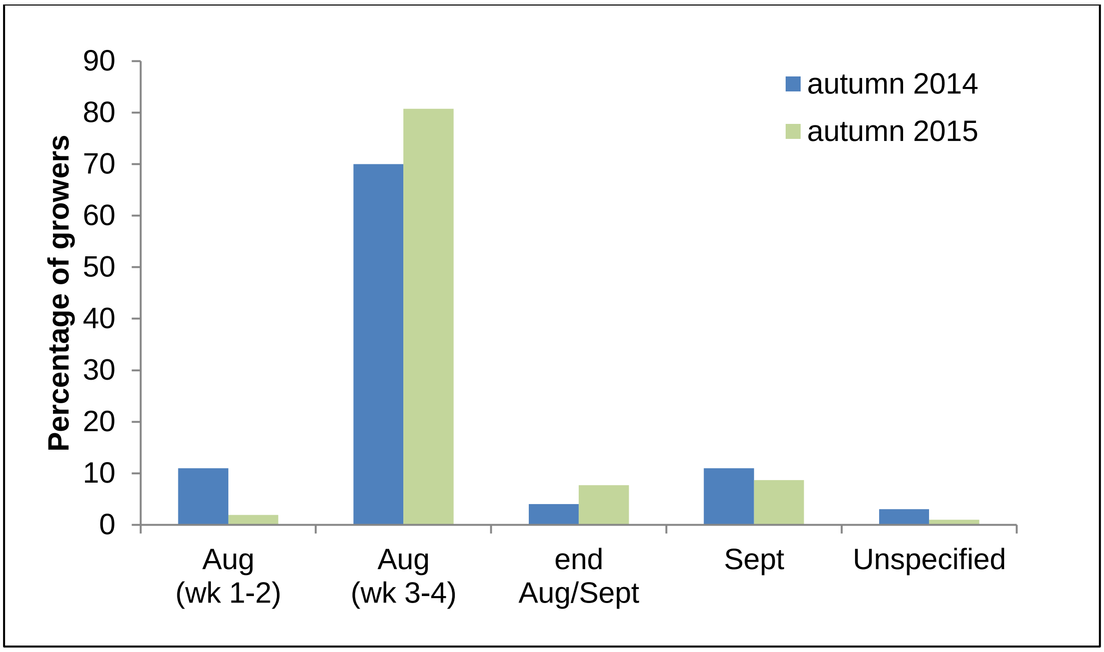


Figure 1 WOSR sowing period in 2014/15 and 2015/16 surveys

Operational changes in crop cultivation in response to restrictions

Growers were asked if they had made any changes to their crop cultivation practices to attempt to mitigate for the absence of insecticidal seed treatments.

A total of 16 growers, 15 per cent of the sample, reported they had made operational changes (Table 3). These cultivation techniques were collectively applied to 847 ha, 15 per cent, of the crop surveyed. In all cases, the stated aim of this adaptation to practice was to reduce the impact of potential CSFB damage.

Six per cent of the growers surveyed, collectively growing 350 ha of crop (six per cent of the sample) adopted different soil cultivation techniques, such as minimum tillage, strip tillage and direct drilling. This change in cultivation was designed to allow the earliest possible establishment of the crop, with the aim of avoiding CSFB migration coinciding with crop emergence, when seedlings are most vulnerable to damage.

A further four per cent of farmers, growing 203 ha, adjusted drilling dates with a similar strategy of production of a well-established crop that could out-compete CSFB damage. Increasing seed rate, or amending row spacing, to mitigate for potential crop loss was implemented by four per cent of the surveyed growers on 221 ha of land. Two participants used fertilisers, in the form of a seed dressing and precision fertiliser delivery at drilling on 56 and 18 ha respectively. The aim of the fertiliser use was to encourage quicker establishment and greater crop vigour, to compensate for insect grazing.

These 16 growers were asked if they thought that the operational changes had helped with crop establishment and performance. The majority of growers (seven, collectively growing 297 ha) stated that they were unaware if their actions had made a difference to crop performance. These growers used a range of operational changes including using fertiliser at drilling and altering seed rate, spacing and cultivation methods. Five growers (collectively growing 370 ha) stated that the actions had improved crop performance. These growers amended drilling dates, soil cultivations and seed rate. Two growers (88 ha) stated that they had seen no improvement in the crop in response to amending soil cultivation techniques and using a fertilising seed treatment. The remaining two growers did not provide a response to this question.

In the previous survey, a greater proportion of the farmers surveyed made operational changes (Figure 2). Twenty five growers (26 per cent of the sample), collectively growing 2,032 ha and representing 37 per cent of the crop surveyed, made one or more cultural changes to their 2014 sown crop.

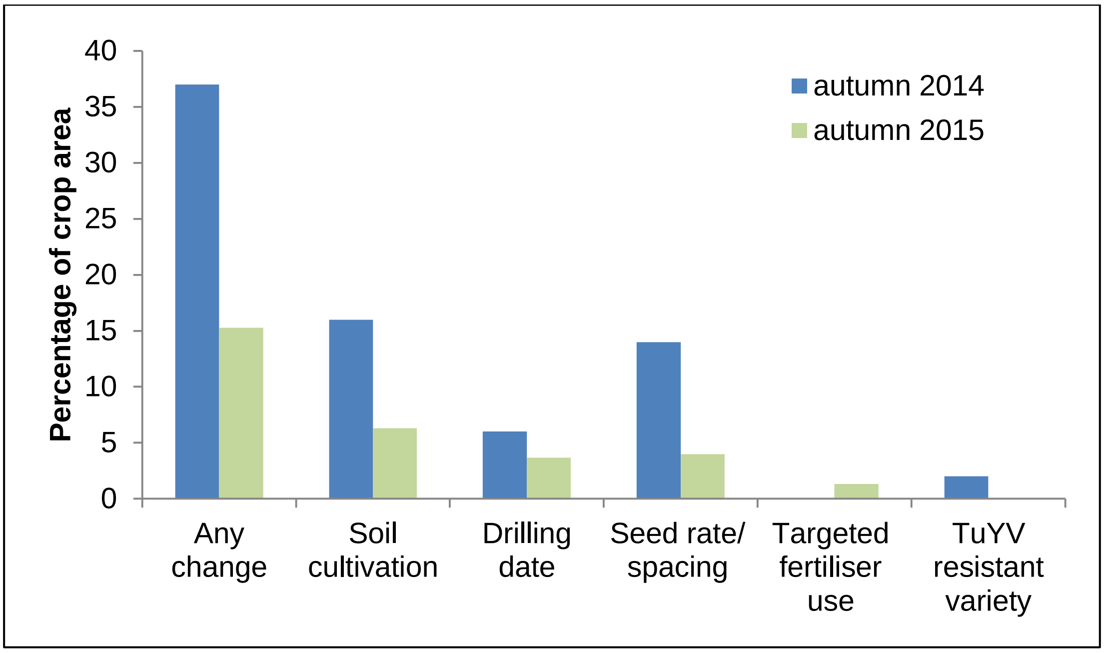


Figure 2 Operational changes in crop cultivation in 2014/15 and 2015/16 surveys

It should be noted that although the decrease in the proportion of growers adopting operational changes was sizable it was not statistically different between years (p=0.052).

The decision to make operational changes in the second year of the restrictions may have been influenced by the growers' prior experiences. In the first season, the impact of the lack of an insecticidal seed treatment was untested, and growers had no practical experience of whether changes to cultivation techniques were required. In contrast, in the second year of the restrictions their approach was informed by their experience in the preceding year. The 2014/15 survey indicated that, in Scotland, there were comparatively low levels of autumn crop loss to CSFB. The damage incurred may have been less than had been anticipated by Scottish growers and by the agricultural industry and press. With experience of a seed treatment free growing season, in which high levels of damage were infrequently encountered, Scottish growers may have considered that fewer interventions were necessary in autumn 2015. In addition, as noted earlier, sowing conditions in autumn 2015 were difficult, this additional pressure may also have influenced the decreased occurrence of adaptation of WOSR cultivations.

Grower perception of insect pest pressure

Growers were asked to rate their perception of aphid and flea beetle populations during crop emergence and establishment as low, moderate or high. As comparative ranking is subjective, growers were asked to report what methods they used to assess pest populations (Table 4). It is important to note that, as in the previous survey, most respondents were growers, and their responses may not capture all actions performed by agronomists on their behalf.

Most growers (71 per cent) used more than one information source when assessing pest numbers. The majority (86 per cent) were advised by agronomists about pest presence in their crops. In addition, 60 per cent of growers reported that they conducted their own crop walking and inspection. Other sources of information used directly by growers included checking thresholds (28 per cent) and using traps (one grower). In addition, 35 per cent stated that they gained information about pest levels from technical bulletins produced by advisory bodies and also from the farming press. Many growers consulted more than one source of this type of general pest warning information. Twenty four and 21 per cent of growers used information from Scotland's Rural College (SRUC) and the Agriculture and Horticulture Development Board (AHDB), respectively and 10 per cent gained information from the farming media.

The adoption of a range of pest monitoring methods, and the reliance on use of agronomists and crop walking to inform growers about pest pressure reported here, is very similar to that encountered in the previous season (Figure 3). In 2014/15, 83 and 58 per cent of growers consulted agronomists and conducted crop walking, respectively. However, far fewer growers reported using thresholds (9 per cent) or consulting technical bulletins (7 per cent). The increased use of additional methods of pest monitoring at crop establishment encountered in the second year of the restrictions may, as discussed previously, indicate an increase in farmer experience and awareness of the importance of monitoring crops to determine the necessity and timing of sprays in the absence of a systemic seed treatment.

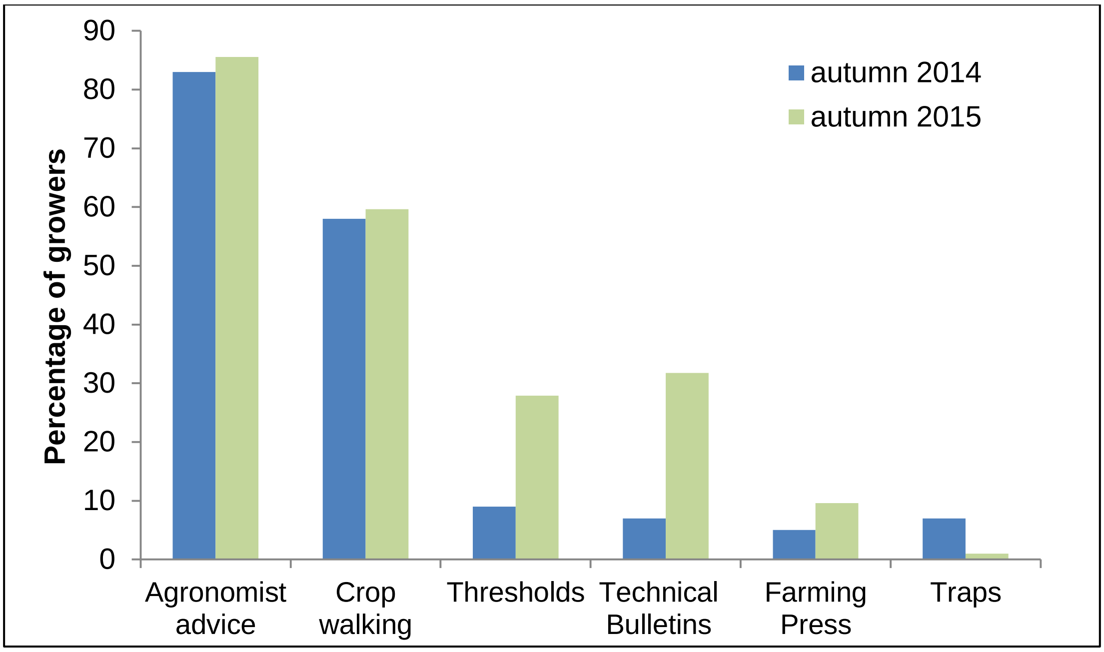


Figure 3 Pest assessment methods in 2014/15 and 2015/16 surveys

In relation to aphid pest pressure during crop establishment, the majority of growers reported that populations were either low (73 per cent) or that aphids were not seen on the crop (13 per cent) (Table 5). A further six per cent reported aphid numbers to be moderate (low/moderate or moderate) and one per cent to be high. The remaining seven per cent did not monitor aphid populations.

Reported autumn aphid levels in this survey year were lower than in the previous year, in which 70 per cent of growers ranked aphids as low or not seen, 21 per cent as low/moderate or moderate and five per cent as moderate to high or high (Figure 4). The proportion of growers reporting aphid numbers as moderate or high in this survey was significantly lower than in the previous survey ($p<0.001$). No information about the species of aphid present was available in either survey year.

In relation to flea beetle presence, the majority of growers (82 per cent) also ranked populations as low or not seen (62 and 20 per cent respectively) (Table 5). A further 13 per cent ranked levels as moderate (low/moderate or moderate) and two per cent as high (moderate/high or high). The remaining three per cent did not monitor flea beetle populations.

As with the aphid data, flea beetle populations were reported to be lower in autumn 2015 than autumn 2014 (Figure 5). In 2014, the majority of growers (62 per cent) reported flea beetle populations to be low or not seen (45 and 17 per cent respectively). A further 25 per cent ranked levels as moderate (low/moderate or moderate) and 10 per cent as high (moderate/high or high). The proportion of growers reporting flea beetle numbers as moderate or high in this survey was significantly lower than in the previous survey ($p<0.001$).

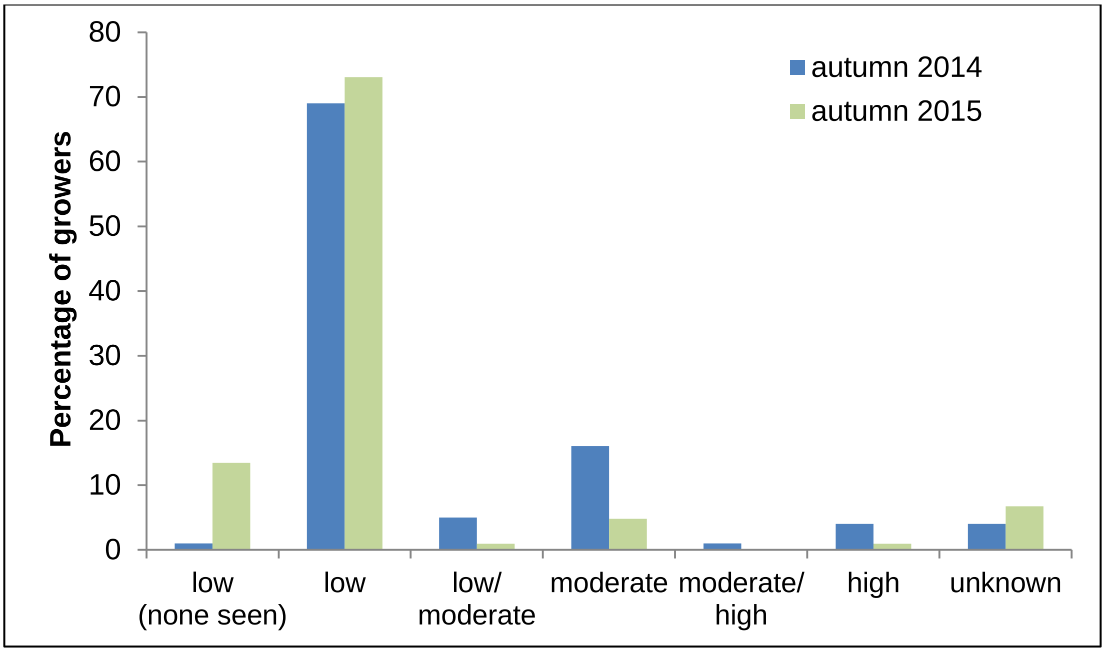


Figure 4 Aphid pest pressure in 2014/15 and 2015/16 surveys

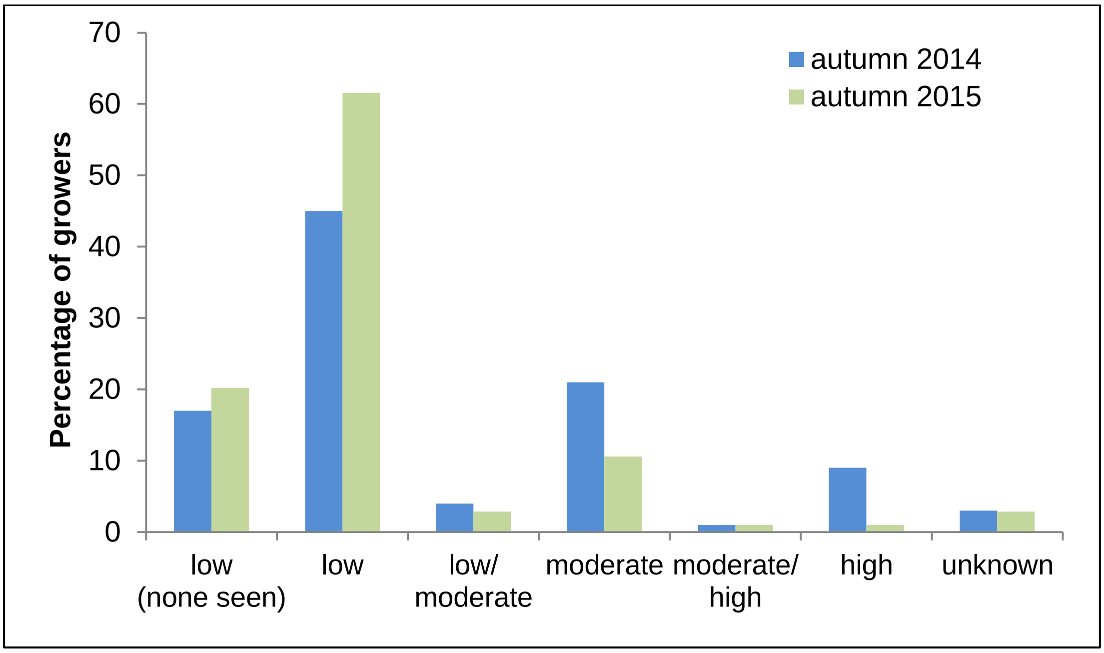


Figure 5 Flea beetle pest pressure in 2014/15 and 2015/16 surveys

Of the 21 growers who reported flea beetles on their crops, the majority (62 per cent) identified them as CSFB. Five per cent stated that they were a combination of CSFB and *Phyllotreta* spp. flea beetles and five per cent as *Phyllotreta* spp. only. The remaining 29 per cent did not know which species of flea beetle were present (Table 6).

This pattern is similar to that reported in the previous season, in which CSFB was also the species most commonly reported by growers who encountered flea beetles on their crops (51 per cent). A larger number of growers could not identify the species present in autumn 2014 (42 per cent) than in autumn 2015 (Figure 6). This may indicate increased grower knowledge of the pest species present, which could be associated with the increased use of thresholds and technical bulletins by growers in this survey. It may also be influenced by increased grower experience in pest identification in this second year of neonicotinoid restrictions.

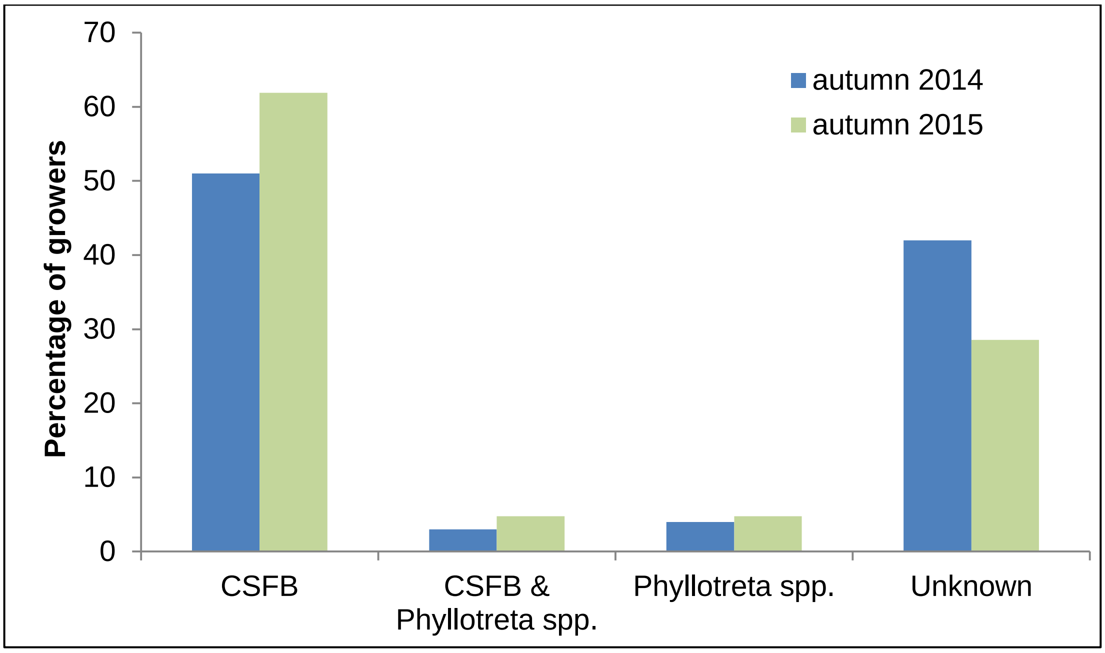


Figure 6 Species of flea beetle in 2014/15 and 2015/16 surveys

Autumn foliar insecticide use

Growers were asked to provide details of all insecticidal sprays applied during autumn 2015. In total, 56 sprays were applied by the 104 growers surveyed; an average of 0.54 sprays per grower.

More than half of the growers surveyed (56 per cent) did not use any insecticides in autumn 2015 (Table 7). The majority of growers who did spray made a single application (36 per cent of the sample). This includes 31 per cent of growers applying a spray to their whole crop area and five per cent of growers who sprayed part of their crop area and left some fields untreated. Eight per cent of growers sprayed their crops with insecticides twice and one grower applied three sprays.

In relation to crop area, 3,090 ha of the crop was untreated, this represented 56 per cent of the survey area, and 2,463 ha received at least one spray. Of the treated crop area, 1,844 ha was treated once, 601 ha was treated twice and 18 ha received three sprays (33, 11 and <1 per cent of the sampled area respectively). The total treated area, including the repeat applications was 3,100 ha.

In the previous survey, growers had been asked about their pesticide use in both autumn 2013 and 2014; representing the year preceding, and the first year after, the introduction of the neonicotinoid restrictions (Figure 7). Fewer growers applied insecticides in this survey than in the previous year (44 and 61 percent respectively) and 24 per cent fewer sprays per grower were encountered (0.54 and 0.71 respectively). This reduction in the number of sprays per grower in 2015 was statistically significant ($p<0.01$).

Both the number of sprays per grower and the percentage of growers applying pesticides in autumn 2015 were similar to those reported in 2013 (0.48 and 47 per cent respectively), the year before the neonicotinoid restrictions were introduced. However, no pest population information is available for 2013; therefore it is not possible to directly compare pest control inputs.

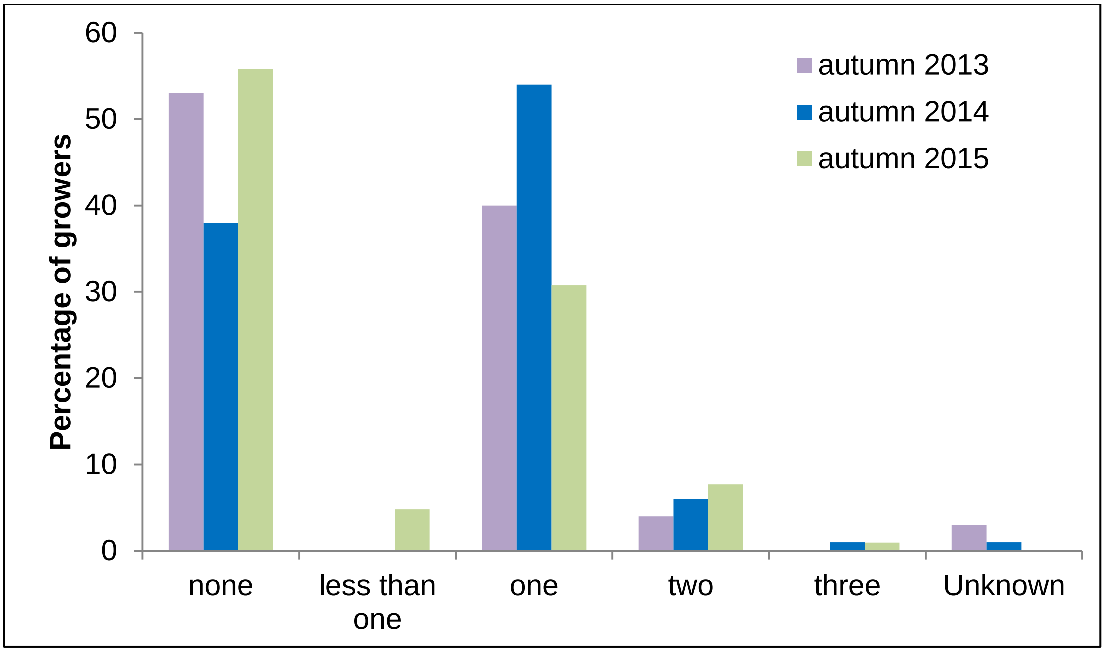


Figure 7 Number of autumn insecticide sprays applied by growers in 2013, 2014 and 2015

There were also reductions in the proportion of the crop area treated between autumn 2014 and 2015 (Figure 8). In 2014, 65 per cent of the crop received an autumn insecticide spray, compared to 44 per cent in 2015. This information is not available for 2013.

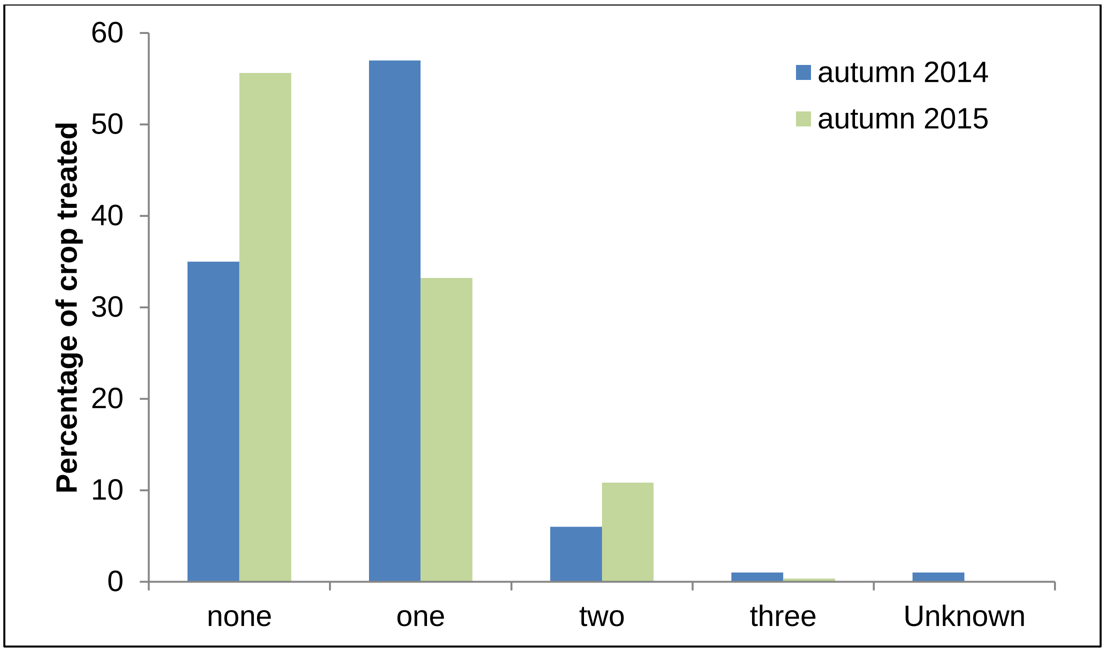


Figure 8 Autumn insecticide sprays by crop area in 2014/15 and 2015/16 surveys

Insecticide application decision making process

Growers were asked what information they used when making the decision whether or not to apply a foliar insecticide to their crop (Table 8). A range of responses were provided, with most farmers giving more than one reason. As this data was supplied by survey respondents, who were primarily growers, it may not capture all actions performed by agronomists on their behalf.

Most growers who applied an insecticide relied on an agronomist's advice when making the decision to spray (89 per cent). They were also informed by crop walking, use of thresholds and by reacting to information in technical bulletins (41, 20 and 4 per cent of those who sprayed, respectively). In addition to these reasons, nine growers (20 per cent of those who sprayed) stated that sprays were precautionary. Those growers that did not use an insecticide based this decision on agronomist advice (74 per cent), crop walking (40 per cent) and use of thresholds (16 per cent).

The reasons given for spraying in this survey were similar to those collected in autumn 2014 (Figure 9), with agronomist advice and crop walking being the most commonly encountered followed by use of thresholds and application of precautionary sprays.

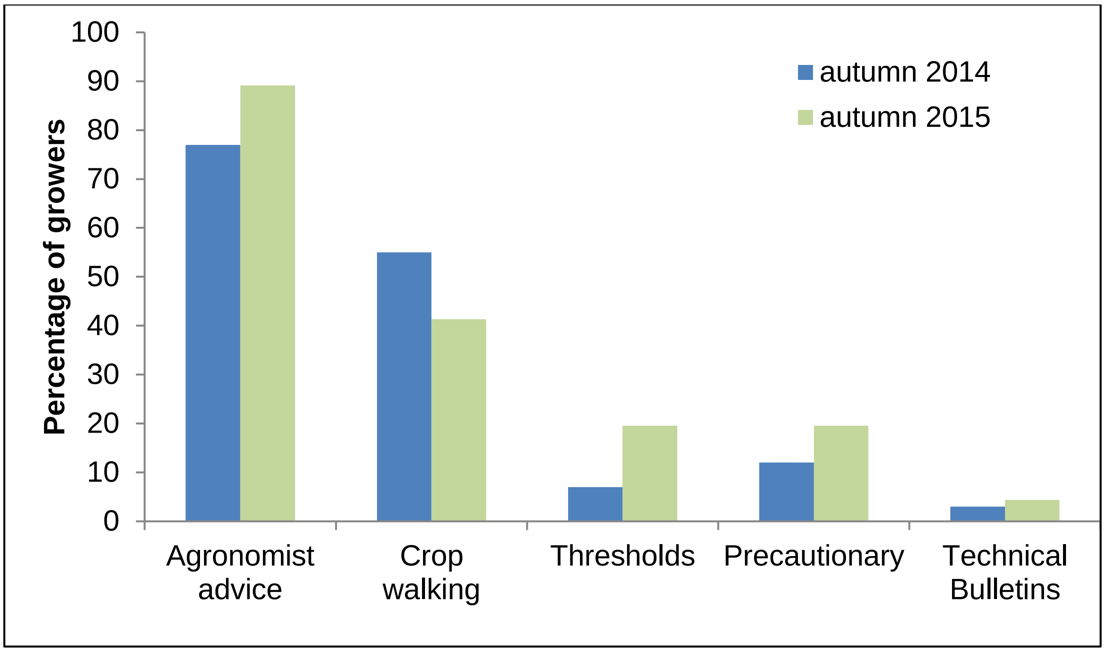


Figure 9 Reasons for insecticide use in 2014/15 and 2015/16 surveys

Targets of pesticide use

The pests targeted by the insecticide sprays applied by growers are presented in Table 9. Sprays were applied to combat aphids, flea beetles and rape winter stem weevil. However, the main focus of insecticide applications was flea beetle control, which accounted for 65 per cent of total sprays, and 71 per cent of the total treated area. Aphids were a target in 9 per cent of sprays (10 per cent of treated area). Rape winter stem weevil, which is not an approved target of neonicotinoid seed treatments, was the focus for 25 per cent of applications (19 per cent of treated area).

The targets encountered in autumn 2015 are very similar to those reported in the previous survey. In autumn 2014, flea beetles, aphids and rape winter stem weevil were the focus of 67, 4 and 22 per cent of sprays respectively and 73, 3 and 15 per cent of the total treated area.

Insecticide active substances applied

The insecticides encountered in this survey were almost exclusively pyrethroid compounds (Table 10). The only exception was a single spray of the active substance pymetrozine, a pyridine insecticide. Four pyrethroid active substances were recorded; alpha cypermethrin, cypermethrin, lambda cyhalothrin, and zeta cypermethrin. Lambda cyhalothrin and zeta cypermethrin were the most frequently used compounds, together accounting for 84 per cent of sprays applied by growers and 80 per cent of the total area treated.

Pyrethroid insecticides were also the most commonly used compounds in the 2014/15 survey, accounting for all but one spray of acetamiprid (Figure 10). A greater range of pyrethroid active ingredients were encountered in autumn

2014, six in total, with the most commonly used being lambda cyhalothrin, zeta cypermethrin and cypermethrin, collectively accounting for 79 per cent of sprays applied by growers and 84 per cent of the total area treated.

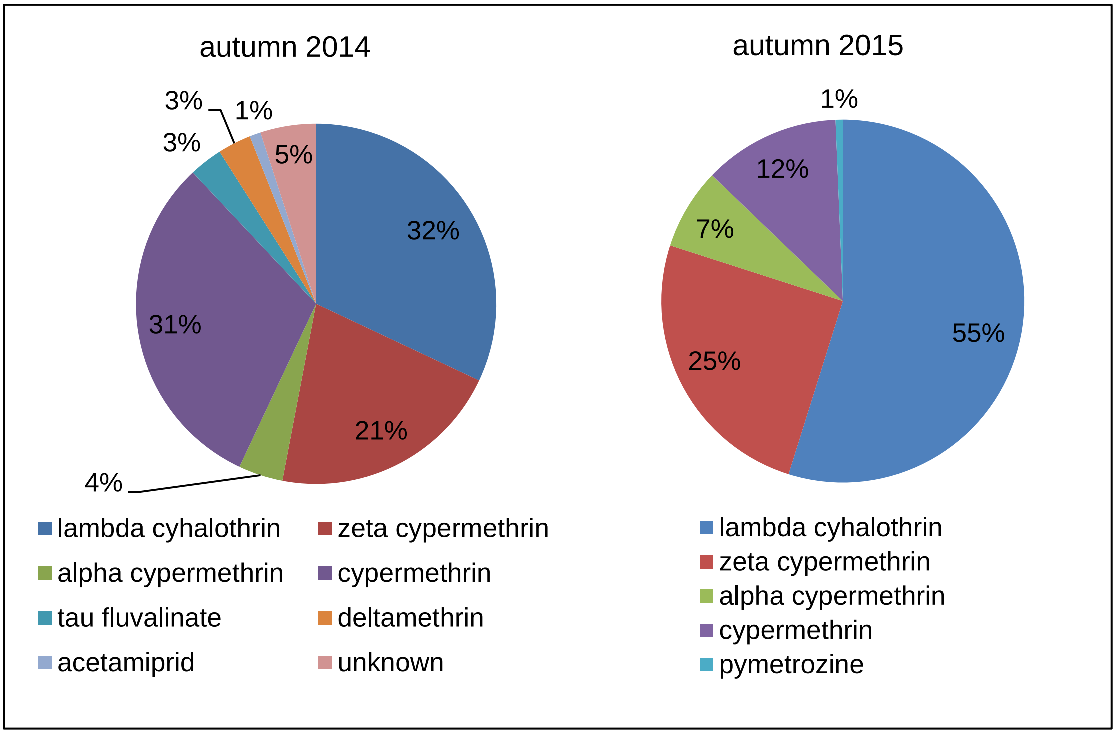


Figure 10 Insecticide active substances applied in 2014/15 and 2015/16 surveys (percentage of total treated area)

Reported efficacy of insecticidal sprays

Growers were asked whether they experienced problems controlling autumn insect pests (Table 11). Despite concerns about the pyrethroid resistance status of both peach potato aphid and CSFB, the majority of the 46 growers who applied a spray did not report any problems with the efficacy of their pest control measures (87 per cent).

Of the six growers that did encounter problems controlling pests with pyrethroid insecticidal sprays, the majority (three growers) stated that high levels of CSFB made foliar control difficult. These growers did not consider this a pyrethroid resistance issue, but that large populations resulted in a continued problem with re-infestation which, in two cases, necessitated a second spray. One grower did state that they could not achieve sufficient efficacy with alpha-cypermethrin against CSFB, necessitating a second spray to control populations. In addition, two growers reported that weather conditions hampered spray application at the time it was needed.

Of the 58 growers that did not apply insecticides, six stated that they may have considered spraying but weather conditions precluded their use at the time at which they were needed.

Very similar responses were received from growers in the previous survey, in which 84 per cent of growers reported encountering no problems with spray efficacy. There was no statistical difference in response between the survey seasons (p>0.05).

Grower perception of autumn pest damage and crop loss

Growers were asked to rate autumn insect damage to their crops (Table 12). They were also asked to indicate which species they thought were responsible for the damage incurred.

Insect damage, during the 2015 crop emergence and establishment period was rated as low by the majority of growers (67 per cent of growers and sample area). An additional 15 per cent of growers did not report any insect damage to their crops. Therefore, 82 per cent of growers, collectively growing 83 of the sampled crops, reported no or low insect damage in 2015. Fifteen percent of growers reported damage to be moderate (low/moderate or moderate) and one per cent reported high damage levels.

In autumn 2014, the proportion of growers reporting damage as moderate (28 per cent) or high (six per cent) was significantly greater than in this survey (p=0.001) (Figure 11). The reduced insect damage incurred in autumn 2015 reflects the reduced pest pressure encountered in this survey.

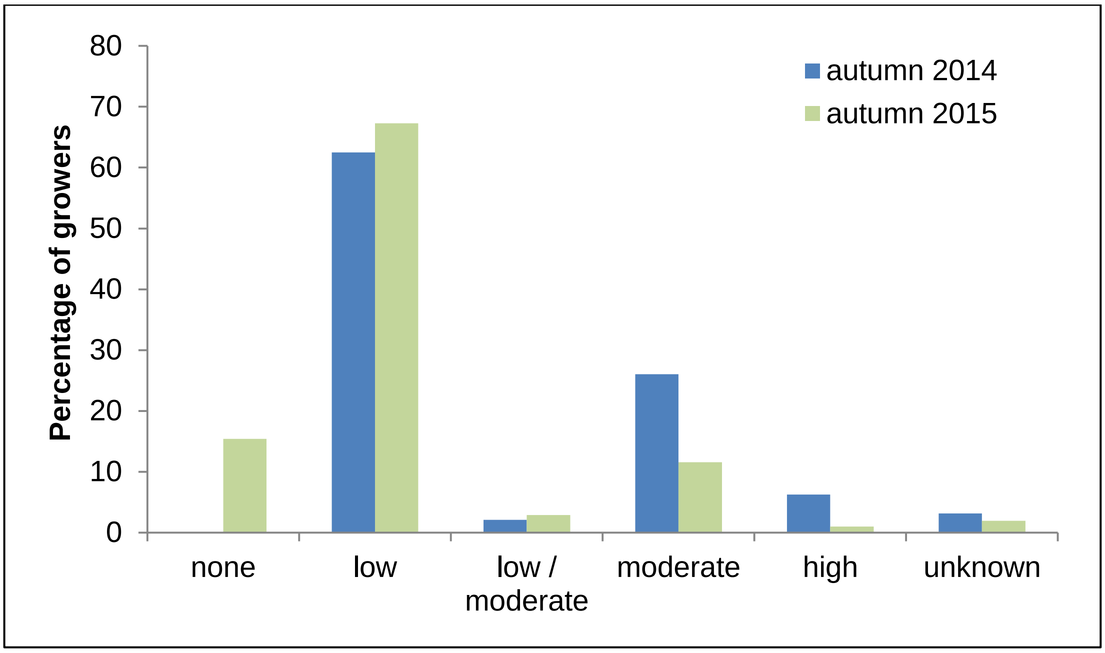


Figure 11 Autumn insect damage in 2014/15 and 2015/16 surveys

Growers were asked to identify the insect pests causing autumn damage to their crops (Table 13). As would be expected, CSFB was the most commonly cited species (61 per cent of growers). Aphids are a vector of virus and symptoms are not apparent until later in the growing season (information about viral monitoring and incidence is presented in the post-harvest section of this report). This pattern is similar to the previous survey, in which the majority of autumn insect damage incurred was attributed to CSFB.

In addition to asking growers to rank damage, they were also asked whether they thought that the lack of seed treatment had resulted in greater autumn insect damage to their crops in 2015 than in the period before the restrictions were in place (Table 14). Thirty eight per cent of growers responded yes, 54 per cent responded no and 8 per cent were not sure. These growers collectively cultivated 48, 47 and five per cent of sample area respectively. In 2014/15 the responses were 46 per cent yes, 49 per cent no and five per cent don't know.

Details of non-insect pest related damage to crops in autumn was also recorded (Table 15). Almost all growers (94 per cent) reported experiencing other pest damage. The most frequent pests encountered were slugs, which were reported by 83 per cent of growers, followed by pigeons reported by 29 per cent. Rabbits, geese and deer were also reported to have damaged WOSR crops by a small number of growers.

For some growers, failure of the crop during emergence and establishment resulted in re-drilling of a proportion of the sample area (Table 16). Of the 104 growers and 5,553 ha surveyed, seven growers collectively re-drilled 98 ha of failed crop (1.8 per cent of sample area). Of that area, 39 ha (0.7 per cent of the sample), grown by four farmers, were re-drilled due to damage from non-insect pests (slugs and geese). The remaining 59 ha (1.1 per cent of sample), grown by three farmers, was lost to poor weather at drilling and establishment. No crop loss was attributed to insect damage in 2015/16.

The overall level of crop loss encountered in this survey was very similar to the previous year in which 2.4 per cent of the sample was lost. There was no statistical difference in the number of growers who redrilled crops between the two years ($p>0.05$). In 2014/15, 1.1 per cent of the crop area was re-drilled due to CSFB damage and the remaining 1.3 percent was lost due to weather at drilling, poor seed vigour and damage from slugs, rabbits and pigeons.

Post-harvest data collection

All 104 growers were contacted post-harvest to collect data about TuYV incidence, yield and their attitude towards growing WOSR in the future. However, not all of the original participants responded at the second data collection point. Post-harvest data were collected from 98 growers, collectively growing 5,170ha of WOSR (17 per cent of the Scottish crop area).

Incidence of TuYV

Of the 98 growers who provided information, the majority (85 per cent) reported that their crops were visually checked for symptoms of TuYV and five per cent reported that viral symptoms were present. This is very similar to the pattern reported in the previous season when 79 per cent of growers checked their crops and four per cent reported the presence of symptoms.

In both years only one grower had crop samples tested for TuYV. In this survey the test was negative, in contrast to the previous survey where viral presence was confirmed. As discussed in the previous report, TuYV may be asymptomatic and can only be definitively diagnosed by serological testing. Therefore these data may underestimate viral presence. There were no significant differences in the proportion of growers checking for TuYV or for the observation of symptoms between the two surveys ($p>0.05$).

Crop yield

The average 2016 WOSR yield reported by the growers in this survey was 3.46 tonnes per hectare (t/ha), with a regional range of 3 to 3.85 t/ha (Table 17). This is similar to the 2016 Scottish average yield of 3.31 t/ha reported by the Scottish Government[(15)].

The majority of growers reported decreased yields in 2016 (84 per cent of growers, 87 percent of crop area). The remaining growers reported that yields were unchanged from the previous season (nine and eight per cent of growers and crop area respectively) or had increased (seven and five per cent of growers and area). Average yield declined in all geographic regions surveyed.

In the previous survey, yields of 4.21 and 4.28 t/ha were reported for 2014 and 2015 respectively (Figure 12). The 2016 survey yield is 19 per cent lower than that reported in 2015 and this decrease is statistically significant ($p<0.001$). There was also evidence of a significant interaction between yield and region ($p=0.002$), suggesting that the magnitude of yield change was not constant amongst regions.

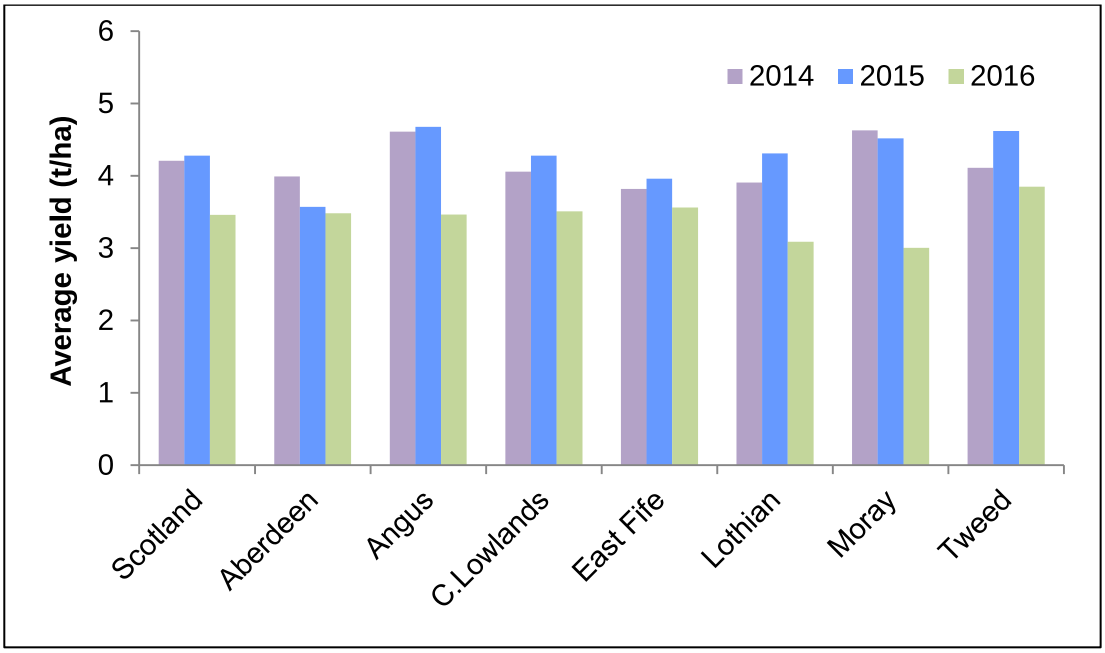


Figure 12 Average WOSR yield of survey area in 2014, 2015 and 2016

Scottish census data[15] also show a 20 per cent decrease in total Scottish oilseed rape yields in 2016 from the 20-year high yield of 4.15 t/ha in 2015 (Figure 13).

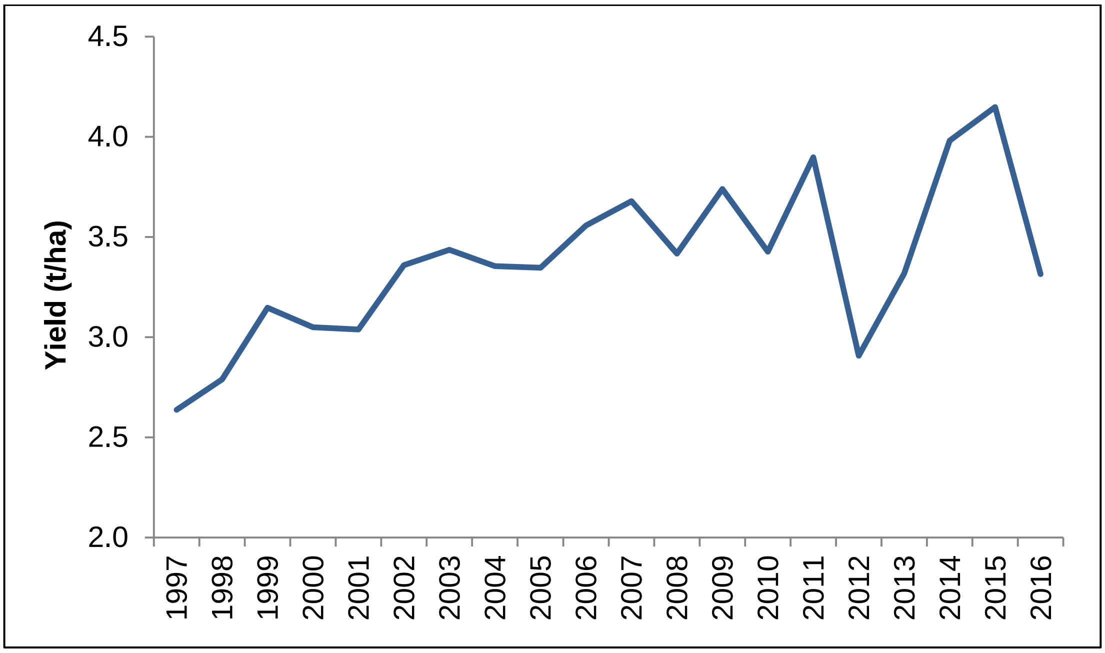


Figure 13 Average Scottish oilseed rape yield 1997-2016[15]

Whilst fluctuations of Scottish yield have been marked in recent years, it was reported that the large decrease in yield in 2016 was influenced by strong winds prior to harvest[15]. This was confirmed in our survey, in which the majority of growers who experienced a decrease in yield attributed this to the weather during the growing season (66 per cent stating weather alone and a further 14 per cent stating weather among other factors) (Table 18). A range of contributing weather conditions were reported to have influenced yield decline; high winds prior to harvest causing seed shed (35 per cent of growers), a lack of sun in late spring/summer causing retardation of crop flowering, growth and impaired grain fill (28 per cent), wet conditions in autumn/winter hampering establishment (23 per cent) and crop growth retarded by the cold spring (six per cent). As well as poor weather conditions, yield was also reported to have been affected by other factors such as disease (clubroot), pigeon and slug damage as well as by weed growth, poor soil and late drilling in autumn 2015. Two growers, representing five per cent of those experiencing yield losses, reported that the CSFB damage had contributed to the decline. Both of these growers, who were located in the south of Scotland, also stated that lack of sun had also influenced yields.

Overall, the growers surveyed reported that a range of factors had contributed to the decline in yield, but that weather conditions, and in particular high winds pre-harvest, were the primary driver responsible for yield declines in comparison to the previous season.

Grower attitudes to future WOSR cultivation

Following harvest, growers were asked whether, based on their current experience, they would grow oilseed rape in future. The majority stated that they would continue to grow WOSR (75 per cent), 16 per cent stated that they would be less likely in future, six per cent more likely and three per cent didn't know. There was no significant difference in reported intentions of future WOSR cultivation between survey years ($p>0.05$, Figure 14).

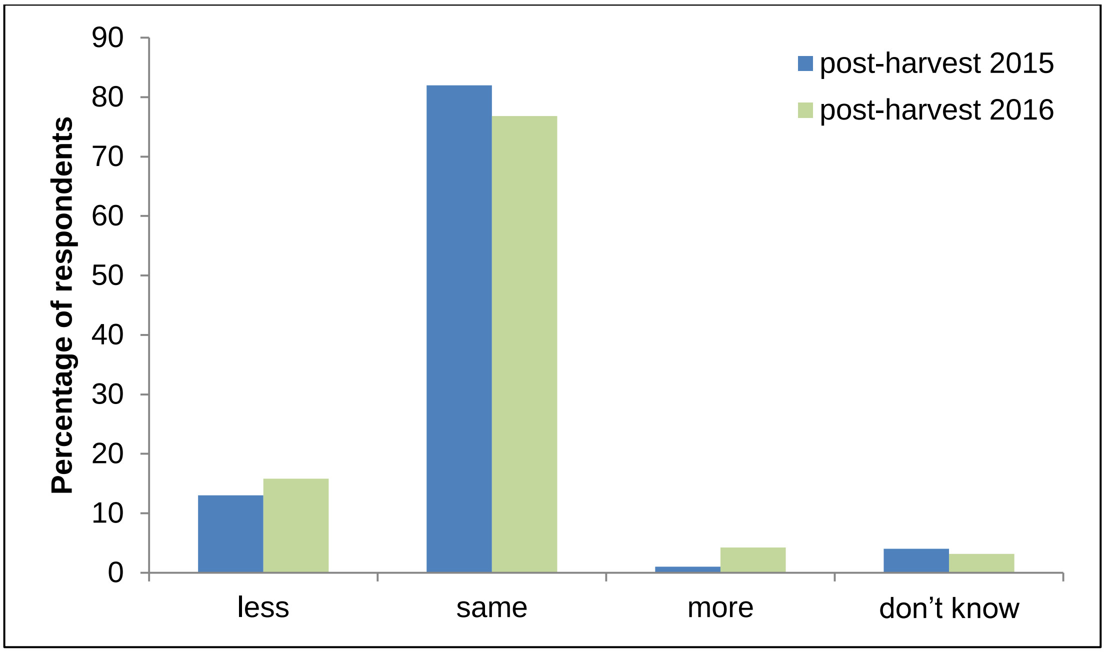


Figure 14 Grower intention to cultivate WOSR in future in 2014/15 and 2015/16 surveys

Growers were given the opportunity to comment on their response. Of the 15 growers who stated that they were less likely to grow WOSR in future, eight provided comments. Five stated that this decision was unrelated to the availability of seed treatments; but was influenced by general economic return, cultivation of alternative break crops and problems with slugs. The other three growers were influenced by the neonicotinoid restrictions. These growers reported that the additional inputs and risk required to grow WOSR in the absence of insecticidal seed treatments made the crop less attractive.

In relation to those growers who specified that they would not change their WOSR cultivation, the majority stated that they had not encountered problems associated with the lack of an insecticidal seed treatment. However, some stated that they would reassess if this changed in future. Of the 6 growers who intended to sow more in 2017, all stated that this was due to not having encountered problems during the neonicotinoid restrictions, with one also citing increasing market price.

As with the previous survey, the common theme from growers was that the main drivers in choosing whether WOSR was grown in future were market price, input costs and economic return.

Discussion

This is the second of two consecutive surveys collecting information about winter oilseed rape cultivation from a large, representative sample of Scottish farmers. In the first survey in this series, the neonicotinoid restrictions made the control of insect pests challenging, both practically and economically, for some growers. The lack of an insecticidal seed treatment resulted in increased use of foliar insecticides and some CSFB related crop loss was encountered(8). However, other growers experienced little or no impact, and the overall effect on Scottish cultivation was less severe than reported elsewhere in the UK, particularly in the South and East of England.

In the first year of the restrictions, climatic conditions were favourable for oilseed rape cultivation and autumn pest pressure was generally low to moderate. This second survey was conducted to help assess the effect of the restrictions, under different conditions, and upon growers who have gained some experience of WOSR cultivation without insecticidal seed treatments.

It was reported, by the majority of survey participants, that climatic conditions were generally unfavourable for the cultivation of Scottish WOSR crops harvested in 2016. The late harvest of 2015 crops, followed by a period of wet weather, led to problems with autumn drilling, and as a consequence some recruited participants were unable to grow WOSR in 2015/16. Those growers that did sow, drilled later than they had in the previous year. Poor climatic conditions were reported to have continued throughout the season. Growers reported a range of adverse weather affecting crop development, including: a wet autumn and winter, cold spring conditions, lack of sun in spring and summer and high winds prior to harvest causing seed shed in many areas.

The Scottish census area of WOSR declined by 14 per cent between 2015 and 2016(6) and reductions in Scottish winter crop areas, both cereals and oilseeds, were partly attributed to the aforementioned late harvest and rainfall(14). Although, it was also noted that changes to the EU Common Agricultural Policy (CAP) support schemes, particularly the crop diversification requirement, may have influenced variation in the areas of crops sown(14). A similar reduction in WOSR area, 11.2 per cent, was reported for the UK as a whole(16). The AHDB 2016 planting survey stated that the key factor behind the lower 2016 oilseed rape area was economic, reflecting the prospect of historically poor market returns(17).

In addition to reducing the area sown in Scotland, the adverse climatic conditions at crop sowing and establishment may also have negatively influenced pest populations. Reported aphid and flea beetle levels were significantly lower than in the previous survey. Reduced CSFB incidence was associated with significant reductions in autumn insect damage compared with the previous year. No CSFB-related crop loss was encountered in autumn 2015, in contrast to the one per cent of the sample lost in autumn 2014. Although the area re-drilled overall, to replace crop lost to a combination of slug, geese and weather related damage, was similar to the previous survey. Incidence of TuYV symptoms, transmitted by aphids, was also low but similar to the previous year.

The crop damage data collected in this survey was comparable to that reported by the ADAS cabbage stem flea beetle incidence and severity monitoring[18]. This monitoring was based on agronomist inspection of 62,000 ha of UK crops, 2,240 ha of which were in Scotland. Despite the differences in survey methodology, agronomist inspection of crops versus grower reports of pest damage, the results were similar. ADAS reported no CSFB flea beetle related crop loss in Scotland and the majority of crops were assigned to no or low damage categories (>90 per cent of crops)[18].

At a UK level, the crop loss attributed to CSFB grazing by the ADAS survey also decreased between the two seasons; from five per cent in autumn 2014[18] to one per cent in autumn 2015[19]. In both years, UK CSFB damage varied with geographic area and the highest losses were in the English Eastern and South East regions, which reported 2 and 1.7 per cent crop loss respectively in 2016. As in this survey, crop loss unrelated to insect damage was also encountered, with an additional 3.1 per cent of the sample re-drilled, primarily in response to slug grazing[18].

The decreases in Scottish pest pressure and damage levels reported in this survey were associated with significantly reduced insecticide use, with sprays primarily focussed on CSFB control. Spray regimes in autumn 2015 were very similar to pre-restriction levels. However, there are no data on comparative pest pressure between these two seasons and 38 per cent of growers still stated that they incurred more damage during autumn 2015 than when neonicotinoid seed treatments were available. The insecticides encountered were almost exclusively pyrethroids. Despite the presence of pyrethroid resistance in UK populations of CSFB, only one grower reported concerns about pesticide efficacy.

UK use of insecticides was also reported to primarily consist of pyrethroid compounds, although around 9 per cent of agronomists reported using Insyst (acetamiprid), which had an emergency use authorisation for CSFB in autumn 2015[18]. However, in line with lower pest pressure and damage, Scottish pesticide use was lower than reported for the UK crop, where 75 per cent of the crop was reported to be treated with an insecticide, with an average of two sprays applied overall[18]. In contrast, 44 per cent of the Scottish crop surveyed was treated and received, on average, 0.5 sprays.

There was a significant decrease in WOSR yield in 2016, both in this survey and at a Scottish and UK level (19, 20[15] and 21[16] per cent respectively). Amongst our survey participants, this decrease was primarily attributed to climatic factors, with other factors such as late drilling, clubroot, competition from weeds and pest damage (including CSFB) playing a minor role. The role of weather conditions was echoed at a Scottish census level[15]. In relation to the UK yield, ADAS reported that there were a number of contributory factors, including a range of climatic factors, high weed pressure, high pest pressure (slugs and, in the South East, CSFB), high disease pressure and, in some cases, the influence of short rotations[(20)].

Overall, despite 2016 being sub-optimal year for Scottish WOSR production, this survey corroborates the findings of the first survey. Under current conditions, the neonicotinoid restrictions have introduced additional challenges for some WOSR growers which will have an economic impact on their operation. In addition, in both surveys, a small proportion of growers stated that these restrictions reduce the likelihood of their growing the crop in future. However, other growers appear to be relatively unaffected and it is clear that the impact of the restrictions are far less severe in Scotland than in other regions of the UK which have greater pest pressure and levels of resistance to approved foliar insecticides.

Whilst both pest pressure, and in particular resistance occurrence, may change with time, the current situation gives Scotland an advantage in this period of uncertainty in relation to pesticide approvals. It appears that Scottish growers can, on the whole, continue to successfully cultivate WOSR whilst research and guidance about alternative control strategies is formulated. ADAS, funded by AHDB, is investigating the factors influencing UK CSFB population dynamics and damage potential, including the relationship between adult and larval infestation and resultant yield impact[(21)]. This project is also investigating the development of non-chemical control strategies for CSFB, such as; varietal susceptibility, use of oilseed rape volunteers as a trap crop and targeted defoliation to stop larvae moving from leaves to stems[(21)]. This research will help to create an integrated pest management (IPM) strategy for CSFB control which can be transferred to agronomists and growers.

There also appears, in this second survey, to be an element of adaptation to the restrictions amongst Scottish growers. Growers reviewed the impact of operational changes to crop cultivation, and made fewer changes in this second season. Growers also made greater use of action thresholds and published data sources when making pest management decisions and displayed a better knowledge of the pest species present on their crops. In this survey we also encountered a greater number of growers implementing more targeted pest control regimes, leaving some areas untreated rather than spraying the whole crop area. The relative success of all of these inputs, alongside the results of future research, can be used by growers to determine which actions should be adopted in future IPM strategies for their crops.

Currently, no follow up surveys on Scottish WOSR crops are scheduled. However, SASA's pesticide survey unit will continue to monitor the situation and reassess this position if the evidence suggests future monitoring is necessary. It should also be noted that the 2016 pesticide use on Scottish arable crop survey, which will be reported in autumn 2017, will provide comparative national estimates of insecticide use on oilseed rape between the crops harvested in 2014 (sown prior to the restrictions) and 2016. These arable pesticide use surveys are routinely conducted every two years.

Appendix 1 - Results tables

Table 1 Distribution of census and survey areas of winter oilseed rape in Scotland in 2015/16

Region	Census Area (ha)	Number of growers surveyed	Number of holdings surveyed(1)	Surveyed Area (ha)	Percentage of census area surveyed
Highlands & Islands	3	0	0	0	0
Caithness & Orkney	0	0	0	0	N/A
Moray	2,493	6	7	319	13
Aberdeen	6,952	25	31	1,559	22
Angus	6,603	28	34	1,204	18
East Fife	1,989	9	11	437	22
Lothian	4,143	14	18	803	19
Central Lowlands	1,388	6	7	226	16
Tweed Valley	6,260	16	23	1,004	16
Southern Uplands	207	0	0	0	0
Solway	103	0	0	0	0
Total Scotland	**30,141**	**104**	**131**	**5,553**	**18**

(1) Some growers cultivated WOSR on more than one holding
N/A = not applicable

Table 2 Drilling date of winter oilseed rape crops in autumn 2015

Drilling Period	Number of growers	Percentage of growers	Crop area (ha)	Percentage of sample area
First two weeks of August	2	2	170	3
Last two weeks of August	84	81	4,472	81
End August/early September	8	8	491	9
September	9	9	359	6
Not specified	1	1	60	1

Table 3 Operational changes in crop cultivation in autumn 2015

Operational Change	Number of growers	Percentage of growers	Crop area (ha)	Percentage of sample area
Soil cultivation(1)	6	6	350	6
Drilling date	4	4	203	4
Seed rate/spacing	4	4	221	4
Targeted fertiliser use(2)	2	2	74	1
Any operational change	**16**	**15**	**847**	**15**

(1) Includes alterations to seed bed production and soil cultivation such as minimum tillage, strip tillage and direct drilling
(2) Includes use of fertilising seed treatment and targeted fertiliser at drilling

Table 4 Methods of pest population assessment conducted in autumn 2015

	Agronomist advice	Crop walking	Published Information(1)	Thresholds	Traps
No. growers	89	62	36	29	1
Percentage of growers	86	60	35	28	1

(1) Includes SRUC, AHDB and Bayer technical bulletins (used by 24, 21 and 1 per cent respectively) and farming press (used by 10 per cent)

Table 5 Insect pest pressure in autumn 2015

Pest pressure ranking	Aphids		Flea beetles	
	Number of growers	Percentage of growers	Number of growers	Percentage of growers
low (none seen)	14	13	21	20
low	76	73	64	62
low/moderate	1	1	3	3
moderate	5	5	11	11
Moderate/high	0	0	1	1
high	1	1	1	1
Unknown	7	7	3	3

Table 6 Flea beetle species encountered in autumn 2015

	CSFB[2]	CSFB & *Phyllotreta* spp.	*Phyllotreta* spp.[3]	unknown
No. growers[1]	13	1	1	6
Percentage of growers	62	5	5	29

(1) Twenty one growers encountered and attempted to identify the flea beetle species present
(2) Cabbage stem flea beetle
(3) *Phyllotreta* spp. flea beetles

Table 7 Insecticidal sprays applied in autumn 2015

Number of sprays[1]	Number of growers	Percentage of growers	Basic area (ha)[2]	Percentage of sample area	Total treated Area[3]
None	58	56	3,090[5]	56	N/A
<1[4]	5	5	N/A[5]	N/A	N/A[5]
One	32	31	1,844[5]	33	1,844[5]
Two	8	8	601	11	1,202
Three	1	1	18	<1	54
Total	**104**		**5,553**		**3,100**

(1) The total number of sprays applied by growers was 56 (32 x one spray, eight x two sprays, one x three sprays and five part sprays[4])
(2) Basic area is the area of crop treated with an insecticide irrespective of the number of times that area is treated. The total basic area treated with an insecticide was 2,463 ha
(3) Total treated area is the basic area of a crop treated with an insecticide multiplied by the number of treatments that were applied. For example if a field of five hectares gets sprayed with the same insecticide twice, the basic area treated is five hectares, and the total treated area is 10 hectares
(4) These growers sprayed part, but not all, of their crop area with a single spray, therefore the total number of sprays applied by these growers is less than one. These five growers treated 33, 53, 64, 77 and 83 per cent of their crop areas
(5) Crop area for part sprays has been assigned to the appropriate spray categories (i.e. the area which was not sprayed is assigned to the none category and the sprayed area assigned to the one category)
N/A = not applicable

Table 8 Reasons for insecticide application in autumn 2015

	All growers (n=104)		Growers who sprayed (n=46)		Growers who didn't spray (n=58)	
	Number	Percentage	Number	Percentage	Number	Percentage
Agronomist advice	84	81	41	89	43	74
Crop walking	42	40	19	41	23	40
Thresholds	18	17	9	20	9	16
Precautionary spray	9	9	9	20	N/A	N/A
Technical Bulletins[(1)]	2	2	2	4	0	N/A

(1) Includes SRUC and AHDB technical bulletins
N/A = not applicable

Table 9 Target of insecticide sprays in autumn 2015

Target pest(s)[(1)]	Number of sprays		Basic area[(3)]		Total treated area[(4)]	
	Number[(2)]	% of total sprays	ha	% of sample area	ha	% of total treated area
CSFB	31	54	1,542	28	1,920	62
Flea beetle (unspecified species)	2	4	53	1	53	2
Rape winter stem weevil	13	23	440	8	518	17
CSFB and rape winter stem weevil	1	2	60	1	60	2
Aphids	3	5	79	1	160	5
CSFB and aphids	2	4	141	3	141	5
Unknown	4	7	133	2	233	7
Phyllotreta spp. flea beetles	1	2	16	<1	16	1
Total	**57**		**2,463**		**3,100**	
Total flea beetle (all species)[(5)(8)]	**37**	**65**	**1,812**	**33**	**2,190**	**71**
Total rape stem weevil[(6)(8)]	**14**	**25**	**500**	**9**	**578**	**19**
Total aphids[(7)(8)]	**5**	**9**	**220**	**4**	**301**	**10**

(1) Targets of sprays identified by growers, grouped into common targets
(2) The sprays in this column add up to 57, not 56 as in Table 7, due to one grower spraying two different spray regimes (with different targets) on different areas of his crop i.e. the total number of sprays each composite area received was two, but three different spray regimes were applied overall
(3) Basic area is the area of crop treated with an insecticide irrespective of the number of times that area is treated
(4) Treated area is the basic area of a crop treated with an insecticide multiplied by the number of treatments that were applied. For example if a field of five hectares gets sprayed with the same insecticide twice, the basic area is five hectares, and the treated area is 10 hectares
(5) Collating all sprays with at least one species of flea beetle as a target (CSFB, flea beetle (unspecified species), CSFB & rape winter stem weevil, CSFB & aphids and *Phyllotreta*)
(6) Collating all sprays with stem weevil as a target (rape winter stem weevil & CSFB and rape winter stem weevil)
(7) Collating all sprays with aphids as a target (Aphids & CSFB and aphids)
(8) Note that as some sprays had more than one target they have been counted more than once in the collated species data. Therefore when collated targets and unknown sprays are added together they exceed 100% of the total sprays

Table 10 Insecticidal active substances applied in autumn 2015

Active substance[1]	Number of sprays[2]		Basic area[3]		Total treated area[5]	
	No.	% of total sprays	ha	% of sample area[4]	ha	% of total treated area[6]
All active substances	57		2,463	44	3,100	
Lambda cyhalothrin	31	54	1,495	27	1,700	55
Zeta cypermethrin	17	30	550	10	779	25
Alpha cypermethrin	5	9	203	4	224	7
Cypermethrin	3	5	195	4	377	12
Pymetrozine	1	2	20	<1	20	<1
Total pyrethroids	**56**	**98**	**2,443**	**44**	**3,080**	**99**
Total non-pyrethroids	**1**	**2**	**20**	**<1**	**20**	**<1**

(1) All products applied contained only one active substance; all of the compounds listed are pyrethroid insecticides with the exception of pymetrozine which is a pyridine insecticide
(2) The total number of sprays is 57, not 56 as in Table 7, due to one grower spraying two different spray regimes (with different active substances) on different areas of his crop i.e. the total number of sprays each composite area received was two, but three different sprays were applied overall
(3) Basic area is the area of crop treated with an insecticide irrespective of the number of times that area is treated
(4) The percentage of sample area is the basic area of each active substance divided by the sample area
(5) Treated area is the basic area of a crop treated with an insecticide multiplied by the number of treatments that were applied. For example if a field of five hectares gets sprayed with the same insecticide twice, the basic area is five hectares, and the treated area is 10 hectares
(6) The percentage of total treated area is the treated area of each active substance divided by the total treated area

Table 11 Efficacy of pest control regime in autumn 2015

	Growers who sprayed (n=46)		Growers who didn't spray (n=58)	
	Number	Percentage	Number	Percentage
High pest numbers made control difficult	3	7	0	0
Weather prevented spraying	2	4	6	10
Insufficient insecticide efficacy	1	2	N/A	N/A
Encountered problems	**6**	**13**	**6**	**10**
Did not encounter problems	**40**	**87**	**52**	**90**

N/A = not applicable

Table 12 Insect damage in autumn 2015

	Number of growers	Percentage of growers	Crop area (ha)	Percentage of sample area
None	16	15	902	16
Low	70	67	3,696	67
Low/moderate	3	3	199	4
Moderate	12	12	594	11
High	1	1	57	1
Unknown	2	2	104	2

Table 13 Insect pests causing crop damage in autumn 2015

Pest	Number of growers	Percentage of growers	Crop area grown(1) (ha)	Percentage of sample area
CSFB(2)	63	61	3,649	66
CSFB/rape winter stem weevil(3)	2	2	101	2
Phyllotreta spp. flea beetles(4)	2	2	26	<1
Rape winter stem weevil(5)	1	1	30	1
Unknown insect pest(6)	18	17	740	13
No insect damage reported	16	15	902	16
Insect damage levels unknown	2	2	104	2

(1) It should be noted that this is the total crop area grown by those who reported damage, not necessarily the crop area affected by that pest
(2) For CSFB damage, levels were ranked as low by 79% of these growers, low/moderate or moderate by 19% and high by 2%
(3) For CSFB/rape winter stem weevil, levels were ranked as low by one grower and moderate by the other
(4) For *Phyllotreta spp*. flea beetle, both growers reported damage to be low
(5) Rape winter stem weevil damage was reported to be low by the single grower who reported this pest
(6) Where the insect pest causing damage was unknown, damage was reported to be low by 94% of growers and moderate by 6%

Table 14 Grower perception of autumn 2015 insect damage in relation to pre-restriction levels

Did the lack of an insecticidal seed treatment result in greater crop damage?	Number of growers	Percentage of growers	Crop area (ha)	Percentage of sample area
Yes	40	38	2,638	48
No	56	54	2,615	47
Don’t know	8	8	300	5

Table 15 Non-insect pests causing crop damage in autumn 2015

Pest	Number of growers	Percentage of growers	Crop area grown[1] (ha)	Percentage of sample area
Slugs[2]	86	83	4,652	84
Pigeons[3]	30	29	1,585	29
Rabbits[4]	2	2	54	1
Geese[5]	1	1	38	1
Deer[6]	1	1	30	1
Non-insect pest damage reported[7]	**98**	**94**	**5,272**	**95**
No non-insect pest damage reported	**5**	**5**	**256**	**5**
Unknown	**1**	**1**	**24**	**<1**

(1) It should be noted that this is the total crop area grown by those who reported damage, not the crop area affected by that pest
(2) For slug damage, levels were ranked as low by 48%, low/moderate or moderate by 33% and moderate/high or high by 20%
(3) For pigeon damage, levels were ranked as low by 30%, moderate by 43%, moderate/high or high by 23% and unknown by 3%
(4) For rabbits, one grower reported damage to be moderate, and one grower as high
(5) Goose damage was reported to be moderate by the single grower who reported this pest
(6) Deer damage level was not reported by the single grower who reported this pest
(7) The total is less than the sum of the pests above as several growers reported more than one pest species

Table 16 WOSR crop loss in autumn 2015

Reason	Number of growers	Percentage of growers	Crop area (ha)	Percentage of sample area
Non-insect pests[1]	4	4	39	0.7
Weather related[2]	3	3	59	1.1
Total crop loss	**7**	**7**	**98**	**1.8**

(1) Slugs (3 growers, 33 ha) and geese (1 grower, 6 ha)
(2) Wet weather and flooding

Table 17 Average WOSR yield in 2016

Region	Number of growers	Area of crop grown	Average 2016 yield (t/ha)
Aberdeen	23	1,460	3.48
Angus	27	1,188	3.47
Central Lowlands	6	226	3.51
East Fife	9	437	3.56
Lothian	14	803	3.09
Moray	5	185	3.00
Tweed	14	871	3.85
Total(1)	**98**	**5,170**	**3.46**

(1) 98 of the 104 original survey respondents provided yield data

Table 18 Reasons for change in 2016 yield

Yield Change[1]	Reason	Number of growers	Percentage of growers[2]	Crop area (ha)	Percentage of area[2]
Decrease (n=82)	Weather conditions[3]	54	66	2,731	61
	Weather conditions[3] & late drilling	1	1	29	1
	Weather conditions[3] & disease[4]	4	5	640	14
	Weather conditions[3] & disease[4] & pests[5]	1	1	26	1
	Weather conditions[3] & pests[5]	4	5	165	4
	Weather conditions[3] & weeds	1	1	20	<1
	Weather conditions[3] & late drilling & pests[5]	1	1	30	1
	Disease[4]	1	1	69	2
	Late drilling	2	2	109	2
	Weeds	1	1	58	1
	Pests[5]	2	2	36	1
	Poor soil	1	1	30	1
	Not recorded/unknown	9	11	561	12
	Total reporting yield decrease	**82**		**4,503**	
Increase (n=7)	Different variety	2	29	47	20
	Better weather conditions	1	14	57	24
	Better weather conditions & fewer pests	1	14	28	12
	Better cultivation and establishment	1	14	49	21
	Not recorded	2	29	51	22
	Total reporting yield increase	**7**		**233**	

(1) Reasons are only reported where a change in yield ($\geq$ 5%) was encountered. No change was reported by nine growers, growing 434 ha (2) Percentage of growers/area is in relation to total growers with a decrease/increase (3) Weather conditions were cited as a reason for yield decrease by 66 growers in total (80% of those whose yield dropped). 35% of growers reported strong winds immediately prior to harvest causing seed shed, 28% cited a lack of sun in late spring/summer, 23% cited wet conditions in autumn/winter and 6% reported that crop growth had been retarded by the cold spring (4) disease (clubroot) was cited as a reason for yield loss by six growers (7%) (5) Pests were reported as a reason for yield loss by 10 growers (12%), six cited slugs, four pigeons and two CSFB

Appendix 2 - Survey methodology

Sampling and data collection

On completion of the previous survey, conducted in 2014/15[8], the 96 participants were asked if they would be willing to take part in a second year of monitoring. Sixty one of these growers initially agreed to participate and 50 were successfully recruited into the 2015/16 survey. The remainder either did not grow WOSR in 2015/16 or were no longer willing to participate.

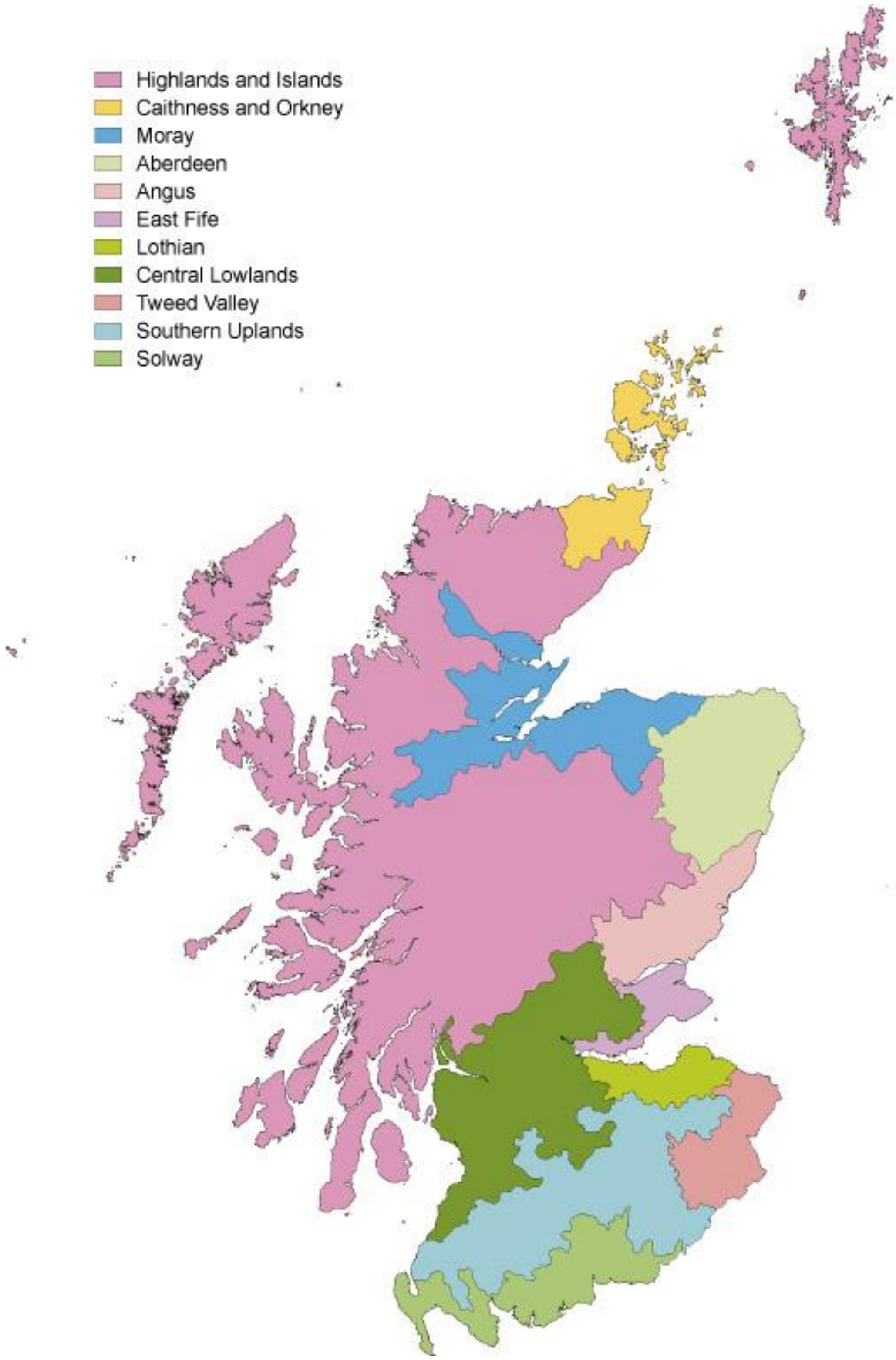
To supplement these participants, a second sample was drawn from the June 2015 Agricultural Census[13] representing winter oilseed rape cultivation in Scotland. The country was divided into 11 land-use regions (Figure 15) and the sample was stratified by these land-use regions and by holding size. The holding size groups were based on the total area of WOSR grown on the holdings. The sampling fractions used within both regions and size groups were based on the areas of relevant crops grown rather than number of holdings, so that smaller holdings would not dominate the sample. This sampling frame took into account the location of the existing participants to ensure a representative geographical spread was obtained. Fifty four growers were recruited from this sample.

These two samples were combined into a single survey sample and WOSR cultivation data were collected from 104 farmers collectively growing 5,553 ha of WOSR, representing 18 per cent of the Scottish crop. The crops surveyed were sown in 2015 and harvested in 2016, representing the second season of WOSR crops sown without insecticidal seed treatments.

Recruited growers were sent an initial explanatory letter outlining the aim of the survey and the data collection process. Data were then collected directly from growers by telephone interview. In some cases growers referred the surveyors to their agronomists for collection of some, or all, of the data.

Growers were contacted twice, once in winter 2015/16 and once in autumn 2016. At the first data collection point, growers were asked for information about their winter oilseed rape cultivation (area, seed rate, drilling date) and about operational changes they had made to mitigate for the lack of insecticidal seed treatments. Growers were also asked for information about their perception of insect pest presence, their use of autumn insecticides, their perception of the efficacy of the insecticides applied and the insect related damage that the crop incurred. Data were also collected relating to the information sources growers used to support decision making about pest and damage assessment and insecticide application. At the second data collection point growers were asked about monitoring and incidence of TuYV, 2016 yields and the about likelihood of their continuing to grow oilseed rape in the future if the restrictions continued. At both data collection points growers were also invited to make any general comments they wished about their experience of growing WOSR.

Figure 15 Land use regions of Scotland[21]



Statistical Analysis

The survey data collected in 2015/16 was compared to that collected in 2014/15. All statistical analyses were conducted by Elizabeth Duff at BioSS (Biomathematics and Statistics Scotland) using the GLMM and REML routines in GenStat 18 (VSN International Ltd, Hemel Hempstead, Herts., UK).

The traits analysed were: operational changes to crop cultivation, perceived autumn aphid pest pressure, perceived autumn flea beetle pest pressure, number of autumn insecticidal sprays, perceived spray efficacy, perceived autumn insect damage, crop re-drilling, TuYV checking and symptom occurrence and grower likelihood of cultivating WOSR in future.

For these analyses, grower was specified as a random effect to allow for repeated survey responses from those growers surveyed in both years. Fixed effects were specified as region (comparing the 7 regions in which crops were surveyed), year (comparing the 2 survey years), and region.year (testing for interactions between the 7 regions and the 2 years in order to assess whether differences between years are consistent over the 7 regions).

However, since there was no evidence of a significant interaction of region with year for the majority of the response variables, suggesting that increases or decreases with year are constant over all regions, the statistician focussed on analyses where fixed effects were specified as region + year. Where response variables showed evidence of a significant year by region interaction, this is clearly stated in the results.

In relation to reporting of mean values, for analyses using generalized linear mixed models (GLMMs) means are presented on the transformed scale. For GLMMs with a Poisson distribution and log link function (e.g. number of sprays) means can be converted from the transformed scale to the response scale by calculating exp(x), where x is the mean on the transformed scale. For GLMMs with a binomial distribution and logit link function (e.g. re-drilling) means can be converted to the response scale by calculating exp(x)/(1+exp(x)), where x is the mean on the transformed scale.

Detailed analyses and results

1) Number of sprays was analysed using a generalized linear mixed model (GLMM) with a Poisson distribution and a log link function. The dispersion was estimated from the data. A small number of growers recorded number of sprays as fractions between 0 and 1 (part-sprays). Number of sprays recorded as 0.5 or below were rounded down to 0, whilst numbers between 0.5 and 1 were rounded up to 1, prior to analysis.

There is some evidence that fewer sprays were applied on average in the second year (p=0.009) and also evidence that the number of sprays differed with region (p=0.001). The dispersion parameter was estimated as 0.472.

Mean number of sprays applied: GLMM, Poisson distribution, log link function. Arithmetic means are given in brackets.

	Year 1	Year 2	SED	p-value
Random=grower Fixed=Region+year	-0.357 (0.705)	-0.720 (0.529)	0.136	0.009

Summary of tests for fixed effects (sequentially adding terms to fixed models)

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Region	23.95	6	3.98	107.2	0.001
year	7.14	1	7.14	128.1	0.009

2) Re-drilling, operational changes and problems controlling pests with sprays were recorded as 'yes' or 'no', and were analysed using a generalised linear mixed model (GLMM) with a Binomial distribution and a logit link function. For statistical analyses of 'problems controlling pests with foliar sprays', growers responding as 'NA' were removed prior to analysis.

Re-drilling: The proportion of growers that re-drilled was very low (8/96 in year 1; 6/104 in year 2). There was no evidence of significant difference between years in the proportions.

Proportion of growers that re-drilled: GLMM, Binomial distribution, logistic link function. Observed proportions are given in brackets.

	Year 1	Year 2	SED	p-value
Random=grower Fixed=Region+year	-2.286 (0.083)	-2.697 (0.058)	0.574	0.475

Summary of tests for fixed effects (sequentially adding terms to fixed models)

Fixed term	Wald statistic	d.f.	Wald/d.f.	chi pr
Region	5.45	6	0.91	0.488
year	0.51	1	0.51	0.475

Operational changes: There was weak evidence of a decrease in the proportion of growers that made operational changes in the second year (p=0.052) but only when the interaction of region with year was not included in the analysis. When the interaction term was included in the analysis, this effect was no longer evident (results not shown).

Proportion of growers that made operational changes: GLMM, Binomial distribution, logistic link function. Observed proportions are given in brackets.

	Year 1	Year 2	SED	p-value
Random=grower Fixed=Region+year	-1.258 (0.260)	-2.009 (0.154)	0.386	0.052

Summary of tests for fixed effects (sequentially adding terms to fixed models)

Fixed term	Wald statistic	d.f.	Wald/d.f.	chi pr
Region	6.14	6	1.02	0.408
year	3.78	1	3.78	0.052

Problems controlling pests with foliar sprays: Ignoring those who responded NA, there was no evidence of significant differences between years in the proportions reporting problems. Similar results were found when the analysis was repeated excluding respondents who did not spray.

Proportion of growers that had problems controlling pests with foliar sprays: GLMM, Binomial distribution, logistic link function. Observed proportions are given in brackets.

	Year 1	Year 2	SED	p-value
All respondents (n=132)				
Random=grower Fixed=Region+year	-3.506 (0.257)	-3.720 (0.210)	0.445	0.631
Only those who sprayed (n=105)				
Random=grower Fixed=Region+year	-4.148 (0.155)	-4.151 (0.149)	0.590	0.995

Summary of tests for fixed effects - all respondents (sequentially adding terms to fixed models)

Fixed term	Wald statistic	d.f.	Wald/d.f.	chi pr
Region	4.06	6	0.68	0.669
year	0.23	1	0.23	0.631

Summary of tests for fixed effects - excluding those who did not spray (sequentially adding terms to fixed models)

Fixed term	Wald statistic	d.f.	Wald/d.f.	chi pr
Region	2.17	6	0.36	0.904
year	0.00	1	0.00	0.995

3) Perceived pest pressure and insect damage

Perception of aphid pest pressure, flea beetle pest pressure and insect damage were recorded on a 5 point scale: none; low; moderate; high; unknown. For statistical analyses, growers responding as ‘unknown’ were removed and the four remaining categories were aggregated as ‘none/low’ and ‘moderate/high’ prior to analysis using a generalised linear mixed model (GLMM) with a Binomial distribution and logit link function.

Aphid pest pressure: The proportions of growers that perceived aphid pest pressure as moderate or high was significantly lower in the second year ($p<0.001$). The random effect was estimated as zero.

Proportion of growers that perceived aphid pest pressure as moderate or high: GLMM, Binomial distribution, logistic link function. Observed proportions are given in brackets.

	Year 1	Year 2	SED	p-value
Random=grower Fixed=Region+year	-1.010 (0.272)	-2.610 (0.072)	0.464	<0.001

Summary of tests for fixed effects (sequentially adding terms to fixed models)

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Region	4.40	6	0.73	179.0	0.624
year	11.91	1	11.91	179.0	<0.001

Flea beetle pest pressure: The proportions of growers that perceived flea beetle pest pressure as moderate or high was significantly lower in the second year (p<0.001).

Proportion of growers that perceived flea beetle pest pressure as moderate or high: GLMM, Binomial distribution, logistic link function. Observed proportions are given in brackets.

	Year 1	Year 2	SED	p-value
Random=grower Fixed=Region+year	-0.470 (0.366)	-1.699 (0.158)	0.370	<0.001

Summary of tests for fixed effects (sequentially adding terms to fixed models)

Fixed term	Wald statistic	d.f.	Wald/d.f.	chi pr
Region	7.53	6	1.25	0.275
year	11.06	1	11.06	<0.001

Insect damage: The proportions of growers that perceived insect damage as moderate or high was significantly lower in the second year (p=0.001).

Proportion of growers that perceived insect damage as moderate or high: GLMM, Binomial distribution, logistic link function. Observed proportions are given in brackets.

	Year 1	Year 2	SED	p-value
Random=grower Fixed=Region+year	-0.457 (0.355)	-1.631 (0.157)	0.368	0.001

Summary of tests for fixed effects (sequentially adding terms to fixed models)

Fixed term	Wald statistic	d.f.	Wald/d.f.	chi pr
Region	6.04	6	1.01	0.418
year	10.17	1	10.17	0.001

Association between perceived insect damage and pest pressure - from the above, we see that the proportion of growers perceiving insect damage as moderate or high was very similar to the proportion of growers perceiving flea beetle pest pressure as moderate or high. This led us to examine, separately by year, whether it was the same growers that were recording both insect damage perception and flea beetle perception as either none/low or moderate/high. For comparison, we have also shown the association between insect damage and aphid pest pressure. As shown below, Insect damage appears to be more closely related to flea beetle presence than aphid presence.

Observed counts: flea beetle and insect damage

	Year 1		Year 2	
	Insect damage		Insect damage	
pest pressure	none/low	moderate/high	none/low	moderate/high
none/low	52	6	80	4
moderate/high	6	26	4	12
Total		90		100

Observed counts: aphid and insect damage

	Year 1		Year 2	
	Insect damage		Insect damage	
pest pressure	none/low	moderate/high	none/low	moderate/high
none/low	46	18	76	13
moderate/high	11	14	5	2
Total		89		96

4) Turnips yellow virus

Visual checking of crops for turnips yellow virus (TuYV) and observing TuYV symptoms were recorded as ‘yes’ or ‘no’, and were analysed using a generalised linear mixed model (GLMM) with a Binomial distribution and a logit link function.

Turnips yellow virus: visually checking crops: There was no evidence of significant differences between years in the proportions of growers that visually checked crops for TuYV.

Proportion of growers that visually checked crops for TuYV: GLMM, Binomial distribution, logistic link function. Observed proportions are given in brackets.

	Year 1	Year 2	SED	p-value
Random=grower Fixed=Region+year	1.518 (0.793)	1.953 (0.847)	0.4113	0.290

Summary of tests for fixed effects (sequentially adding terms to fixed models)

Fixed term	Wald statistic	d.f.	Wald/d.f.	chi pr
Region	1.79	6	0.30	0.938
year	1.12	1	1.12	0.290

<u>Turnips yellow virus; observing symptoms</u>: Focussing on only those respondents who checked crops for TuYV, the proportion of growers that saw symptoms of TuYV was very low (3/69 in year 1; 5/83 in year 2). There was no evidence of significant differences between years in the proportions of growers that observed symptoms of TuYV. Since models including the effect of region failed to converge, we show results from analysis where fixed effects were specified as year only.

Proportion of growers that saw symptoms of TuYV: GLMM, Binomial distribution, logistic link function. Observed proportions are given in brackets.

	Year 1	Year 2	SED	p-value
Only those who checked for TuYV (n=152)				
Random=grower Fixed=year	-3.091 (0.043)	-2.746 (0.060)	0.753	0.646

Summary of tests for fixed effects (sequentially adding terms to fixed models)

Fixed term	Wald statistic	d.f.	Wald/d.f.	chi pr
year	0.21	1	0.21	0.646

<u>Turnips yellow virus: testing crop</u>: The proportion of growers that tested crop for TuYV was extremely low (1/87 in year 1; 1/98 in year 2), so it was not possible to analyse these data using GLMM analysis.

5) <u>Yield</u>

Yield was analysed using residual maximum likelihood (REML) analysis. Plots of the residuals from the analysis indicated that the data did not require any transformation prior to analysis. There is evidence that yields were higher on average in the first year (p<0.001). There is also evidence that yield differed significantly on average with region (p=0.001), and evidence of a significant interaction between year and region (p=0.002), suggesting that the magnitude of changes between years was not constant over all regions but was dependent on region (see table and figure below). Since there was evidence of a significant interaction of year and region, we show results from the analyses where fixed effects were specified as region*year.

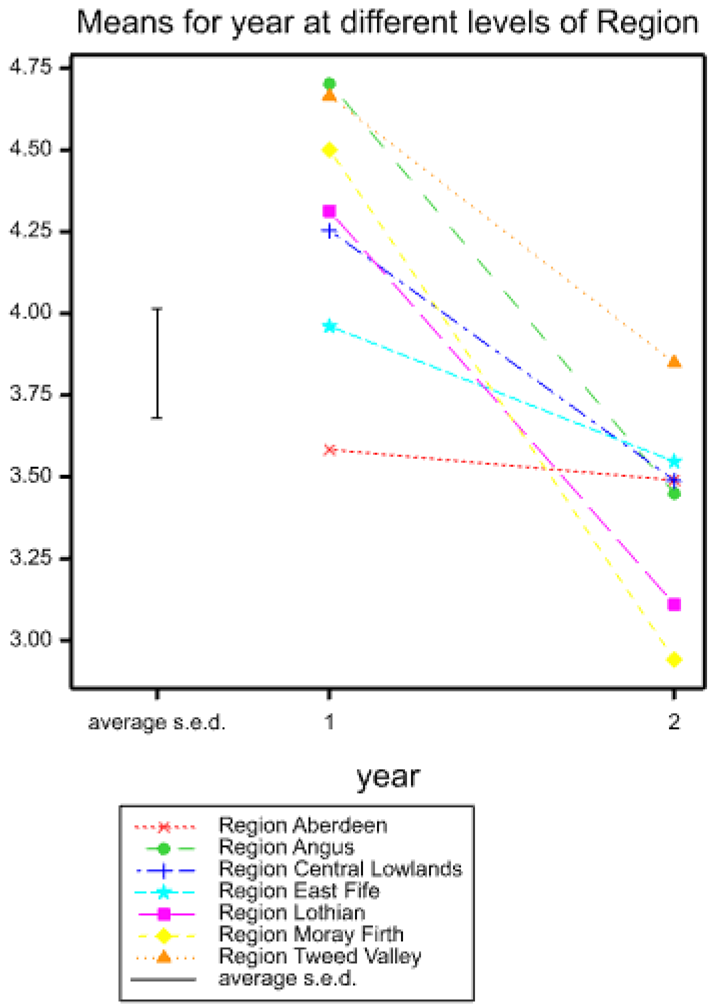
Mean yield: REML.

Region	**Year 1**	**Year 2**	**Mean**
Aberdeen	3.583	3.490	3.536
Angus	4.703	3.449	*4.076*
Central Lowlands	4.254	3.489	3.871
East Fife	3.960	3.547	3.754
Lothian	4.312	3.111	3.712
Moray Firth	4.500	2.942	3.721
Tweed Valley	4.664	3.849	4.257
Mean	*4.282*	*3.411*	

SED=0.1182 for overall year comparisons; average SED=0.2586 for overall region comparisons; average SED=0.3349 for comparisons between year by region means.

Summary of tests for fixed effects (sequentially adding terms to fixed models)

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Region	23.09	6	3.85	130.9	0.001
year	66.73	1	66.73	106.5	<0.001
Region.year	22.11	6	3.68	99.7	0.002

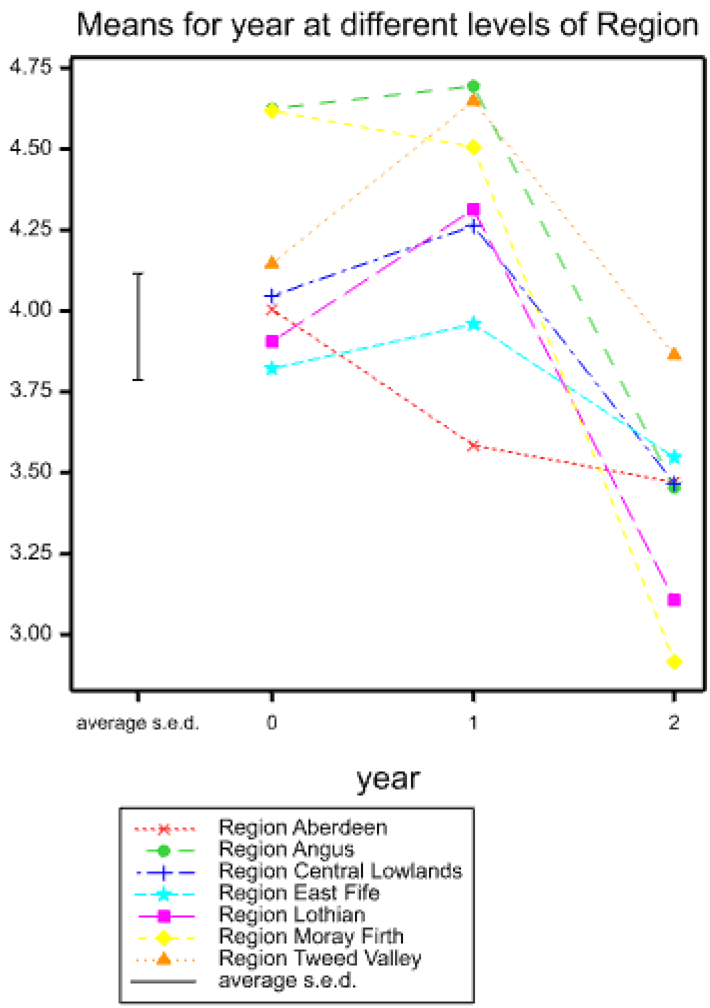


Similar results were found when the analysis was repeated including yields for 2014 (Year 0), with significant overall effects of year (p<0.001), region (p<0.001) and the interaction of year by region (p=0.002); the significant interaction suggesting that changes between years was dependent on region (see table and figure below). Since there was evidence of a significant interaction of year and region, we again show results from the analyses where fixed effects were specified as region*year. However, care must be taken when interpreting comparisons of yield between years. Year-to-year variation in yield is generally high so significant differences between years does not imply that this is due to something else that is also changing with year.

Mean yield: REML

Region	**Year 0**	**Year 1**	**Year 2**	**Mean**
Aberdeen	4.005	3.584	3.470	*3.686*
Angus	4.625	4.695	3.454	*4.258*
Central Lowlands	4.046	4.263	3.466	*3.925*
East Fife	3.822	3.960	3.547	*3.776*
Lothian	3.905	4.314	3.108	*3.776*
Moray Firth	4.619	4.506	2.916	*4.014*
Tweed Valley	4.146	4.649	3.863	*4.219*
Mean	*4.167*	*4.282*	*3.403*	

Average SED=0.1170 for overall year comparisons; average SED=0.2192 for overall region comparisons; average SED=0.3281 for comparisons between year by region means.



6) Growing WOSR in future

The likelihood of growing WOSR in future if restrictions remain was recorded on a 4 point scale: less; same; more; don't know. For statistical analysis, growers responding as 'don't know' were removed and the three remaining categories were aggregated into 2 categories, 'less' and 'same/more', prior to analysis using a generalised linear mixed model (GLMM) with a Binomial distribution and logit link function. There was no evidence of significant differences between years in the proportions that would be equally likely or more likely to grow WOSR in future.

Proportion of growers that would be equally likely or more likely to grow WOSR in future: GLMM, Binomial distribution, logistic link function. Observed proportions are given in brackets.

	Year 1	Year 2	SED	p-value
Random=grower Fixed=Region+year	1.860 (0.866)	1.616 (0.837)	0.4749	0.607

Summary of tests for fixed effects (sequentially adding terms to fixed models)

Fixed term	Wald statistic	d.f.	Wald/d.f.	chi pr
Region	7.60	6	1.27	0.269
year	0.26	1	0.26	0.607

Statistical Conclusions

Some evidence of differences between years was detected in six of the response variables analysed. However, analyses such as these describing changes over time need to be interpreted with caution since there are limitations of the inference that can be drawn. When a difference in response is detected between years, this does not imply that it is driven by something else that also changes between years.

Data quality assurance

The dataset underwent several validation processes as follows; (i) checking for any obvious errors upon data receipt (ii) checking and identifying inconsistencies and omissions once entered into spreadsheets (iii) 100 per cent checking of data held in the spreadsheets against the raw data. Where inconsistencies or errors were found these were checked against the records and with the farmer where necessary. Additional quality assurance is provided by sending reports for independent review before publication.

Main sources of bias

The data presented in this report were produced by surveying a representative sample of holdings rather than conducting a census of all the holdings in Scotland. The data, therefore, represents that sample of crop only and not all Scottish winter oilseed rape cultivation.

This survey may be subject to measurement bias as it is reliant on respondents recording and reporting data accurately. As this survey was not compulsory it may also be subject to non-response bias, as some farmers may be more likely to agree to participate than others. However, experience indicates that stratified random sampling coupled with collection of data by personal interview, delivers the highest quality data and minimises non-response bias.

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