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Farming Oilseed Rape without Neonicotinoids

Acknowledgements

This report is written by Sandra Bell, Friends of the Earth Bee Cause campaigner, based on a research report by Ellie Crane commissioned by Friends of the Earth.

Contents

Executive Summary

In 2013, following a thorough scientific review by the European Food Safety Authority (EFSA) and a vote by Member States, the European Commission restricted the use of three neonicotinoid pesticides which posed a “high acute risk” to honey bees. The current restrictions are unlikely to be changed before 2017, at which time they could be extended or made permanent. Friends of the Earth believes that, due to the mounting evidence of harm to bees since the restrictions were introduced the ban should be made permanent and applied to all crops in order to protect bees and other wildlife.

Farmers need effective alternatives to neonicotinoids that do not harm bees or other beneficial insects. This report looks at evidence and farmer practice in using non-chemical methods of pest control in oilseed rape (OSR). Our research found that combining a range of alternative techniques in a genuine Integrated Pest Management (IPM) approach should enable farmers to significantly improve control of OSR pests without neonicotinoids.

Abbreviations used in this report

CSFB = cabbage stem flea beetle
IPM = Integrated Pest Management
OSR = oilseed rape
TuYV = turnip yellows virus

The need for an alternative approach

There is a clear need to develop an alternative approach to pest control in OSR. Evidence is mounting that insecticides are harming the very ecosystem services – such as pollination and natural pest control – that farming relies upon. Added to this is the increasing development of resistance of key pests to the chemicals used to control them, making these controls ineffective in the long term.

Under EU law (EU Directive 2009/128/EC), farmers are already expected to practice Integrated Pest Management. But it is increasingly clear from surveys that much of the OSR in the UK has not been grown according to IPM principles. For example, crop rotations have been shortened, and pest thresholds and monitoring protocols are available but not widely used.

Instead insect pest management in OSR has hinged around the use of both pyrethroids and neonicotinoids. Many of the commercial neonicotinoid seed dressings, such as Modesto, also contain a pyrethroid, so neonicotinoids did not replace pyrethroids. Over-use of pyrethroids has led to widespread resistance in key pests, despite which they continue to be widely used, and resistance to neonicotinoids is also becoming apparent. Using insecticide treated seed is not compatible with IPM because it involves treating the crop before any assessment of pest threat is undertaken, it is basically an insurance treatment against possible pest attack.

Surveys show that there was not a widespread take up of IPM measures following the restrictions on neonicotinoids. However there are farmers (some who are featured in this report) who are farming successfully without neonicotinoid and reducing their overall reliance on chemicals.

Towards non-chemical pest control in OSR

Our research concluded that there is plenty that farmers can do now to reduce pest pressure using a variety of non-chemical approaches in line with a genuine IPM approach. Doing so will bring additional benefits including control of other pests and nitrogen retention.

From available evidence and existing practice it is clear that the following measures are effective and should be more widely employed in OSR production:

- **Wider use of current advice on pest monitoring and thresholds**.
  The first step of IPM should be to assess the threat to the crop (including for weeds and diseases, as well as insects) so that pesticides are only used when the thresholds are exceeded.

- **Use of natural enemies of key OSR pests**.
  Natural enemies can be encouraged via a network of habitats around the farm, including hedgerows, beetle banks and flower-rich margins. Encouraging natural enemies into the cropped area to maximise pest control will require reduced spraying of insecticides, fungicides and broad spectrum herbicides.

- **Follow current agronomic advice for crop establishment**:
  - Establish the crop early
  - Avoid sowing into bare earth

- Use a method that minimises soil disturbance.
- Minimum tillage has also been found to help conserve natural enemies.

These are all current good practice guidance but recognising that particular local conditions of each farm could sometimes require a different approach.

- **Disease resistant OSR varieties.**
  - Can reduce the need to completely control aphids – an OSR variety resistant to turnip yellows virus (TuYV) is now available to farmers.

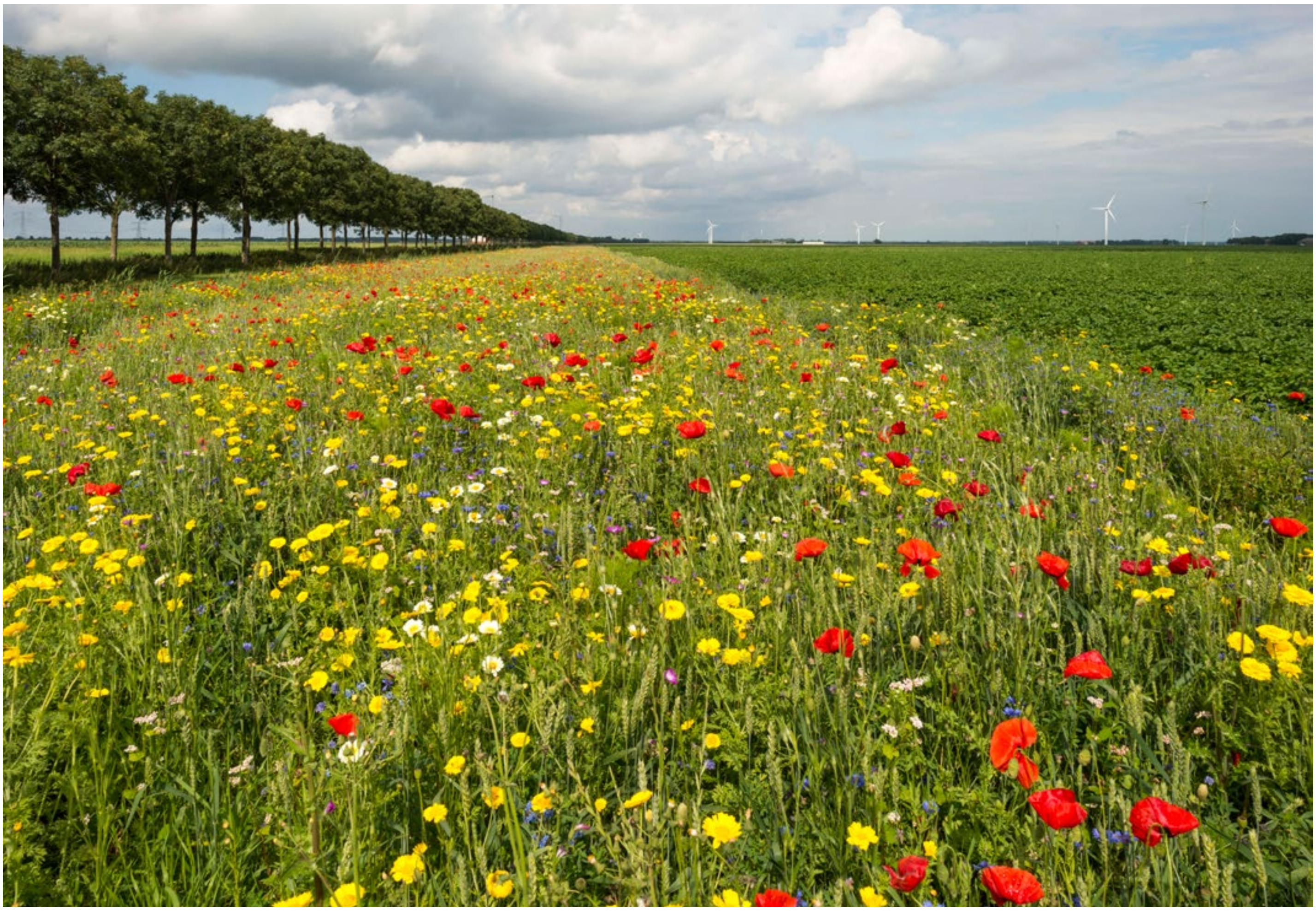
The following measures also show considerable potential, and deliver other benefits to farmers:

- **Trap crops** e.g. of turnip rape around fields of OSR. Good results in reducing pest attack on OSR have been obtained in some but not all trials.

- **Companion crops** can provide a range of agronomic benefits (e.g. improving nitrogen retention and out-competing weeds) and in some trials has shown potential to reduce pest pressure.

- **Introducing new crops to the rotation** to increase the interval between OSR crops, reduce the financial risk should the OSR crop fail, and diversify sources of farm income.

Some methods have stronger evidence of effective pest control than others, partly due to non-chemical controls not being given priority for research. But all these methods show benefits to farmers and the environment. The same cannot be said of chemical controls.



Are neonicotinoids effective?

In 2015 the NFU successfully applied for an emergency authorisation for the use of two of the restricted neonicotinoid seed treatments (Modesto and Cruiser). Part of its case was that non-chemical controls for cabbage stem flea beetle (CSFB) are not proven. Yet there is no consistent evidence of the effectiveness of neonicotinoid seed treatments as has been noted by the Defra Chief Scientist and a review of evidence relating to neonicotinoids published by the Royal Society (Godfray el at)

In 2014/2015, the first year that the restricted neonicotinoids were unavailable, OSR yields were above the 10 year average. In the following growing year, AHDB surveys show that early crop losses attributed to CSFB in December 2015 from OSR that was mostly grown from untreated seed were similar to, but slightly lower than, crop losses at the same stage in 2014. Loss due to CSFB was at similar levels to losses recorded from other causes. Some farmers (including one featured in this report) who used treated seeds under the 2015 emergency authorisation are reporting seeing little difference in CSFB damage between treated and untreated fields.

Increasingly evidence suggests limitations to the use of neonicotinoids including:

- Most of the pesticide (up to 90%) is not absorbed by the crop and is released into the environment
- Susceptibility to the pesticide leaching into soil in heavy rainfall
- Potential to harm beneficial insects that are important for controlling other pests of OSR such as slugs
- Pests developing resistance to neonicotinoids.

There has been a focus on the challenges farmers will face in controlling CSFB,for which neonicotinoids have been marketed to farmers as an effective means of control, but in 2015 damage from slugs was at least equivalent to damage from CSFB. Neonicotinoids do not control slugs and could harm natural predators relied upon for slug control such as carabid beetles. This, combined with evidence of harm to pollinators, suggests that neonicotinoids could be doing more harm to food security than good.

Neonicotinoid seed dressings are often used prophylactically without reference to the level of actual pest risk. The emerging picture from research and monitoring is that in many cases their use was not economically justified.

It would not be reasonable or scientific to set a higher bar for proof of efficacy for non-chemical controls over pesticides such as neonicotinoids. There needs to be a more balanced consideration in decisions regarding applications for emergency authorisation of neonicotinoids, and in advice that the NFU, AHDB, and other industry bodies give to farmers about pest control.

The way forward – sustainable Oilseed Rape

At the time of writing this report OSR prices are rising and so it seems likely that farmers may decide to plant more OSR in Autumn 2016, than last year, since surveys show that generally price is a stronger factor in decisions about what to plant than pest pressure.

Our research shows that non-chemical controls are a valid alternative to neonicotinoids for farmers choosing to grow OSR. There are methods that should certainly be used more widely now and a longer list of options that should continue to be trialled over the longer term as the basis for developing a more sustainable system of OSR production.

Continued research to improve our understanding of, and maximise the effectiveness of, non-chemical techniques will benefit farmers. Despite the emerging problems with efficacy and resistance, the past availability of chemical control for key OSR pests has meant that research into pest monitoring and thresholds, natural pest control, cultural approaches and resistant crop varieties has been treated as a low priority by industry and Government. This needs to change.

Sharing information and knowledge among farmers will also be key to ensuring that non-chemical methods are adopted more widely.

The restrictions on neonicotinoids must stay in place to protect bees and other beneficial insects. As our knowledge develops about the damage to ecosystems caused by pesticides, and about our dependence on natural systems it is increasingly clear that farming needs to reduce its use of chemical pesticides.

Our future food production and the protection of much of our best loved and most valuable nature including bees requires a new approach based on non-chemical control as the main means of pest control with pesticides only used as a last resort.

Introduction

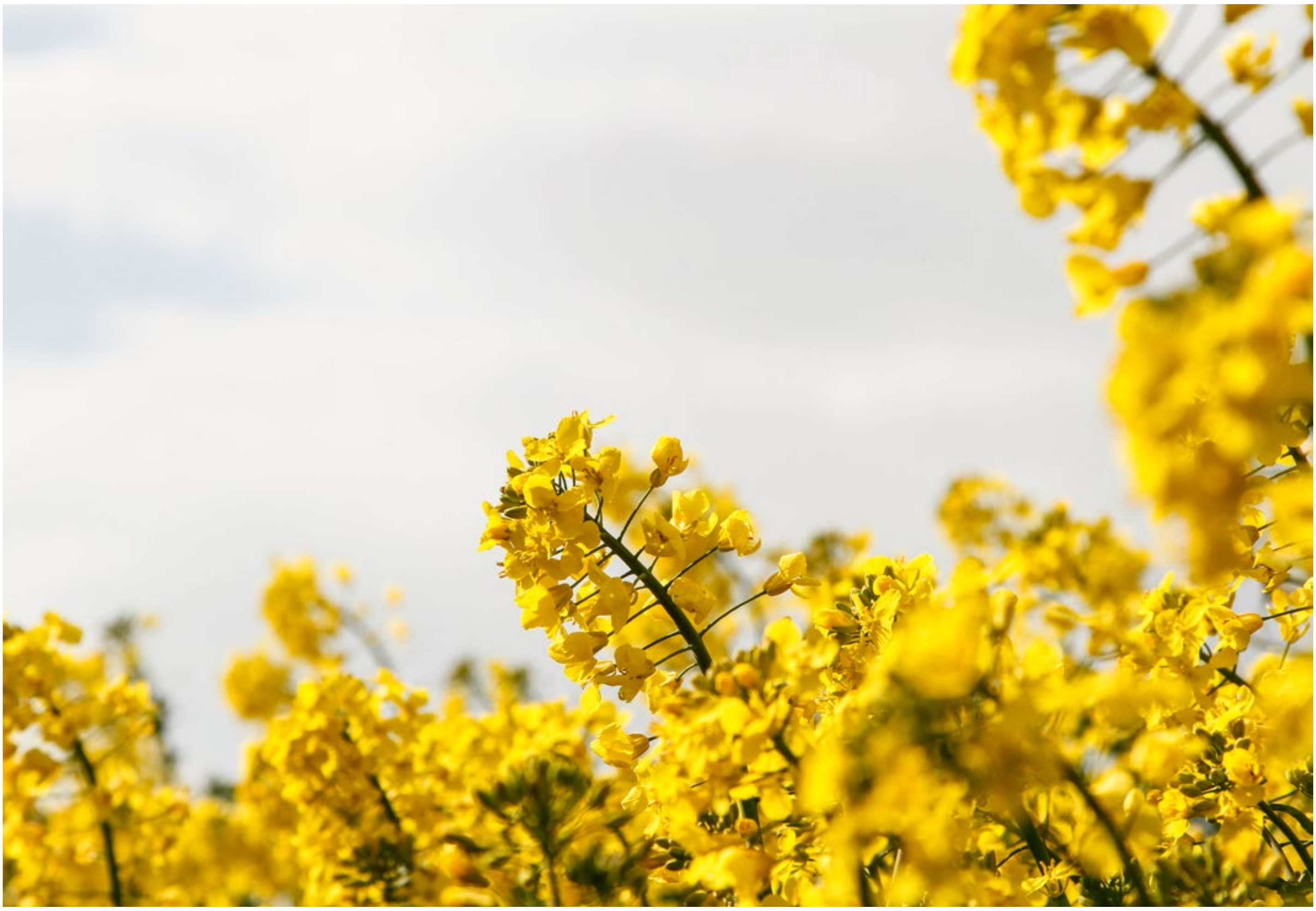
Three neonicotinoid insecticides (imidacloprid, thiamethoxam and clothianidin) are currently restricted for use on flowering crops in the EU, in response to evidence of harm to pollinating insects. Evidence continues to accumulate that neonicotinoids pose significant risks to wildlife and the environment, including two major reviews of the evidence (EASAC, 2015 & WIA 2015).

In the UK, OSR is a major crop affected by the restrictions. The purpose of the current report is to review what alternative means of insect pest control are available drawing on research and existing practice.

This report examines the following pest management tools:

- Choice of crop variety
- Crop husbandry, in particular sowing date, establishment methods and crop nutrition
- Use of pest monitoring and thresholds
- Encouraging natural enemies of pests, both by making the crop more hospitable to these species and by providing suitable habitat outside the crop
- Companion planting
- Trap crops
- Biopesticides

The role of organic farming is also explored.



Background

Key pests affecting OSR

Winter OSR can be affected by a range of invertebrate pests (HGCA, 2014). Before the current restrictions, neonicotinoid insecticides were promoted as the primary means of control for two insects in particular: cabbage stem flea beetle (CSFB) and peach-potato aphid (a major vector of the crop disease turnip yellows virus) (Defra, 2015). This report will therefore focus primarily on these two pests. *Pollen beetle* is another pest of OSR. Although it seldom reduces yields (AHDB, 2014a), and in recent years has rarely exceeded treatment thresholds (Croprotect website), there are concerns that it may emerge as an economically significant pest in future. The current report will consider pollen beetle control where relevant.

Adult CSFB feed on emerging OSR plants in autumn, causing very visible 'shot-holing' damage to leaves and in worst cases destroying the crop. Larvae over-winter within the plants, and their feeding in stems and leaves can lead to stunting or plant death (Croprotec website).

However, crop damage at the early stages of growth does not necessarily result in a lower eventual yield (see section on monitoring and thresholds below). In January 2016 Caroline Nicholls from AHDB noted that "We have a growing body of evidence that shows that once oilseed rape has emerged it can tolerate severe defoliation in good growing conditions" (AHDB, January 2016).

Work is ongoing in Denmark to improve forecasting of CSFB numbers. Attacks have peaked in cycles of seven years and researchers believe this behaviour to be caused mainly by cold winters and natural enemies (Mathiasen, 2013). Studies have found significant temperature effects on the pre-oviposition period, total number of eggs laid, daily oviposition rate, female longevity, egg-development rate and viability of CSFB (Mathiasen, 2015).

Peach-potato aphid rarely causes serious direct damage, but is the most important vector of turnip yellows virus (TuYV). TuYV is very common in OSR in many years and most of the time it causes few or no noticeable symptoms, so growers may not even know it is present (Walsh, date unknown). However it is believed to cause an average OSR yield loss of 15% in the UK, with some estimates as high as 30% (AHDB, 2014a).

Pollen beetles overwinter in sheltered spots and adults migrate into OSR crops when temperatures exceed 15°C. They feed on pollen inside buds or in open flowers. Eggs are laid in buds and the larvae feed on pollen before pupating. Adult and larval feeding can destroy buds and reduce the number of pods produced, but OSR crops will usually compensate for early damage so that yield is not affected. Once OSR flowers are open, pollen beetles become beneficial to the crop, acting as pollinators (AHDB, 2014a).

Chemical control of pests

Alternative chemical pesticides exist for the control of insects in OSR, in particular the class of insecticides known as pyrethroids. There are conventional farmers who have been growing OSR without neonicotinoids for some years. For example, Friends of the Earth in 2014 commissioned Peter Lundgren to produce a report of the non-neonicotinoid pesticide regime he has successfully employed on his OSR (Lundgren, 2014). Peter has found that he can successfully produce OSR using some pyrethroid sprays and is now working towards a low input approach across the whole farm (see case study at the end of this report).

The RSPB ceased to use neonicotinoids on its own holdings as of December 2012, and the manager of Hope Farm (a conventional arable holding in Cambridgeshire run by the RSPB as a commercial farm) has written about growing OSR without these pesticides (RSPB, 2013).

Alternative chemical-based approaches may be used in the short term. However, they are not a long term sustainable solution if they pose risks to wildlife and the environment. In addition, all pesticides have a limited life-span because pest populations become resistant to them. Resistance to pyrethroids is widespread in CSFB and peach-potato aphid and is increasing in pollen beetle (Croprotect website). Resistance to neonicotinoids has been reported in peach-potato aphid in continental Europe (IRAG, 2012) and is a growing concern in the UK (Defra project PS2725).

It is therefore necessary to significantly reduce farmers' reliance on chemical pesticides. Recognising this, the current report will focus on non-chemical and agro-ecological approaches to pest management.

Integrated Pest Management (IPM)

IPM is a holistic farming approach that combines a variety of pest management techniques in a planned fashion, to achieve adequate pest control while minimising risks to human health and the environment.

IPM should aim to prioritise non chemical means of control, and minimise the use of pesticides (EU Directive 2009/128/EC). Any pesticide use should be conducted in line with best practice in pesticide stewardship. This would include choosing the most specific pesticide available for the task, timing the application to minimise risk to non-target organisms (including natural enemies of pests), and using the minimum effective dose.

The basis of IPM is farming systems that prevent the build-up of pest organisms. In IPM, potential pests are monitored closely, and the farmer only intervenes when the population exceeds a specific threshold.

Neonicotinoid treated seeds are not compatible with this approach because they are not based on monitoring of the need for pest control and because the first priority is placed on chemicals instead of seeing them as a last resort. (EASAC, 2015)

Following the IPM hierarchy, this report first considers choice of variety and general crop husbandry, followed by monitoring and setting thresholds, before going on to some specific non-chemical interventions (companion planting, trap crops and biopesticides). The role of organic farming is also considered.

IPM profitable for OSR

MASTER, an EU project running between 2001 and 2006, aimed to design and evaluate an IPM system for OSR which would maximise biological control of pests and minimise pesticide use. The resulting system was compared with standard OSR management during trials in five EU countries including the UK (Nilsson, 2015). The main differences between the IPM and standard systems were soil tillage (non-inversion tillage in the IPM system; ploughing in the standard system) and insecticide use (applied according to pest thresholds in the IPM system; applied prophylactically to a fixed schedule in the standard system). Differences in yield between the two systems were found to be small, but the IPM system had lower total production costs, total energy use, labour and fuel costs. The authors concluded that "*A farming system based on the principles of [IPM] with non-inversion cultivation of soil can be recommended to farmers as a strategy to improve natural control of economically-important pests of winter oilseed rape, usually increase net return, decrease environmental impact and use less resources*." In similar vein, a study in France found that, despite a small yield reduction, IPM systems on OSR were more profitable than the standard pest control approach because of reduced operating costs (Valantin-Morison, 2013).

PART 1

Non-chemical pest control options for Oilseed Rape

Crop variety

The AHDB (AHDB Recommended List, 2016) rates winter OSR varieties for the following characteristics: gross output (yield adjusted for oil content); resistance to lodging; stem stiffness; shortness of stem; earliness of flowering; resistance to light leaf spot; earliness of maturity; resistance to phoma stem canker; oil content and glucosinolate content (HGCA, 2014).

There are two major types of OSR variety available.

Conventional open-pollinated varieties are produced by inbreeding plants with the desired characteristics to produce a 'pure' line. These varieties are self-pollinating and home-saved seed will produce plants with the same characteristics as the parent. Growers home-saving seeds are legally obliged to pay a royalty to the plant breeder, and should test the saved seed to ensure it has high germination and no disease problems (HGCA, 2014). Some agronomists have recommended using conventional varieties as a response to high CSFB damage, as these seeds are cheaper and can be sown at higher rates (Farmers Weekly, 16 June 2015).

Hybrid varieties are more expensive. They produce comparable yields to conventional varieties, but are often sown at a lower seed rate. Seed companies produce them by crossing a male-sterile 'female' plant with a pollen-producing 'male' plant. Breeding in this way enables a wide range of characteristics to be incorporated into a new variety. Hybrid varieties cannot be grown from home-saved seed as the offspring will not have the same characteristics as the parent.

Gross output is usually the most important factor determining what OSR variety farmers select (HGCA, 2014). However, variety selection can also have implications for pest control.

Varietal choice for pest and disease control

There are currently no commercial OSR varieties that are fully resistant to insect pests (Sam Cook, Rothamsted Research, March 2016, personal communication), but different varieties may experience different levels of pest damage.

OSR varieties that have lower glucosinolate levels are less attractive to pollen beetle (Cook, 2006). Having landed in the crop, pollen beetles appear to be more likely to attack the buds of some OSR varieties than others (Hervé 2013).

CSFB are known to be attracted to the breakdown product of glucosinolate, which is produced when plants are damaged (Bruce, 2014). However, trials funded by Defra have found no relationship between CSFB damage and glucosinolate levels, at least within the range found within commercially-available OSR varieties (Defra project AR0203). This could be an area for further research.

Peach-potato aphid rarely impacts on OSR yields directly, but even low numbers of aphids present a risk of infection with TuYV. The use of OSR varieties that are resistant to the disease – rather than attempting complete control of the aphid – therefore seems the most logical approach (Walsh, date unknown). One study tested 49 commercial OSR varieties for their response to TuYV. None had complete resistance, but the level of infection and its effects differed in different varieties. In some varieties, for example, infection led to increased seed mass but decreased oil content. This study provided evidence that the virus has a clear effect on plant physiology, which depends on the variety of OSR rather than on the extent of the infection (as measured by the amount of virus present in the plant) (Coleman, 2014).

Complete resistance to TuYV has been found in some wild relatives of the cabbage family (Walsh, date unknown). A recently-developed conventional open-pollinated OSR variety, Amalie, is the first commercial variety to be resistant to turnip yellows virus (as well as having other desirable agronomic characteristics) (LG Seeds website).

Crop husbandry

This section covers the general decisions farmers make on how to manage their crop and how these can affect pest control. Farmers have access to a large volume of advice from sources including their farming peers, agronomists, academic and government institutions, the farming media and agrochemical and seed companies. Farmers need to weigh pest management considerations alongside other agronomic requirements and conditions on their particular farm, as well as potentially trading off improved control of one pest against increased risk from another. Understanding risk factors for particular pests should inform farmers' decision making (including, critically, whether to grow OSR at all in a given year).

One study of organic systems found that regions with high proportions of land under winter OSR tended to have a smaller proportion of plants with

CSFB damage. In regions with a lower percentage of land under OSR, woodland around the field reduced the occurrence of pest attacks (Valantin-Morison, 2007). This was just one study and further research would be needed before any firm recommendations could be made.

Sowing date

Box 1 shows the broad timing of sowing and harvest for OSR in the UK. The large majority of OSR grown in the UK is Winter OSR (DEFRA June Survey, 2014).

Current advice is to sow early. If sowing is delayed beyond mid-September there is a risk of significant reductions in plant establishment and crop yield (HGCA, 2014). Farmers also need to consider the condition of the soil: putting heavy machinery on fields in wet conditions can damage soil structure, so (especially for farms on heavy soils) drilling cannot be left too late into the autumn. It is worth noting that different varieties of OSR may be better suited to earlier or later sowing (Farmers Weekly, 27 July 2007).

Sowing early (i.e. towards the start of the window shown in Box 1) should allow the crop to get beyond the vulnerable emergence stage before CSFB migrate into the fields and begin to lay their eggs (Croprotect website). This usually occurs in early September, but a warm autumn will favour egg laying and early hatch of larvae (AHDB, 2014a). Delayed sowing date provides a clear management option in reducing the number of adults attracted and hence eggs laid as beetles prefer developed crops to lay their eggs into. However this option provides an increased risk if eggs are laid as smaller plants are more vulnerable to attack.

However it is possible that earlier-sown winter OSR will attract more CSFB adults (HGCA Information Sheet 24) and may suffer worse damage (ENDURE, 2007) (although one study of organic winter OSR actually found that early sowing was associated with a *lower* level of attack by CSFB (Valantin-Morison, 2007)). In the past, farmers have been told that delaying sowing reduces the numbers of CSFB adults attracted and eggs laid (HGCA, 2003). However, this is traded off against greater risk of crop failure if eggs are laid, as smaller plants are more vulnerable to attack (Scott, 2015).

For peach-potato aphid, greater numbers of overwintering adults will survive if winter conditions have been mild. This is likely to lead to a larger and earlier spring migration and a greater level of virus spread in early sown crops. Early sown winter OSR crops tend to be at greatest risk from aphids during warm autumns, while later-sown spring crops tend to be at greater risk after mild winters (AHDB, 2014a).

OSR is at risk from pollen beetle when warm, dry weather (over 15°C) coincides with the vulnerable green to yellow bud phase of the crop. This is more likely to occur in Spring OSR (see Box 1).

Box 1: the oilseed rape growing cycle (the year is specified to aid interpretation: note that winter OSR is sown in the calendar year before it is harvested)

Sources: ADAS Harvest Report 2014, Senova, AHDB Cereals & Oilseeds

		Winter OSR	Spring OSR
2015	August	Sowing	
	September	Sowing	
	October		
	November		
	December		
2016	January		
	February		
	March		Sowing
	April		Sowing
	May		
	June		
	July	Harvest 2016	
	August		Harvest 2016
	September		Harvest 2016

Establishment method

There are various methods of sowing OSR, including ploughing systems, non-inversion tillage, direct drilling and broadcasting into a standing crop or stubble. Each has its advantages and disadvantages in terms of time, cost, effects on soil condition, weed control, and attractiveness of the newly-sown crop to slugs and pigeons (HGCA, 2014). Each also has implications for insect pests.

It has been suggested that crop plants not silhouetted against a bare-soil background are less obvious to CSFB adults (Croprotect website). One study in Germany found that the presence of stubble and debris reduced CSFB infestation (Ulber and Schierbaum-Schickler, 2003, as referenced in ENDURE 2007).

An EU study, including UK trials (Nilsson, 2015) concluded that non-inversion cultivation of soil should be recommended to OSR farmers as part of an IPM approach. Some agronomists in 2015 were advising farmers to minimize the amount of cultivation carried out before the crop was sown, as more disturbance of the soil seemed to lead to greater CSFB pressure (Farmers Weekly, 16 June 2015).

However, overall there is a lack of clear advice for farmers on how choice of establishment method could impact on different pests. This seems be an area which would benefit from more communication.

Seed rates

To maximise oilseed yields, farmers are advised to aim for 25 – 35 OSR plants per square metre. The seed rate needed to achieve this varies according to the percentage plant establishment, which in turn depends on field conditions and pressure from slugs (HGCA, 2014). Hybrid OSR varieties are usually sown at a lower seed rate than conventional varieties (HGCA, 2014) (see crop variety section in the current report).

Farmers are advised to use higher seed rates to compensate for young plants being destroyed by CSFB (Croprotect website). Agronomists were quoted in the farming media as recommending a seed rate (for conventional varieties) of 60 – 70 seeds per square metre in 2015 (Farmers Weekly, 16 June 2015). All else being equal, a higher plant population will dilute the impact a given population of beetles will have (Alan Dewar, Dewar Crop Protection Ltd, March 2016, personal communication). However, one study in Germany (Nuss, 2007) compared OSR sowing rates of 30, 60 and 90 seeds per square metre. At the lower plant densities more CSFB larvae were found per plant, but fewer per square metre of the field. The final crop yield was not affected by seed rate. The authors concluded that OSR plants grown at low density, although subjected to higher levels of pest infestation, have a higher ability to compensate for damage. In this study, even under high pest pressure, yield per unit area was not affected negatively by reduced sowing rates. Similarly, farmers are advised that less dense crops are more able to compensate for pollen beetle damage because each plant produces more flowers on average (AHDB, 2014a).

Crop nutrition

Nitrogen status of the crop can affect pest pressure in a variety of ways (Valantin-Morison, 2007; Altieri, 2003; Rusch, 2010). Healthy crops are generally more able to recover from pest damage, but excess nitrogen may increase the attractiveness of crops to pests. It is possible that avoiding nitrogen spikes by applying nitrogen fertilisers 'little and often', or using products that release active nitrogen to the plants more slowly, may reduce pest attack (Barr, 2015)

Farmers are advised that providing good nutrition and favourable growing conditions shortens the vulnerable early growth stages of OSR and helps plants survive CSFB attack (Croprotect website). Similarly, healthy plants are more able to compensate for any bud damage by pollen beetles (AHDB, 2014a).

Crop rotation

Crop rotation, used to prevent build up of pests, weeds and diseases and to maintain soil health, is one of the foundations of IPM. OSR was initially grown in one-in-five rotations with cereals, but rotations of one-in-two or three (i.e. with OSR grown in any given field every other year, or every three years) are now common. There is evidence that national OSR yields are depressed as a result, because of increased impact of soil-borne and foliar diseases, more volunteer OSR, and reductions in rooting (HGCA, 2014).

There are therefore good reasons to advocate longer rotations with OSR appearing less frequently. However, it is less clear to what extent this might help with management of insect pests. The adults of CSFB, peach-potato aphid and pollen beetle are all highly mobile (ENDURE, 2007) and can easily migrate between fields, so crop rotation in itself is unlikely to disrupt their life cycle. Rotation is not in itself considered a viable management strategy for CSFB (Croprotect website) – although longer rotations and wider spatial separation of blocks of OSR could form a useful part of a package of measures (Alan Dewar, March 2016, personal communication). In the case of pollen beetle, farmers are actually advised that planting OSR *close* to where it was grown the previous year can help to increase natural pest control by parasitic wasps (AHDB, 2014a).

It may be helpful to remove OSR volunteers, which would otherwise provide a food source for CSFB (and other pests) before the crop emerges (Alan Dewar, March 2016, personal communication).

Grazing as a CSFB control approach

CSFB larvae move from the leaves to the central stems of OSR seedlings during autumn and winter. 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 leaves into the stem (Ellis, 2015). It has been suggested that mowing or grazing the crop in autumn to remove the leaves with the larvae in them could be a viable pest management approach (Steve Ellis, ADAS, personal communication, 2015). There has been one reported instance of a grower in Essex who grazed sheep on a small block of OSR. The area was experiencing high CSFB pressure, but the OSR which had been grazed down to the ground in autumn went on to produce a good yield while other OSR in the area did not (Farmers Weekly, 22 January 2016). The grower himself attributed this to the fertiliser effect of the sheep droppings. He had not been aware of any potential benefit to pest control and was grazing the sheep on his OSR solely to help fill a shortfall in feed (Alan Dewar, March 2016, personal communication). Nevertheless, this could be a technique worthy of further investigation.

Monitoring and thresholds

A key feature of the IPM approach is that pesticides and other interventions are only applied when a pest population exceeds a pre-determined threshold. The threshold should be set at the level where the predicted cost of pest damage would exceed the cost of intervention. IPM therefore requires close monitoring of pests in the crop.

AHDB provides guidance for farmers on thresholds for CSFB and pollen beetle in OSR (see Box 2). However, Ellis (2015) found that, under ideal growing conditions in glasshouses, OSR seedlings have significant ability to compensate for loss of leaf area. In other words, crop damage at the early stages of growth does not necessarily result in a lower eventual yield. These results now require further validation in the field. On the basis of these results, the authors suggested that the current defoliation thresholds for CSFB are too conservative. They propose a number of research questions that need to be answered in order to "*contribute to the development of a rational approach to pest control minimising reliance on insecticide sprays*".

There are currently no satisfactory thresholds for peach-potato aphid, and farmers are advised that if *any* aphids are present they should be assumed to be carrying TuYV (AHDB, 2014a).

A balance needs to be found between monitoring methods that are as quick and straightforward as possible while also being accurate (Holland, 2007; Cook, 2013). The abundance of OSR pests varies within fields. For example, in one study infestation of rape plants by CSFB larvae was greatest within the central area of the crop (Defra Project AR0302). It is therefore important to take a sufficient number of samples from appropriate locations to get an accurate picture of overall pest pressure in the crop. AHDB currently recommends that to assess CSFB larvae numbers, farmers should set two yellow water traps on the headland and two in the field along a wheeling. For plant dissection farmers should take a random sample of 25 plants from the field.

Peach-potato aphid monitoring is carried out nationally and farmers can access online information about aphid migration and numbers (AHDB, 2014a; AHDB, 2014b).

Cook *et al.* (2013) carried out detailed sampling of pollen beetles and used the data to test existing decision support systems. They found that a freely-available online system, proPlant, could help focus monitoring effort to where it is most needed, and could reduce unnecessary sprays. They also developed a monitoring trap that could help with pollen beetle risk assessment.

It is difficult to find out to what extent farmers are applying thresholds and monitoring in reality. A survey of Scottish farmers in 2015 (Hughes, 2016) indicated that only 7% used traps and 9% used thresholds to assess pest numbers. 83% relied on advice from agronomists (who may themselves have been using traps and thresholds), and 58% based their perception of insect numbers on their own observation when walking their crops. Holland and Oakley (2007) reported a view that, in general, thresholds are not widely used because of the time and effort required in obtaining meaningful assessments. This view was echoed by agronomist Alan Dewar in a recent presentation to the AICC Annual Technical Conference (Alan Dewar, March 2016, personal communication).

Box 2: AHDB guidance on thresholds for CSFB and pollen beetle

CSFB

Assessing the need to spray adults in oilseed rape:

- >25% leaf area eaten at the cotyledon–2 leaf stage
- >50% leaf area eaten at the 3–4 leaf stage
- The crop is growing more slowly than it is being consumed

Assessing the need to spray larvae in oilseed rape:

- >96 beetles/trap (average) caught over the monitoring period
- >5 larvae/plant, when dissected
- >50% of petioles damaged

Pollen beetle

- If there are fewer than 30 plants/m^2, the threshold is 25 beetles per plant
- If there are 30–50 plants/m^2, the threshold is 18 beetles per plant
- If there are 50–70 plants/m^2, the threshold is 11 beetles per plant
- If there are more than 70 plants/m^2, the threshold is 7 beetles per plant

Restricting pest control interventions to when they are strictly necessary is a vital element of IPM and of sustainable pest management. Aside from wasting resources and contributing to the development of pest resistance, unnecessary pesticide applications can potentially make pest infestations worse by destroying the natural enemies of pests (see 'natural enemies' section of this report). AHDB (2014a) notes that all parasitoids of CSFB may be vulnerable to pyrethroids. Guidance from Rothamsted states that "*...repeated applications of pyrethroid may do more harm them good especially when the target pest has evolved resistance to them.*" (Croprotect website).

An important consideration with seed treatments (including the neonicotinoid products affected by the ban) is that they are necessarily applied *before* the farmer can determine whether the pest population will exceed the damage threshold. This implies that at least some past use of seed treatments may have been unnecessary, which may help to explain the findings of several studies that using neonicotinoid seed treatments has no consistent effect on yield or profitability (Ellis, 2015; Budge, 2015). Ceasing use of neonicotinoid seed treatments, if coupled with improved use of monitoring and thresholds, will present farmers with an opportunity to reduce inputs by eliminating unnecessary pesticide use.

Are farmers altering crop husbandry in response to the neonicotinoids ban?

A survey of 205 English farmers growing OSR for the 2015 harvest (Scott, 2015) revealed that only a minority had changed agronomic practices in response to the neonicotinoids ban. 11 farmers increased spray applications and 8 moved to an earlier drilling date (while 1 drilled later). Other changes included increased monitoring of the crop (4 farmers), increased the seed rate (2 farmers), used autumn fertilizer (3 farmers), changed to a different OSR variety (3 farmers), or made another, unspecified change (4 farmers).

Of 96 Scottish farmers surveyed in 2015 (growing 16% of the total Scottish OSR crop), 25 made management changes in response to the neonicotinoid restrictions (Hughes, 2016). These changes were mostly intended to reduce CSFB damage and included: altering seed rate to compensate for potential plant loss from insect damage (11% of respondents); using minimum tillage or direct drilling instead of ploughing to allow quicker establishment of the crop following the previous harvest (9%), and earlier drilling dates (5%).

Natural enemies

Natural enemies of pests are species naturally present in the environment that eat, parasitise or otherwise harm the pest species. They can include (for example) birds, insects and micro-organisms. In the highly simplified environment of a conventional arable field, only a few species are able to thrive. Species that can feed and live on the crop are likely to increase, but populations of their natural enemies and competitors might remain low because the habitat is unsuitable for them (Bianchi, 2006). In such cases, there is nothing to control the crop-eating species and its population can explode. This is the point at which it becomes a "pest" and must be controlled by artificial means such as pesticides. The challenge and the opportunity for farmers is to maximise the levels of natural pest control which occur within farming systems.

A Defra-funded project concluded that specialist parasitoids and generalist carabid predators are the key natural enemies of CSFB and some other winter OSR pests, with significant potential for biological control (Defra Project AR0302). The most important natural enemy of CSFB is believed to be *Tersilochus microgaster,* a wasp which parasitises larvae in the spring (AHDB, 2014a). A field trial in northern Germany confirmed the importance of parasitoids in controlling CSFB numbers, finding high rates of parasitism (more than 50% of individuals in some cases) in flea beetle larvae collected from winter OSR and winter turnip rape (Döring, 2013a).

The natural enemies of peach-potato aphid include parasitic wasps, ladybirds, predatory flies, spiders, ground beetles, rove beetles, lacewings and insect-pathogenic fungi. The current industry advice is that providing habitats that benefit these groups can help control aphid numbers, but that this may not be effective in preventing transmission of TuYV as it can occur even at low aphid densities (Croprotect website).

Pollen beetle larvae are attacked by parasitic wasps. On unsprayed crops, 25 – 50% of larvae are killed by these natural enemies (Croprotect website).

General guidance for farmers on identifying and encouraging beneficial invertebrates is readily available (for example HGCA, 2008). Holland and Oakley (2007) point out that "*It is important that a diverse and abundant natural enemy community is maintained to ensure that pests are* *attacked throughout their lifecycle and by a wide variety of natural enemies. Thus if any particular natural enemy of group thereof become scarce, as commonly occurs, then another will take over.*" Strategies to increase populations of natural enemies must therefore consider the needs of a variety of species throughout their lifecycles.

Natural enemies are also important for controlling other pests of OSR including slugs.

Making the crop more hospitable to natural enemies

Intensively managed crops are generally hostile environments for natural enemy species. Pesticides can kill organisms that are natural enemies of pests, or that provide habitat for those organisms. Levels of parasitism of pollen beetle are significantly reduced in intensively sprayed crops (Croprotect website). One study (Jansen, 2014) went so far as to say "*the regular use of Biscaya and/or Pyrinex on a large scale [in winter OSR] before flowering is favourable to the long term development of pollen beetle populations by negatively impacting the populations of their parasitoids.*"

Insect predators might be particularly vulnerable to spraying in autumn, when there is no crop canopy to shelter them (Alford, 2000). Clearly, minimising the use of broad spectrum insecticides and carefully targeting any applications of insecticides (in terms of timing, spatial area and target species) is key to promoting natural enemies. There is a need to incorporate information about natural enemy lifecycles into agronomic advice about when to spray insecticides (Cook, 2015a).

Reducing herbicide inputs and tolerating greater weediness in the crop might also help to encourage natural enemies (Holland, 2007; HGCA, 2008). Reducing fungicide use could also potentially be important: entomopathogenic fungi are considered to play a vital role as biological control agent of insect populations (Gul, 2014). Barr (2015) makes the point that the extensive use of fungicides in modern farming might be expected to have a detrimental effect on this group of natural enemies.

Pesticides are not the only threat. The pupae of parasitoids overwinter in the soil and can be damaged by ploughing. Furthermore, to maintain their population at numbers that provide effective pest control, natural enemies need alternative food sources when the pest species is not abundant. These alternative prey species can themselves be harmed by insecticides and ploughing (Defra Project AR0302). Minimum or zero tillage has potential to help conserve both natural enemies and their alternative prey (Defra Project AR0302; Holland, 2007; Nilsson, 2010).

There is evidence that undersowing cereal crops (for example with grass or legume species) can increase populations of natural enemies, and this approach is now being researched for OSR (see companion crop section of the current report).

Applying compost to fields has been shown to increase predator numbers, possibly through providing an alternative food source to sustain their populations before the pest numbers reach high levels (Bell, 2008).

Providing resources for natural enemies outside the crop

Other approaches involve providing habitat for natural enemies outside the crop, for example field margins, hedgerows, beetle banks or fallow land. FERA (2012) refers to an 'Integrated Pest Management treadmill': a virtuous circle whereby encouraging natural enemies through habitat management results in fewer pests, reducing the need for (and thus use of) insecticides, which further encourages populations of natural enemies. In their report, FERA found that that many of the options offered as part of English agri-environment schemes can provide resources for natural enemies. However, they found while there is good evidence that these habitats can contain large and diverse populations of natural enemies, there are few studies that attempt to quantify the effects on natural pest control in the crop. Holland and Oakley (2007) similarly concluded that habitats created under agri-environment schemes can provide a range of resources for natural enemies: pollen and nectar, above-ground overwintering habitats, alternative prey, refuges from disturbance and uncultivated land. The single habitat feature providing the most resources was found to be well-managed hedgerows comprising a substantial shrubby component with a 2m wide, floristically diverse hedge base (Holland, 2007). Like FERA and others (see for example Östman, 2004), these authors found that quantifying the improved pest control resulting from habitat enhancement will require further research.

For habitat manipulation to be successful in increasing biological control, natural enemies must move out of the habitats created for them, into the crop where the pests are. Clearly it will be important to ensure the crop is not hostile to these species (see previous section). One study (Golterman, 1994 as referenced in Holland *et al.* 2007) looked at natural enemies in field margins of winter wheat and OSR. The author found that movement of natural enemies from field margins into OSR is slower and reduced compared to movement into winter wheat, possibly due to the cooler and more shaded conditions created by OSR. There is a risk that, if the created habitats are more attractive to natural enemies than the crop, they may act as sinks, pulling natural enemies out of the crop and actually lowering levels of natural pest control (Holland, 2007). Solutions now being explored include spatially separating early and late flowering margins so that natural enemies would have to move across the field as resources in the early flowering margin decline; and assessing the potential of insect pathogenic fungi to act as repellents (Rothamsted field margins project).

Natural enemies vary in their degree of mobility, and some habitats will present a barrier to the movement of certain species. For example uncultivated habitats, although potentially acting as a reservoir of natural enemies, may prevent the movement of ground-active invertebrates like carabids (Holland, 2007). Thus certain features might prevent natural enemies from moving around the farm from year to year as crops are rotated.

Promising results have been obtained for field margins designed to promote the natural enemies of aphid species. A Defra-funded project found that, if designed and managed appropriately, field margins can serve as valuable reservoirs of aphid natural enemies. Margins containing legumes performed particularly well, and margins containing wild flowers were more valuable than simple grass margins. Adult aphid parasitoids could readily move between margin and crop habitats. The researchers also found that foraging female parasitoids could be induced to stay longer in crops with low aphid densities by the presence of the aphid sex pheromone nepetalactone, raising the possibility of developing products that increase the effectiveness of natural biological control (Defra project AR0318).

It is worth noting that a recent study in the UK (Pywell, 2015) found that removing up to 8% of land from production at field edges to create wildlife habitat resulted in no net loss of yield over a typical arable rotation. The authors explain this finding through a combination of the typically poor crop yields at the edges of fields (i.e. the area removed from production would not have produced much in any case), and the increase in beneficial natural processes including pollination and biological pest control.

Designing field margins for better biological control in oilseed rape

An EU-funded study (Cook, 2015b) explored how field margins could be specifically designed to increase their beneficial effect on populations of natural enemies, with field studies carried in the UK and Denmark. The work particularly focused on field margins containing brassica plant species, aimed at providing resources for natural enemies of OSR pests. Results suggested that while the brassica margins did increase the abundance and diversity of natural enemies found in field margins, and would probably continue to support these species throughout phases of the crop rotation where OSR was absent, there were only limited positive effects on biocontrol in the crop or on yield. The authors commented "*it seems that getting biocontrol agents into the open field remains one of the greatest challenges in delivering crop protection via conservation biocontrol*." (Cook, 2015c). The authors concluded that there are potential benefits to including brassicas in field margins, but these margins are likely to require annual management, so the additional costs to farmers need to be weighed against the pest control benefits. Furthermore, the plant species need to be chosen carefully to maximize the beneficial effects and ensure that production of parasitoids is favoured over production of the pests themselves. Holland and Oakley (2007) made a similar point, cautioning that the presence of suitable habitats in field boundaries could act as a reservoir of CSFB from year to year (Holland, 2007).

Companion planting

Companion crops are under-sown in the field with the main crop (also known as intercropping). They can perform a variety of functions, such as weed suppression, nitrogen fixation or improving soil condition (Agrovista, 2015; Lorin, 2015), and their potential to help with pest management is of increasing interest (see also the case studies in this report).

A system has been developed in France where companion plants are sown alongside the OSR crop in autumn. The companion plant mix is chosen to be frost-sensitive, so the plants die over the winter and gradually release their nutrients back to the soil. This system offers a clear benefit in reducing nitrogen loss over winter, but also has the potential to reduce pest pressure. The French company's commercial manager claims that in fields with the companion crop CSFB numbers are reduced from 10-25 pests per plant to 5-10 per plant, and that farmers are spraying less frequently. The mechanism by which the companion crop has this effect is not yet clear (Farmers Weekly, 17 April 2012). There is no data from the UK about CSFB as yet, but trials by Agrovista confirm the nitrogen benefits and have demonstrated significant reduction in slug damage to OSR (Agrovista, 2015).

The benefits of companion crops are, however, not clear-cut. One study in France found that undersowing winter OSR with a legume companion crop did not significantly reduce numbers of CSFB larvae. The authors also cite other studies that demonstrated an *increase* in pest damage where companion crops are used (Valantin-Morison, 2011).

NIAB is currently carrying out trials looking at the potential of companion crops to reduce the impact of CSFB in OSR (Howard, 2015). Trials include a brassica mix (Chinese cabbage, rocket, pak choi and linseed) intended to dilute the impacts of CSFB on the crop, Fenugreek which is intended to repel pests, and a legume mix (common vetch, crimson clover, Berseem clover and Persian clover). These trials are at an early stage and results will be published in due course, after they have first been made available to NIAB members (Simon Kightley, NIAB, personal communication, 24 February 2016).

Trials of companion cropping at Rothamsted in 2015 initially looked promising, but by January 2016 all OSR plants had been destroyed by CSFB (Sam Cook, Rothamsted Research, March 2016, personal communication).

Some farmers already use companion crops, usually for the benefits to nitrogen retention and/ or weed suppression (see for example the case studies in the current report). As yet there is no clear picture as to whether or in what circumstances these companion crops help with pest control. It would be useful to gather data nationally on whether OSR with companion crops experience reduced pest pressure.

A study on organic winter OSR in Germany looked at the potential of mixed cropping with OSR and turnip rape in a 9:1 ratio to reduce pest damage to the OSR. Turnip rape was found to be more attractive to CSFB and other pests than the OSR. However this resulted in increased overall abundance of pests in the field, which in some cases actually led to lower OSR yield. The authors concluded strongly that this approach would not be successful (Ludwig, 2013). Turnip rape would appear to be more suitable as a trap crop: see next section.

Trap crops

Trap crops are designed to be attractive to pests, drawing them away from the main crop to reduce economic damage. Turnip rape is known to be attractive to OSR pests, and various authors have explored its potential as a trap crop.

One study found that, although CSFB preferred turnip rape to OSR, the higher numbers of pests in the turnip rape borders did not result in lower pest numbers in the OSR crop itself, nor any increase in yield (Döring, 2013b). However, other authors have found that turnip rape borders do reduce CSFB infestation of OSR plots. A study in the UK (Barari, 2005) found that turnip rape trap crops contained more CSFB larvae than the adjacent OSR crop, and the presence of the trap crop significantly reduced the number of larvae found in the centre of the OSR crop (crop trial plots were 36m x 30m and the trap crop strips were 6m x 30m). Spraying the trap crop with insecticide in autumn and spring reduced the number of larvae in the trap crop but had no effect on numbers in the OSR crop. Spraying the trap crop therefore appears to bring no direct benefit to the OSR crop, although it might reduce the number of pests surviving from year to year. Additional reasons for leaving trap crops untreated include slowing the development of resistance in the pest population and providing a refuge for biodiversity, including beneficial insects. The authors of this study felt that turnip rape trap crops are potentially an effective way to reduce CSFB pressure on OSR. They attempted to repeat the trials in 2015 but unfortunately by December all the OSR plants had been destroyed by CSFB (Sam Cook, Rothamsted Research, March 2016, personal communication).

A Defra-funded study found that OSR plots with a turnip rape border had fewer CSFB larvae than control plots, and – in this case – the infestation was reduced further by treating the trap crop with an insecticide. Parasitoids also appeared earlier and were present in higher numbers in the turnip rape borders compared with the OSR control. A preliminary cost benefit analysis indicated that a turnip rape trap crop could provide an economically viable pest control option (Defra project PI0340). A promising area for research may be the use of turnip rape trap crops in conjunction with a companion crop that repels pests in a 'push-pull' system (Andrew Barr, personal communication, 24 February 2016).

Turnip rape may also have value as a trap crop for pollen beetle (Cook, 2007). One study (Cook, 2013) found that this strategy worked well in some years but not others. The authors concluded that turnip rape trap crops were only economically and practically feasible for organic growers. However, this study only considered pollen beetle: if impacts on CSFB and pollen beetle were considered at the same time then turnip rape trap crops might start to make economic sense for more growers. Kaasik *et al.* (2013) found that close relatives of OSR (turnip rape, mustard greens, white mustard) might be used to trap pollen beetle adults and also to support populations of natural enemies.

Biopesticides

The term 'biopesticide' refers to a wide variety of pest management agents based on living micro-organisms or natural products. While the section on 'natural enemies' in the current report deals with approaches to maximise control from organisms already present in the environment, the current section looks at the development of products that farmers can apply to their crops. Biopesticides, like chemical pesticides, are an intervention based on introducing a new substance or organism to the farmed environment. Biopesticides are generally understood to be more environmentally benign than chemical pesticides, but are clearly not risk-free.

Although biopesticides are widely used in protected crops (i.e. crops grown in greenhouses), there are various technical and other obstacles to their adoption in field crops (Chandler, 2011).

There are several promising areas of research into biopesticides for use on OSR. For example:

- Studies of CSFB reproductive behavior and morphology have established that there are antennal glands unique to the males (Bartlet, 1994) and abdominal glands unique to the females (Defra project AR0203). This implies that CSFB use sex pheromones in their courtship, which could be used as a biopesticide (for example in traps). Further research is needed on this topic (Cook, 2015a).

- CSFB are attracted to traps containing allyl isothiocyanate, indicating that this chemical may play a role in the chemical communication of the species (Tóth, 2007).

- The entomopathogenic fungus *Metarhizium anisopliae* is known to be pathogenic for CSFB and other pests, while being relatively benign to beneficial insects. *Metarhizium anisopliae* is therefore a potential biopesticide if an efficient means of dissemination of fungal spores to the target insects could be developed (Defra project AR0203). Honeybees have been successfully used to infect pollen beetles with the fungus, with good levels of control and no evidence of adverse effect on the bees (Butt, 1998). According to Alford (2000), oil-spray formulations of *M. anisopliae* have been used in the UK against CSFB (no further detail given). There is clear industry interest in developing a commercial product that could be used against CSFB (Farmers Weekly, 17 September 2015; RealIPM UK).

- Entomopathogenic nematodes can be highly effective at controlling insect pests but appear to occur only at very low densities in European OSR fields. Initial trials where nematodes were applied directly to OSR trial plots gave encouraging results, including an average 41.5% reduction in CSFB numbers (Hokkanen, 2006).

- Pollen beetles are known to be repelled by lavender oil, and other (cheaper) essential oils have also shown promising results (Daniel, 2013).

- Peach-potato aphids are repelled by neem-based compounds and commercial formulations are available for use in greenhouses (Shannag, 2014).

Organic farming

Very little organically certified OSR is grown in the UK. According to EU data (Eurostat), UK farmers grew just 74 hectares of organic oilseeds in 2014, less than 0.01% of the total oilseed area[1]. While most of the major supermarket chains stock products such as organic rapeseed oil, and in the EU as a whole demand for organic OSR may be

1 'Oilseeds' includes oilseed rape, turnip rape and sunflower seeds. 'Organic' here includes both fully certified crops and those in conversion.

increasing (Ludwig, 2013), it appears that market demand in the UK is largely met by growers elsewhere.

OSR is not considered a 'useful' crop in organic rotations. Weed and slug control can be problematic (Josiah Meldrum, Hodmedod Ltd, personal communication, 18 February 2016) and insect control can be a challenge (Nelder, 2012; Ludwig, 2013). Yields of organic winter OSR tend to be low and unpredictable (Valantin-Morison, 2008). OSR requires relatively high levels of nitrogen. This means that in an organic rotation it either needs to be grown immediately after the fertility-building phase (displacing a potentially more profitable crop like wheat), or manure will need to be added. A survey of French farms found a variety of insect pests in organic winter OSR, with levels of damage varying between years and regions. The authors observed that the incidence of CSFB was very variable and depended on the region (Valantin-Morison, 2008). Overall, insect pest pressure only accounted for a small amount of variance in yields. The study concluded that a key way to increase yields of organic winter OSR would be to reduce competition with weeds for nutrients by raising the levels of nitrogen in the soil before sowing.

What further research is needed?

It is of key importance that researchers, farmers and agronomists work together to identify topics in need of further research and to carry out on-farm trials. This does not mean that techniques should not be taken up more widely now – in fact the wider take up of new ways of pest control will be a crucial part of ongoing research.

The following are suggestions for useful research arising from this report:

- Improve understanding of the ecology of natural enemies to inform advice to farmers on maximising pest control.
- Design margins and companion crops to maximise natural pest control.
- Develop quick and accurate monitoring techniques for key pests.
- Refine pest thresholds based on improved understanding of the relationship between pest numbers and yield impacts.
- Refine pest forecasting services and understanding of risk factors such as weather conditions.
- Improve understanding of the impacts of OSR establishment techniques on pest damage and crop yields.
- Establish what effects the presence of OSR and cereal volunteers has on pest pressure.
- Carry out trials of mowing and grazing OSR in autumn to determine whether this is a viable management technique for CSFB.
- Develop OSR varieties with improved ability to tolerate insect pests.
- Develop biopesticides for use against key insect pests in OSR.
- Help farmers test pests for resistance so better understanding developed.

PART 2

Efficacy of Neonicotinoid Seed treatments

It is often assumed that neonicotinoids offer the most effective means of control for pests such as CSFB. But there is a lack of robust evidence to demonstrate this.

In 2015, commenting on an application for emergency authorisation of two neonicotinoid seed treatments Defra's Chief Scientific Adviser, Professor Ian Boyd, referred to the lack of evidence of efficacy of neonicotinoids concluding that "There has been insufficient work done to properly assess whether the benefits outweigh the costs" when all the positive and negative effects are considered (Chief Scientific Adviser, 2015).

There have been few independent studies comparing the efficacy of neonicotinoid seed treatments compared to other means of control. A scientific review of evidence on neonicotinoids recently noted that "Efficacy studies are largely conducted by industry, the sector that benefits most from the data". The authors of the review were wary about drawing conclusions on efficacy due to the lack of scientific literature but commented that "we believe few would doubt that in some circumstances (combinations of crops, pests and locales) they are highly effective and in other circumstances they do not justify the costs of their purchase." (Godfray et al, 2015)

The lack of proven efficacy of neonicotinoid seed treatments was also apparent during the consideration of an application by the NFU in 2015 for emergency authorisation of two neonic seed treatments. In a document written by Defra officials the emergency authorisation is referred to as "a good opportunity to evaluate the efficacy of neonicotinoids relative to other treatments". Even the NFU – which usually refers to the reliability of neonics with a high degree of confidence – promoted to Defra the idea that comparing treated and untreated areas of OSR would be a useful exercise. (Defra redacted report 2015)

Oilseed rape has shown no increase in yield coincident with the introduction of neonicotinoids, and since the current restrictions were brought in yields were actually above average (see below). According to HGCA average oilseed rape yields have increased only very slowly since the early 1980's *[HGCA Oilseed rape guide, updated January 2014].*

A recent study into the benefits of neonicotinoid seed coatings, published in Nature, found no consistent yield benefits of using imidacloprid seed coating and found a negative effect in 2008 which it attributed to heavy rainfall causing the chemical to leach (Budge et al, 2015)

Oilseed Rape yields 2015

In 2015, the first harvest since the current restrictions on neonicotinoids were in force, average oilseed rape yields were above the 10 year average. Defra reported that despite a 3.3% reduction in planted area, the oilseed rape harvest showed an increase of 3.4% to just over 2.5 million tonnes. The increase in production was the result of a 6.9% increase in yield from 3.6 tonnes per hectare in 2014 to 3.9 tonnes per hectare in 2015.

In 2015 all regions – including the East where pest pressure tends to be high – had averages at or above the ten year average. According to media reports one Lincolnshire farmer set an oilseed rape yield world record in 2015. See table on next page.

In reality a number of factors influence yield with weather being a key factor alongside pest pressure. Defra notes that mild weather conditions in autumn and winter 2014 meant that crops established well and survived winter well.

Are neonicotinoids targeted?

Studies have estimated that only between 1.6 and 20 per cent of the active chemical in a seed coating is actually absorbed by the crop making seed dressings less targeted than many sprays (Sur & Stork, 2003). With up to 90% of the active ingredient entering the environment there is increasing concern about the impact on other organisms and the environmental fate of the chemical (EASAC, 2015). Recent studies have found higher residues of neonicotinoids in the pollen of wildflowers and hedgerows adjacent to arable fields than in the crop itself (David et al, 2015) increasing the overall exposure of bees and other pollinating insects to these pesticides.

Cabbage Stem Flea Beetle in 2015

Cabbage Stem Flea Beetle (CSFB) is one of the main pests of oilseed rape and a key reason that farmers were advised to use neonicotinoid treated seeds. The NFU has regularly asserted that without neonicotinoids farmers would struggle to control CSFB and in 2015 was successful in securing an emergency authorisation for farmers to use restricted seed treatments in some parts of the UK.

Reports for crop losses attributed to CSFB in 2015, when the vast majority of farmers could not use neonicotinoid treated seed, were slightly lower than in 2014 (3% of the crop nationally at 1 December 2015 compared to 3.5% of the crop nationally at 1 December 2014) (AHDB, 2016),

Oilseed Rape yields 2015

Taken from cereal and oilseed area, yield and production DEFRA statistics, 17/12/2015

OSR Yields	2014	2015	10 year ave	%change 2015/2014
United Kingdom	3.6	3.9	3.4	6.9
England	3.6	3.9	3.4	7.1
England: winter sown	3.7	3.9	3.5	6.6
North East	3.7	4.3	3.4	16.6
North West & Merseyside	3.9	3.6	3.5	-8.6
Yorkshire & the Humber	3.8	4.2	3.6	10.3
East Midlands	3.7	4.1	3.5	9.2
West Midlands	3.9	4.1	3.6	4.5
Eastern	3.7	3.6	3.5	-3.8
South East and London	3.3	3.8	3.4	13.4
South West	3.3	3.7	3.5	12.4
England: spring sown	1.8	1.6	1.9	-13.3
England: on set-aside	0.0	0.0	0.5	n/a
Rest of UK set-aside	0.0	0.0	0.8	n/a
Wales	3.6	3.9	3.4	7.1
Scotland	4.0	4.1	3.6	4.2
Northern Ireland	3.6	3.9	3.4	6.9

and similar to the level of crop loss from other causes such as slug grazing. The majority of the crop loss from CSFB occurred in the East where pest pressure was already known to be high.

This damage could have happened even if neonicotinoid seed treatments had been used – Defra officials reporting to Ministers on the NFU's emergency authorisation application for two neonicotinoid seed treatments in 2015 referred to previous flea beetle damage noting that "It is not known how much of this would have been successfully protected by neonicotinoids and it is not known how much yield loss would ultimately have been caused by pests." (Defra redacted report, 2015)

At the time of writing ADAS research comparing CSFB damage in fields where treated seeds were used and untreated fields had not been published. However at least one farmer who used treated seeds on part of his farm in 2015 has reported no difference in the control of CSFB, compared to the untreated area, and in fact found more larvae in the treated area. He concluded that "*The only certainly at this point is that neonics are most definitely not a guaranteed way to keep flea beetle at bay.*" [see case study for David Walston at the end of this report]

AHDB concluded that "It seems likely that CSFB had an impact on yield, however there was no simple relationship between larval numbers and yield" (AHDB, 2016, Cabbage Stem Flea Beetle larval survey).

Could neonicotinoids increase pressure from other pests?

The AHDB assessments found that CSFB was not the only cause of crop losses in 2015 with 3.1% losses from other causes predominantly slug grazing. Neonicotinoids do not control slugs. In fact neonicotinoids could have made the problem worse by killing the predatory ground beetles that would otherwise reduce slug abundance (Douglas, 2015).

Future for UK oilseed rape

Despite some warnings from the NFU that OSR would be difficult to grow without neonicotinoids there is good evidence from 2015 yields and the experience of individual farmers that OSR will continue to be a viable crop without access to neonics in most parts of the UK.

Although there has been some decrease in the areas of OSR grown, economic factors such as price on the global market and the cost of inputs are affecting farmers' decisions on whether to grow OSR and in fact are probably more important drivers of farmers' decisions than pest pressure (Scott, 2015). For example, following a recent rise in OSR prices, which estimates OSR prices now at 2.5 times the price of wheat, farmers have been encouraged by a commercial seed manager in the farming press to put OSR back in place as the key autumn-planted rotational crop. "The establishment challenges remain, especially in the CSFB hot-spots...However, away from these specific areas, if given close attention to best practice over soil management pre-drilling, soil moisture preservation and a little luck, it is possible for the majority of the national crop to be successfully established." (Farmers Weekly, 16 April 2016). Monsanto's Geoff Hall is predicting a 3% rise in OSR sown this year commenting that "We are likely to see a fall in the area in bad flea beetle regions, but are likely to see an increase elsewhere." (Farmers Weekly, 25 April 2016).

In some regions of the country where pest pressure is consistently high, it may make economic sense for farmers to move away from OSR, as has been acknowledged by many agronomists (in personal communications to the researcher for this report). In areas of the UK most affected by CSFB it is not clear whether the availability of neonicotinoids would make a difference.

OSR has become an important crop for UK farming since the 1980s: it is a useful break crop for conventional cereal farmers and is a valuable commodity on global markets (ADAS, 2009). However, there may be agronomic, environmental and economic benefits in reducing the frequency of OSR in rotations (see crop rotation section of this report). For individual farmers, more diverse rotations will bring challenges but also potential economic benefit in the form of more resilient businesses, less tied to the fortunes of one commodity crop. The Stringer family case study in the current report demonstrates an approach to OSR that is different to the current norm, where OSR forms a small and non-essential part of the rotation but produces a high-value product. There is a market for more high value rapeseed oil products.

Our research has shown that there is a lot of potential to change the way that OSR is farmed, using more non-chemical means of pest control, so that pollinators and profitable crops can go hand in hand.

Case studies

Please note that the inclusion of these case studies in this report, and the conclusions drawn from them, should not be taken as indicating their support for policies of Friends of the Earth outlined in this report unless they state otherwise. They have all given consent for their inclusion in these case studies.

Jake Freestone, Farm Manager at Overbury Farms, Gloucestershire – a successful move away from neonicotinoids

Overbury Farms is an arable farm with sheep, located on the Worcestershire/ Gloucestershire borders. Overbury Farms produces wheat, barley, beans, OSR and grass, and rents land to other businesses who grow spring onions, peas and potatoes. The farm has been LEAF Marque accredited since 2007 and has been in agri-environment schemes since 2000. A range of wildlife habitats including beetle banks and pollen and nectar strips have been created on the farm and Jake is aiming to continually reduce the use of insecticides on the arable crops.

OSR is grown in a 1 year in 6 rotation on the hill land, and 1 year in 5 on the rest of the farm. Neonicotinoid seed treatments were always used until the ban was introduced, with very occasional pyrethroid sprays as needed to control pollen beetle and other pests.

The OSR crop sown in 2014 (for 2015 harvest) was the first to be grown from non-neonicotinoid treated seeds. One pyrethroid spray was needed against CSFB soon after the crop emerged, but other than that no insecticides were applied. Interestingly, a field of stubble turnip elsewhere on the farm was completely destroyed by CSFB in May 2015 – it was redrilled but destroyed again in June. This was in an isolated field surrounded by trees, with no history of growing OSR.

This year's OSR crop has not required any insecticides so far. Jake did not observe much shot holing damage from adult CSFB in autumn 2015, and so far (as of mid-March) has not seen any signs of damage from larvae when walking the crop. He will soon carry out a detailed survey to check if larvae are present.

Jake sometimes uses yellow water-traps, but more to get a general picture of what invertebrates are present in the crop than as a monitoring tool for CSFB. He has generally based spraying decisions on shot-holing damage in the autumn. He has noticed (particularly on social media) that many farmers are increasingly worried about damage from larvae. Adult CSFB can arrive and lay eggs late in the season (October – November), which can lead to a heavy larval infestation in spring even if there was minimal shot-holing damage in autumn. It seems likely that this anxiety is leading some farmers to spray at the first signs of CSFB rather than sticking to thresholds.

Jake is applying many management approaches that might be expected to reduce CSFB risks (see elsewhere in this report). The diverse crop rotation, abundance of wildlife habitats and focus on minimising insecticide use should help to ensure good populations of beneficial insects on the farm. Jake drills OSR early in the season (starting on 11th August in 2015) as experience has shown that this gives the crop a better chance of recovering from pigeon and slug damage. Zero tillage is practiced, so OSR is directly drilled into either barley stubble or chopped straw if it follows a wheat crop, with slug pellets applied at the same time. This year, for the first time, Jake has used a companion crop (buckwheat and vetch) with some of the OSR crop. This is reducing herbicide costs by out-competing weeds, as well as fixing nitrogen and increasing soil phosphorus availability. Importantly, the companion crop also hosts mycorrhizal fungi, maintaining their populations throughout the rotation (OSR itself is non-mycorrhizal). Whether or not the companion crop proves to be helpful in managing pest pressure, it should reduce input costs and improve soil health over the long term.

Andrew Barr, East Lenham Farm, Kent
– on-farm trials of different approaches

East Lenham Farm is a 700 hectare holding, with approximately 400 hectares under conventional arable and the remainder raising sheep and cattle. The arable land produces milling wheat, spring barley, oilseed rape, beans, peas and oats. Andrew has a strong interest in promoting soil health through conservation agriculture. He has adopted a zero-tillage approach for the last five years, with only shallow tiling for the ten years before that. The diverse crop rotation and use of cover crops also help to safeguard soil health. The farm is in Countryside Stewardship and is LEAF Marque accredited. Andrew is a member of BASE UK (Biodiversity Agriculture Soil and Environment), a group helping farmers who are interested in conservation agriculture to share their knowledge.

Andrew sees an urgent need for farmers to decrease their reliance on insecticides. He has carried out trials of alternative pest management approaches with his oilseed rape (OSR) and is in communication with researchers at Rothamsted about emerging techniques. East Lenham Farm is in a part of the country that has not experienced high pressure from cabbage stem flea beetle (CSFB). Because pest numbers are so low to start with it has not been possible to carry out statistical analyses of the effects of the trials on pest numbers. However Andrew has made detailed observations in the field.

Several types of OSR companion cropping have been tried: vetch, a vetch and clover mix, and most recently beans. The vetch appeared to experience similar levels of CSFB damage as the OSR, so at best it might have a dilution effect (rather than being a deterrent or a diversion). Aphid numbers were also monitored, but were so low in both the OSR-only fields and the companion cropped fields that no conclusions could be drawn. Overall, the use of vetch companion crops had no clear impact on pest pressure or yield. Beans have been used as a companion crop in France to combat rape winter stem weevil (not currently a pest in the UK). From Andrew's observations so far the presence of a bean companion crop has no effect on the numbers of CSFB larvae in the stems of OSR. Andrew speculates that the companion crop plants may not be sufficiently developed at the early stage in the crop growth when the CSFB attacks, so it may pay to investigate planting the OSR into an already established companion crop.

It is usual practice, when wheat or barley plants from last year's crop come up in an OSR field, to spray them off straight away. However, Andrew and some other farmers in the area have observed that the presence of these cereal volunteers in an OSR crop can reduce CSFB damage. Leaving cereal volunteers for longer also seems to result in lower aphid numbers, although there is a risk of aphid attack when the volunteers are eventually sprayed off. It is not clear whether this effect is due to visual or olfactory confusion of pests, or some other mechanism. Andrew has experimented with leaving barley volunteers in the OSR for longer but it has not proved possible to get significant results, so for now this effect remains anecdotal only.

Finally, Andrew has tried sowing a strip of neonicotinoid-treated kale around the margins of the oilseed rape crop. Kale is not included in the ban and can be killed off before flowering to reduce risk to pollinators. The idea is that it would act as a trap crop, drawing pests away from the OSR and killing them. Again, no significant results have been obtained so far but this may be because of the very low background level of pests.

Andrew is very interested in the potential of a 'push-pull' approach to OSR pest management, which combines companion crops that repel pest with trap crops in the margins to attract them. Push-pull systems are being used to great effect in African agriculture but much research remains to be done in the UK.

David Walston, Thriplow Farms, Cambridgeshire

Thriplow Farms is a 900-hectare farm producing crops such as wheat, barley, oilseed rape, peas, beans, oats, linseed and maize. The farm also supports sheep and cattle on herbal and grass leys. Techniques like no-till, cover crops, companion cropping and mob grazing are used to improve the quality and productivity of the soils.

Thriplow Farms is located in an area that has experienced high pressure from cabbage stem flea beetle (CSFB), and in 2015 was one of the farms that secured permission to use neonicotinoids on oilseed rape (OSR), under the terms of the emergency authorization. This case study is adapted from David's blog, with his kind permission.

David is growing two fields of winter oilseed rape for harvest in 2016 (see Box 3). Field 1 is OSR with a companion crop of buckwheat, lentils and fenugreek. The OSR in half of this field was treated with Cruiser, a neonicotinoid seed dressing which also contains fungicides, while the other half was treated with a fungicide-only seed dressing. No other insecticides have been applied to either half of the field.

Field 2 is OSR with a companion crop of vetch, buckwheat and lentils, treated with a fungicide-only seed dressing. The main function of the companion crops is to improve soil health and nitrogen supply, but David has observed that they also seem to dramatically reduce damage by pigeons. In September there was some CSFB pressure in Field 2, so the agronomist recommended spraying with a pyrethroid. At this point David decided to leave 25% of the field unsprayed. A month later, the whole field was sprayed with pyrethroid to control stem weevil.

David has counted the number of CSFB larvae in samples of plants from both fields, and has calculated estimates for larvae per petiole (the stalk that attaches a leaf to the plant stem) and total number of larvae per square metre of field.

In Field 1, there were fewer CSFB larvae per plant in the neonic-treated area than in the untreated area. It is worth noting that in even in the treated area the larvae exceeded the current recommended threshold for spraying (see Box 2). However, because they were sown later and with a higher seed rate, the plants in the treated area were smaller and more densely packed than in the untreated area. David calculated that there were *more* CSFB larvae per square metre in the *treated* area, and a similar number of larvae per petiole in each area.

In Field 2, there were more CSFB larvae per plant in the area that had only been sprayed once compared to the area that been sprayed twice (although in both cases numbers were under the treatment threshold). There were also more larvae per petiole and per square metre.

The figures are summarised in the table below. It is important to note that ***these figures do not allow any conclusion about the relative efficacy of the different pesticides*** because of several extra variables not taken into account (variety of OSR used, companion crop mixes, sowing date, field location etc). It should also be noted that the crops have not been harvested yet, so final yield is not known. This case study does however illustrate clearly the importance of appropriate monitoring and the need for careful interpretation of what is being observed. David's conclusion was that "*The only certainty at this point is that neonics [neonicotinoid insecticides] are most definitely not a guaranteed way to keep flea beetle at bay.*" David does not intend to use any neonicotinoids on OSR in 2016, even if authorization is granted.

Box 3

Treatment (NB there were other variables not reported here: interpret with caution)	Larvae per plant	Larvae per petiole	Larvae per m2
Field 1, neonic + fungicide seed dressing	8.6	1.2	503
Field 1, fungicide only seed dressing	10.5	1.2	345
Field 2, fungicide dressing + pyrethroid spray x 2	1.5	0.2	94
Field 2, fungicide dressing + pyrethroid spray x 1	3.6	0.5	293

Mike Stringer, Stringer and Sons
– organic oilseed rape

The Stringer family farms at High Callis Wold, East Yorkshire. The farm comprises about 445 hectares and includes cattle, sheep and arable crops. In 1999, all of the livestock production and about half of the arable land were converted to organic production.

The organic arable land is under a seven-year rotation, typically as follows:

- **Year 1:** spring oats undersown with grass and red clover
- **Years 2-3:** grass and clover ley stays down
- **Year 4:** spring barley
- **Year 5:** winter oats
- **Year 6:** spring beans
- **Year 7:** winter wheat

For the last few years Mike has been experimenting with including oilseed rape (OSR) in the organic rotation. Yields have been variable, with some very poor years and some good. Winter OSR was tried one year but failed, mainly due to damage by cabbage stem flea beetle in the early stages of growth. Spring OSR has proved more successful, although it tends to have intrinsically lower yields than Winter OSR.

The main pests Mike has to contend with in spring OSR are pigeons and slugs. Cabbage stem flea beetle is also a problem in some years. Mike drills his Spring OSR fairly late in the season, and believes that the fast growth rate in the early stages helps the crop to 'get away' from pests. By contrast, Winter OSR is established in autumn, when plant growth rates are slowing down, meaning the crop is less able to recover from early damage by flea beetles. No insecticides are used in the organic rotation – this should mean that natural enemies of pests are present in good numbers, although Mike has not specifically monitored this.

Mike has been trialing Spring OSR at different points in the rotation. The main considerations are soil fertility and avoiding pests carrying over between years from one crop to the next. In any given field, OSR is grown no more than 1 year in 7 (compared with 1 year in 2 or 3 on many conventional arable farms). The crop did well when grown immediately following two years of cereals, although it required inputs of manure to provide sufficient nitrogen. Mike intends to try it immediately following the clover ley, when levels of soil nitrogen should be high.

The oilseed rape produced on High Callis Wold is pressed locally and sold as organically certified rapeseed oil for use in cooking. The ability to access a local, small-scale press that is able to meet organic standards has been an important factor enabling the Stringer family to market their crop as an organic product.

Peter Lundgren
– Lincolnshire, oilseed rape and wheat.

Peter is keen to show other farmers that farming without bee-harming neonicotinoid pesticides is feasible. "The oilseed rape on my farm is pretty robust, and with sympathetic management I can control pests whilst limiting the impact on bees".

Peter calculated what the economic consequences of giving up the use of neonicotinoids on his farm would be, before they were restricted by the EU in 2013. The move cost him £2.20/ha in oilseed rape (OSR) – compared with the £230 industry estimate. He saved £13/ha in wheat – instead of an industry-predicted £225/ha loss. The analysis of the cost of the neonicotinoid ban to Peter's farm is available here.

In the short term Peter replaced neonicotinoids with other pesticides but he is working towards a whole farm low-input approach, including encouraging beneficial insects. "There's a payoff for ensuring healthy and increasing populations of bees and beneficial insects. They can do our work for us – and they don't charge for providing the service!" Peter ensures that he provides habitat on his farm for beneficial insects, believing this is more important than a tidy farm. For example the dykes on his farm act as "inverted beetle banks" because Peter does not flail them instead leaving them to be habitats for insects.

Peter believes that it's not sufficient to provide habitats such as wildflowers in odd corners of the farm when the cropped area is a no-fly zone – the whole cropped area has to be safe for bees and pollinators.

Peter says the lack of independent advice available to farmers is impeding progress on the path to farming which supports bees and other pollinators. Current advice is based on research funded by pesticide companies that favours high pesticide use as an insurance measure. Instead, farmers should monitor crops for pests, use pest thresholds as a guide, and only use pesticides when the need occurs.

Peter suggests that neonicotinoids can be avoided by a combination of methods:

- For direct attack on crops by insects, better assessment of threshold levels – the level of damage a plant can tolerate – could allow for a more targeted response and a reduction in insecticide use.
- Insect-borne diseases are becoming harder to deal with – some of these diseases are not evident until the damage is done so insurance treatments are applied. Developing conventional (non GM) resistant crop varieties could be a cost effective way of avoiding disease damage and cutting pesticide use.
- Companion planting and trap cropping have both demonstrated success in reducing pesticide use and maintaining or increasing yields of oil seed rape.
- Creating habitats for pollinators – and natural pest control

Ultimately Peter believes that farmers need to be more in tune with public opinion. "We cannot afford to be the generation of farmers who are responsible for the loss of the bee from our countryside".

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