The impact of agricultural policy reforms on plant health risks in Scotland: Guidance on maximizing plant health benefits

Project Final Report

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This work was commissioned by Scotland's Centre of Expertise for Plant Health Funded by Scottish Government through the Rural & Environment Science and Analytical Services (RESAS) Division under grant agreement No PHC2023/05

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Please cite this report as follows: K. Topp, H. Creissen, M. Elliot, N. Havis, F. Daramola, L. Cole (2025). The impact of agricultural policy reforms on plant health risks in Scotland: Guidance on maximizing plant health benefits: Project Final Report. PHC2023/05. Scotland's Centre of Expertise for Plant Health (PHC). DOI: https://doi.org/10.5281/zenodo.14848812

Available online at: planthealthcentre.scot/publications

Dissemination status: Unrestricted

Content

1 Executive Summary

1.1 Aims

The Scottish Government is committed to achieve net zero by 2045 (Scottish Government, 2020), whilst restoring and regenerating biodiversity. To meet these targets, they are transforming the agricultural support system to focus on climate mitigation and adaptation, and nature restoration in addition to high quality food production. In collaboration with NatureScot and the industry, they are appraising a range of agricultural management practices with the potential to restore nature, increase the efficiency of production and help farm businesses mitigate and adapt to climate change. These practices are outlined in the Agricultural Reform List of Measures[1]. It is conceivable that these measures could have unintended consequences on plant health, which may require further investigation. The aim of this review and stakeholder engagement was therefore to assess the evidence for the effect of practices identified in the list of measures on plant health, specifically assessing the impacts on pests, natural enemies, weeds and plant diseases. The evidence from the literature was identified through a Rapid Evidence Assessment (REA) supplemented by grey literature and other key sources including unpublished research. In addition, we assessed the role that plant health regulations play in reducing plant health risks associated with the widespread adoption of the Agricultural Reform List of Measures to determine how these regulations mitigate risk.

1.2 Results

The farming community have diverse opinions regarding the potential impact the Agricultural Reform Measures will have on pest, natural enemies, weeds and diseases. Similarly, the evidence gathered through the REA was inconclusive for many of the proposed Agricultural Measures on plant health (Table 1). However, comprehensive evidence was lacking and impacts on plant health differed between studies, taxa and crops. In some cases, the evidence was inconclusive with research indicating that a specific measure was potentially positive for one type of natural enemy, pest or disease whilst having negative impacts on others. Across studies, reduced pesticides are expected to increase pests and minimum or zero tillage can increase the prevalence of soil borne pests (e.g. wireworm). In-field diversity is also expected to increase weeds, while improvements to hedgerows is likely to increase plant diseases.

It is likely that some of the measures will be implemented as a package by farmers, whereby several practices are combined to optimise the outcomes achieved (e.g. a package focussing on reducing soil erosion could combine winter cover with reduced tillage). In such instances, there may be interactions between the measures affecting the overall outcome. Consequently, looking at single practices in silo may not be appropriate. The interactions between the measure(s), weather, soil conditions, and crop choice will determine the outcome on plant health. Furthermore, actions to mitigate risk are likely to be context specific depending on pests, weeds and diseases present, and factors that influence these (e.g. soil, weather patterns, previous crop).

Farmers typically perceived that diversified crop rotation and the incorporation of grass leys into arable systems were likely to reduce the incidence of pests, weeds and diseases. Intercropping was also expected to reduce pests and diseases. The farmers were either neutral or expected winter cover crops and minimum or no tillage to increase pests, weeds and diseases. The farmers were least likely to adopt intercropping and minimum tillage due to financial implications.

[1] Agricultural Reform List of Measures

Table 1 Impact of measures on plant health identified from the REA[1]

	pests	natural enemies	weeds	diseases
winter cover	+/-	+/=	=/-	+
minimum/no tillage	-	+/=	+	+/-
reduced fertiliser	=	=	+/=	+/-
replace with organic fertiliser	+/=	=		
reduced pesticides	-		=/-	+
arable/ley rotations	+/=		+/-	=/-
nitrogen fixing crops		+		
diversified rotations	=	+/=	+/-	+/-
hedgerows	=/-	+/-	=	-
in-field biodiversity	+/-	+/=	-	
intercropping	=/-	+/-	=/-	+/=
silvo-arable	+/-	+/-	+/-	
water margins		+		

[1] + represents a positive impact (i.e. decrease in pests, weeds, disease or increase in natural enemies), = represents no change, - represents adverse impacts (i.e. increase in pests, weeds, disease or decrease in natural enemies), blank cells mean that there is no evidence

1.3 Gaps

- There is a lack of evidence on the impact that the adoption of multiple measures will have on all aspects of plant health.
- Although not assessed as part of the review, very few studies reported the effect of the measures on yield resulting in a lack of evidence of how the reported impacts on plant health could impact on productivity.
- An assessment of long-term impacts of the adoption of the agricultural reform measures on plant health is required. It is also important to consider the economic implications of the reforms on plant health and the wider farm operations.

1.4 Conclusions

The REA highlights that the adoption of more regenerative practices, as outlined in the Scottish Government's Agricultural Reform List of Measures can have both positive and negative implications to plant health with impacts varying between measures, and plant health risks. Overall, the REA did not suggest that the proposed measures will result in any major risks for plant health, and no evidence was found that indicated current plant health regulations would need adapted. Nevertheless, as a precaution current practices that monitor plant health should be continued to ensure risks are identified at an early stage, and mitigation measures implemented promptly. It is important that knowledge exchange and guidance towards best practices is provided to the arable sector to reduce risk and ensure successful adoption of the practices. As management actions to reduce one risk may simultaneously increase another, best practice is likely to be context specific. It is also crucial that the impact of climate and soil interactions on the success or failure of both the practice and the effect the measures will have on plant health needs to be better understood.

2 Project Background

Mitigating and adapting to climate change, restoring biodiversity and sustainably meeting future human nutritional demands are three of the most important global challenges Scotland faces. Enhancing the societal, economic, and environmental performance of food production is vital to meet these challenges. Indeed, the Scottish Government (SG) has committed to meet global targets relating to safeguarding biodiversity (outlined in The Kunming-Montreal Global Biodiversity Framework, (FAO, 2024)). The SG has also committed to reduce greenhouse gas emissions by 75% by 2030 compared to 1990 and achieve net zero by 2045 (Scottish Government, 2020).

To meet these targets, the SG aims to become a global leader in sustainable and regenerative agriculture. To realise this ambition, they are transforming the agricultural support system to focus on climate mitigation and adaptation, and nature restoration in addition to high quality food production. The Agriculture and Rural Communities (Scotland) Act which came into effect in June 2024 provides a legally binding framework targeted to support land managers deliver this vision through the 4-tier structure (Figure 1).

Under Tier 1 it will be mandatory for farms to complete a whole farm plan to receive their single farm payment. In 2025 farmers will have to complete two of five audits (Biodiversity Audit, Carbon Audit, Integrated Pest Management, Animal Health and Welfare Plan, and Soil Analysis) with all five audits required by 2028. These audits are designed to help farmers baseline the current performance of their farm, and in raising awareness of the current state of play they will help farmers identify actions to improve both environmental performance and efficiency.

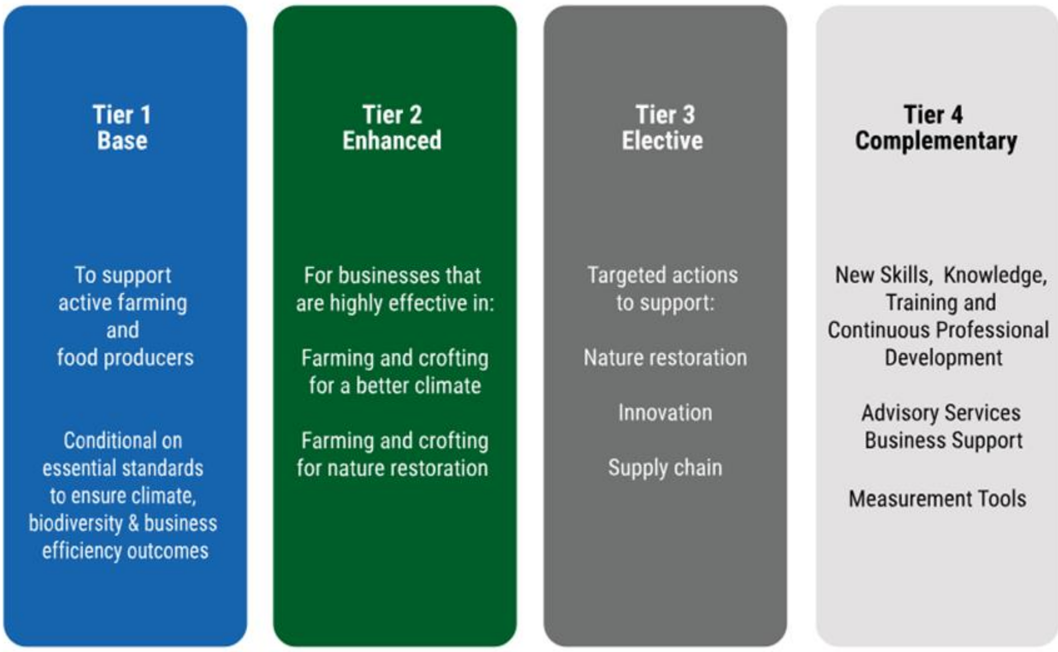

Figure 1: Agricultural support package post 2025

In 2026 we will see direct support split between Tier 1 (Base Level Direct Payment) and Tier 2 (Enhanced Level Direct Payment). Tier 2 payments will not be competitive, but to be eligible for these payments farmers will need to adopt more regenerative farming practices – i.e. enhanced conditionality. The SG, NatureScot, and industry (e.g. via the Agriculture Reform

Implementation Oversight Board (ARIOB)) have identified a range of practices with the potential to restore nature, increase the efficiency of production and help farm businesses mitigate and adapt to climate change. These actions are outlined in the Agricultural Reform List of Measures (Table A1) (Scottish Government 2023) and are currently being appraised by the SG.

Exact details on how enhanced conditionality will be administered is currently lacking, however, as delivery will be linked to a farm's single farm payment it is assumed that uptake will be extensive, transforming our food production systems. We are likely to see widespread change in farm management, with a surge in agroecological practices delivered on farm. While the focus of this transformation is to increase efficiency, sustainability and restore nature, it is possible that there could be unintended consequences that could impact on food security. For example, if cover crops act as a green bridge allowing pests and diseases to persist in fields overwinter, widespread uptake could increase the prevalence of pests and diseases adversely impacting on production. Similarly, cover crops can also positively impact plant health through improving soil health, water regulation, and natural enemy predation.

2.1 Aims and objectives

The Plant Health Centre commissioned SRUC to undertake this research aiming to assess the plant health risks associated with the Scottish Government's List of Measures for arable and horticultural crops. To achieve this, we combined a Rapid Evidence Assessment (REA) to identify potential risks and benefits with stakeholder knowledge. Ultimately enhancing our understanding of these risks and benefits, will help us co-design best practice options targeted to minimise potential negative plant health impacts to crops and the wider natural environment. To meet these aims we:

1. Undertook a rapid evidence assessment (including the scientific and grey literature and existing data) to identify the plant health impacts of the proposed List of Measures, with reference to Scotland's key crops and the likely uptake of measures.
2. Identified potential regulatory options (statutory, basic or enhanced) that could pose an emerging risk for plant health and biosecurity in the context of likely uptake of measures.
3. Held stakeholder workshops to co-design best practice guidance to mitigate plant health risk whilst delivering biodiversity, climate and wider environmental goals.
4. Summarised findings in a Final Report with an executive summary which contains key sources, analysis, findings and recommendations for implementation or further work.
5. Prepared a policy briefing outlining and prioritising plant health risks associated with the proposed changes to the rural payment system. This briefing will outline key vehicles (policy, practical implementation) within agricultural reform to protect plant health while achieving environmental sustainability ambitions for policy makers.
6. Worked with SAC Consultancy and others to raise awareness of plant health risks associated with the List of Measures and to disseminate best practice guidance to mitigate risk.

3 The evidence of impact of agricultural policy reforms on plant health

This study focussed on the agricultural reform list of measures that were most likely to have a direct impact on plant health in arable or horticultural systems. In agreement with the Plant Health Centre, the practices assessed were (1) winter cover, (2) minimum / no tillage, (3) efficient use of synthetic fertilisers and (4) pesticides, (5) nitrogen fixing crops, (6) diversified crop rotations, (7) enhancement of hedgerows, (8) in-field biodiversity, (9) inter-cropping, (10) silvo-arable systems and (11) water margins (see Annex 1, Table A1 for more details on these practices). It was also agreed with the Plant Health Centre that this review would focus on the impact on pests and natural enemies, weeds and diseases, and would not consider the wider aspects of nutrition and climate change on plant health. The effect of these practices on plant health were assessed through a Rapid Evidence Assessment (REA). The practices were assessed for their impact on pests, natural enemies, weeds and diseases. Details on the methodology are described in Annex 2.

3.1 Winter cover

The use of cover crops in rotations is increasing in popularity across arable growers in Scotland. They are generally grown for environmental benefits such as nutrient retention, soil erosion and plant health. There are four main groups of cover crops: legumes, cereal and grasses, brassicas or herbs [2] with the retention of the previous crops stubble overwinter also being considered for inclusion. It is more challenging for cover crops to be sown in wet autumns and at increasing latitudes particularly if farmers are sowing after harvest i.e. later in the year. Nevertheless, farmers are adopting alternative strategies such as broadcasting cover crop seed into a standing crop, to increase the likelihood of getting cover crops established.

3.1.1 Impacts of winter cover on pests and natural enemies

In providing continued growth throughout the season, winter cover has the potential to stabilise fluctuations in soil temperatures, improve soil structure and act as a green bridge, allowing pest populations (e.g. aphids) to persist from one growing season to the next (Martinez et al., 2020). This could put subsequent crops at risk of pest outbreaks during establishment, when they are particularly vulnerable. Evidence emerging from the AHDB Scottish strategic farm trials indicates that slug damage is more prevalent in crops that follow a cover crop. Determining how the timing and methods of cover crop destruction (e.g. grazed, destruction pre-drilling, destruction post-drilling) impacts on pests could help mitigate risk and provides an important avenue for research.

Cover crops can in some instances provide alternative hosts for economically damaging pests. For example, stem and bulb nematodes *Ditylenchus gigas* and *Ditylenchus dipsaci* are economically damaging to peas and beans, with *Ditylenchus dipsaci* also damaging potatoes. Vetch provides an alternative host for *Ditylenchus gigas* while a wide range of species play host to *Ditylenchus dipsaci*, including oats, black mustard, wild radish, vetch, and clover (CABI, 2022). This pest can be transmitted through contaminated seed. With cover crops not routinely monitored, the introduction (e.g. via contaminated seed) and build-up of pests could go unnoticed. Some cover crops (e.g. *Sinapis alba*) can also act as a biofumigant (i.e. releases bioactive chemicals that are toxic to pests) suppressing *Ditylenchus gigas* (Musa, 2021). Determining the extent that different cover crop species act as host plant, or biofumigant, to

[2] Types of cover crops | AHDB

economically important pests and raising awareness of the importance of clean cover crop seed are key actions to reduce this risk.

Cover crops, similarly, can provide resources such as food and shelter for natural enemies allowing infield populations to persist overwinter. The REA found both neutral and positive impacts of cover crops on these natural enemies. Cover crops enhanced aphid parasitism rates, and this was attributed to mustard (*Synapis alba*) providing floral resources benefiting populations of parasitic wasps (Damien et al., 2017). Cover crops (primarily radish and mustard) were also reported to increase spider abundance (Puliga et al., 2021), however, carabids abundance (Puliga et al., 2021) and natural enemy predation rates (Fioratti Junod et al., 2024; Puliga et al., 2021) were not impacted. In Scotland, cover crops have a relatively short growing period, and as a result typically don't flower, and thus fail to provide resources for natural enemies such as hoverflies and parasitic wasps. With natural enemies and pests interacting, consideration should be given to identifying cover crop mixtures and their method of destruction/incorporation that benefit natural enemy populations while reducing pest populations.

The impact of cover crops on natural enemies and pests will depend on a variety of factors including the species planted, how well the cover crop establishes, and timing and method of destruction. Incorporating cover crops into the soil could help increase soil health and fertility, with increased organic matter promoting soil organisms, however, this is only viable with cultivation. Destruction of cover crops via livestock grazing may be an alternative to chemical destruction, although this can be challenging due to insufficient cover crop biomass. The integration of livestock requires access to livestock and changes to farm infrastructure (e.g. stock proof fields and the availability of watering points). This is more easily achieved in mixed farming systems; however, there are several examples in Scotland where livestock and arable farms have collaborated.

3.1.2 Impact of winter cover on weeds

The incorporation of cover crops in rotations reduces the weed density and emergence(Fioratti Junod et al., 2024). However, the effect on weed biomass depends on the tillage regime adopted (Fioratti Junod et al., 2024; Kadziene et al., 2020). The inclusion of cover crops combined with either harrowing or ploughing reduced the weed biomass (Kadziene et al., 2020). However, depending on the following crop, direct drilling either reduced or had no effect on the annual and perennial weeds biomass (Kadziene et al., 2020). The choice of both the species sown as the winter cover (Kwiatkowski et al., 2016), and the following crop (Kadziene et al., 2020) impacts on the number of annual and perennial weeds.

3.1.3 Impact of cover crops on disease

Fusarium head blight, which produces mycotoxins is a major issue for cereal growers. Mycotoxins are harmful to animals and humans when they enter the food chain. One of the major toxin producing species in the complex is *Fusarium gramineaurm*. The use of white clover as a cover crop has been shown to reduce infection by *F. gramineaurm* in spring wheat (Kadziene et al., 2020), with white mustard reducing *F. graminearum* levels in spring barley (Kadziene et al., 2020). Kwiatkowski et al. (2016) demonstrated a range of cover crops, including white mustard, Phacelia and Faba bean+vetch+oats mix, significantly reduced Fusarium infection at the base of the following wheat crop. The same authors found a greater response in disease suppression from the cover crop than from a change in tillage system (Kwiatkowski et al., 2016). Oats as a cover crop have also been shown to reduce disease levels in following high value vegetable crops e.g. carrots (Patkowska et al., 2020). Rye as a cover crop has been shown to reduce disease levels in following potato crops impressively increasing the numbers of marketable tubers after storage by 37% (Rittl et al., 2023).

Our REA found largely positive impacts of cover crops on disease. There are, however, concerns that with local sourced seeds frequently lacking, cover crop seed is often imported from overseas. They therefore could act as a source of disease and a means of introducing new diseases to the UK. Focus on increasing the availability of locally sourced seeds will not only help to mitigate this risk but also ensure that the cover crop is adapted to the local environment increasing the likelihood of establishment.

3.2 Minimum/No tillage

Minimum till and no till systems reduce the number of tractor passes and hence fuel use. In addition, minimum tillage can lead to increases in soil carbon (Topp et al., 2023) and reduced soil compaction. Cultivation can directly harm larger soil organisms, such as earthworms, and reducing soil disturbance allows more stable soil aggregates to form, providing key resources for soil biota.

3.2.1 Impact of minimum/no tillage on pests and natural enemies

Our RAE found that when compared to conventional tillage both minimum tillage and no tillage rotations increased the prevalence of wireworms (Le Cointe et al., 2023). Aphids, on the other hand, were significantly reduced under minimum-tillage indicating that impacts are likely to vary between pest species (Kennedy et al., 2010). Exploring the wider evidence suggests that conventional cultivation help control soil borne pests such as slugs which are directly killed by ploughing and deep ploughing can bury the overwintering stage of the pea midge (*Contarinia pisi*) (AHDB, 2024). Furthermore, the residue from the previous crop is incorporated into the ground reducing both harbourage and food. Cultivation is thought to bury perennial weeds (although our REA found no evidence for this – see below), reducing the risk of volunteers and grass weeds acting as a green-bridge enabling pests such as aphids to persist overwinter (SAC 2006).

A meta-analysis exploring the impact of minimum tillage on predatory ground beetles indicated increased abundance, richness and diversity under minimum/no tillage when compared to conventional tillage. The wider research found both positive and neutral impacts of minimum/no tillage on natural enemy populations. Positive impacts were found for ground beetles (Puliga et al., 2021) and free-living nematodes (Junge et al., 2020), whereas parasitoids (Nilsson, 2010) and spiders (Puliga et al., 2021) were not influenced.

3.2.2 Impact of minimum/no tillage on weeds

In cropping systems without cover crops, the number of weeds and their biomass was not typically affected by tillage regime (Kadziene et al., 2020). In contrast, in cropping systems with a cover crop, annual weed biomass and abundance can be increased by adopting minimum tillage practices (Colnenne-David et al., 2017; Kadziene et al., 2020). Reduced tillage regimes result in increased herbicide use to control the weeds (Colnenne-David et al., 2017). Initial trials in Midlothian indicate that while meadow-grass increased under reduced tillage, many broad-leaved weeds decreased with grass weeds more difficult to control in cereals (SAC, 2006).

3.2.3 Impact of minimum/no tillage on diseases

The use of minimum tillage can increase trash and soil borne diseases. While previous work in Scotland has found the impact of reduced tillage to be both crop and disease specific, a reduction in eyespot infection under minimum tillage systems has been consistently observed[3]. A study in the Czech Republic suggested moving to a minimum tillage regime in wheat did not increase the demand for protection from root and stem base diseases and also reduced Fusarium on harvested grain (Váňová et al., 2011). In contrast to the Czech study, another study indicated minimum tillage increased colonisation of wheat grains by *Alternaria, Aspergillus* and *Cladosporium sp*. (SUPRONIENE et al., 2011). A study in Ireland suggested that barley and wheat under minimum tillage had reduced virus infections in due to reduced aphid numbers (Kennedy et al., 2010). A multi-year study in Poland showed that disease levels from the take all fungus (*Gaeumannomyces graminis var. tritici*) were higher in no tillage systems than in reduced tillage or conventional systems (Woźniak, 2023). Reduced soil tillage can increase levels of tan spot in wheat, while levels of Septoria leaf blotch were unaffected by cultivation (Bankina et al., 2018). The authors later reported that stem base diseases in the same trials were unaffected by cultivation system (Bankina et al., 2019). Recent trial results in Scotland suggest that a shift to minimum or no tillage systems could increase the risk from trash borne barley diseases e.g. net blotch, but conversely barley crops planted after ploughing may be denser and more prone to foliar diseases, such as powdery mildew (Creissen and Newton, unpublished).

3.3 Efficient / Reduced use of inorganic fertilisers and lime

Efficient use of fertilisers is fundamental to balancing food production and greenhouse gas emissions.

3.3.1 Impact of reduced use of inorganic fertilisers on pests and natural enemies

With respect to pests and natural enemies, two studies were identified that explored the impact of reduced inorganic fertilisers. Both studies compared inorganic fertilisation with no fertilisation and with organic fertilisation. These studies found a similar abundance of aphids in crops (e.g. cabbage, spring barley) receiving inorganic fertilisers and those receiving no fertilisers (Duchovskienė et al., 2012; Garratt et al., 2010). When comparing inorganic with organic fertilisers, a more realistic scenario, findings differed between studies. Duchovskienė et al. (2012) found higher cabbage aphid (*Brevicoryne brassicae*) abundances under organic fertiliser regimes. Garratt et al. (2010) on the other hand, found similar abundances of rose-grain aphids (*Metopolophium dirhodum*) in organically and inorganically fertilised treatments. Garratt et al. (2010) did, however, find aphids in the inorganic fertiliser regime were larger than those in organic or no fertiliser regime indicating substituting inorganic fertilisers with organic fertilisers could reduce aphid damage (assuming larger aphids cause more damage). Fertiliser regimes are likely to impact on both crop biomass and chemical composition which makes it difficult to determine if differences between fertiliser regimes were simply due to changes in plant biomass or chemistry. Neither study found an impact of fertiliser regime on aphid parasitism rates which remained relatively consistent across the three fertiliser treatments (Duchovskienė et al., 2012; Garratt et al., 2010).

3.3.2 Impact of reduced use of inorganic fertilisers on weeds

In a long-term study from Dahnsdorf, Germany, the number of weeds tended to increase in a continuous cereal monoculture but was not affected in complex rotation when no fertiliser was

[3] The development of a risk assessment method to identify wheat crops at risk from eyespot | AHDB

applied (Schwarz, 2018). However, this contradicts the evidence from the SRUC long-term organic experiment, as the weeds increased over time in a complex arable rotation where there were no external inputs of either synthetic or organic nitrogen fertiliser (R. Walker, personal communication).

3.3.3 Impact of reduced use of inorganic fertilisers on diseases

The literature review found evidence that high application rates of nitrogen can lead to disease risks. A study on wheat showed that diseased crops have a lower optimal nitrogen requirement compared to treated disease-free crops (Olesen et al., 2003). However, there is evidence that high nitrogen application rates can lead to an increase in *Fusarium* and *Penicillium sp.* in harvested wheat grains (Supronienė et al., 2012). The form of fertilisers used can influence the levels of disease. Work on oilseed rape found that high levels of nitrogen combined with sulphur can reduce levels of *Verticillium* and other rape diseases, but this was varietal dependent (Cwalina-Ambroziak et al., 2016). Interestingly, the same authors reported that the use of liquid organic nitrogen rather than mineral fertilisers increased the production of antifungal compounds in the plants and enhanced disease resistance. There is ongoing interest in tissue testing to monitor and precisely manage plant nutrition but there is no definitive evidence of this approach influencing disease levels.

3.4 Efficient / Reduced use of synthetic pesticides

The reduction in synthetic pesticide use forms a cornerstone of Integrated Pest Management (IPM) programmes. IPM strategies are increasingly being adopted by farmers, an action driven by both national policies and the reduction in pesticide availability. Reduced selection pressure from pesticides is generally regarded as beneficial in terms of stewardship against resistance, however. There are specific example for insects and weeds where dose reductions have been linked to an increased risk of resistance[4]. For fungicides reduced doses are beneficial in terms of reducing the risk of resistance.

3.4.1 Efficient / Reduced use of synthetic pesticides on pests and natural enemies

The Food and Environment Protection Act ensures that all plant protection products safeguard the environment, human health and wildlife and that they provide safe, efficient and humane ways to control the pests. Consequently, prior to approval, pesticides undergo efficacy trials to demonstrate their effectiveness at controlling the target pest and to determine the correct dose rate and mode of action[5]. Testing must also demonstrate that when applied correctly (i.e. following label guidelines), pesticides do not adversely impact on non-target organisms. Previous research for the Plant Health Centre highlighted that withdrawing key active substances would significantly impact on the ability of Scottish agriculture to control pests, weeds and diseases effectively and economically (Evans, 2020). Research has found that stem weevil larvae and pollen beetle larvae were more abundant in plants that did not receive insecticides when compared to those receiving insecticides (Juran et al., 2020) The effectiveness of alternative control measures to reduce the need for synthetic pesticides is receiving a lot of attention. Our REA found mesh covers to be effective at reducing cabbage root fly damage (*Delia radicum*) (Witkowska et al., 2018), with biological insecticides effective at controlling pea aphid (*Acyrthosiphon pisum) (*Nikolova and Georgieva, 2019).

Our REA only found one paper that indirectly explored the impact of a reduction of synthetic pesticides on natural enemies. This paper identified that volatiles (i.e. compounds emitted by

[4] The Fungicide Resistance Action Group (FRAG-UK) | AHDB
[5] Efficacy Evaluations and Guidelines

damaged plants) could increase predation of cabbage root fly eggs by ground active predators (Kergunteuil et al., 2012). Wider evidence indicates that despite tight environmental controls on pesticides, adverse impacts on natural enemies occur (Calvo-Agudo et al., 2020; Desneux et al., 2007; Henriques Martins et al., 2024; Sánchez-Bayo, 2021). Sublethal effects of insecticides include reduced emergence in parasitic wasps, reduced attack rates in predatory bugs, and uncoordinated movement in parasitic wasps (Desneux et al., 2007). Neonicotinoids have largely been withdrawn from use in the UK due to their potential to accumulate in the soil and their presence in pollen and nectar. While hoverflies appear to be less sensitive to neonicotinoids than bees, exposure was found to significantly affect fecundity (Henriques Martins et al., 2024). Honeydew (a sugar-based waste product secreted by bugs) contaminated with flonicamid increased mortality in the hoverfly *Sphaerophoria rueppellii* but had no impact on the parasitic wasp *Anagyrus vladimiri* (Calvo-Agudo et al., 2020). Pesticides can also impact on natural enemies indirectly, for example a reduction in herbicides could result in a greater abundance and diversity of in field floral resources providing forage for natural enemies such as hoverflies and parasitic wasps (Sánchez-Bayo, 2021). At the same time, however, a reduction in herbicide could also provide pests with alternative host plants and act as a green-bridge, enabling pests to persist overwinter.

Research focussed on comparing pesticide treatments with no-pesticide controls. The focus of this measure, however, is on better targeting pesticide use through precision agriculture techniques and integrated pest management (IPM) (e.g. use of economic thresholds and cultural control measures). Better targeting pesticide applications will reduce the risk of resistance developing and will help to promote natural pest control services. Impacts of reducing pesticides are, however, likely to be complex, involving interactions between pests, weeds and natural enemies (Sánchez-Bayo, 2021) and a better understanding of sublethal and indirect effects of pesticides is key to developing successful IPM strategies.

3.4.2 Efficient / Reduced use of synthetic pesticides on weeds

The impact of reducing herbicide applications on weeds was variable, with either no effect (Klocke et al., 2023) or increases in weeds (Edesi et al., 2012; Schwarz, 2018) being reported. Recent work within the PCN Action Scotland project shows the potential for potato groundkeeper image recognition that enables targeted herbicide applications, such that efficacy can be maintained but inputs reduced by over 70%. This demonstrates that better targeting applications can result in efficient control, whilst reducing pesticide inputs.

3.4.3 Efficient / Reduced use of synthetic pesticides on diseases

The use of alternative products to conventional synthetic fungicides is attracting a lot of attention, although results can be conflicting. The RAE identified one study in Poland which suggested that *Trichoderma asperellum* as a biopesticide gave only a small, insignificant decrease in dark leaf spot severity in oilseed rape (Kowalska, 2014). The option of reducing fungicide use, through management zones based on satellite and drone images and disease predictions, offers the potential to reduce fungicide use by 25% in wheat crops (Whetton et al., 2018). A recent study in Germany looked at rye crops and showed that a 50% reduction in fungicide use did lead to higher disease levels but only reduced crop yield by 4%, resulting in no change to the net margin for the farmer (Klocke et al., 2023).

Alternatives to fungicidal seed treatments have also been investigated and, while they have been shown to reduce the number of pathogens, control is considerably inferior to chemical options (Pekarskas et al., 2013). One alternative plant protection product, based on brown seaweed extract, has been approved for use in UK wheat crops, and has been shown to reduce levels of septoria leaf blotch by 42% compared to untreated plants (de Borba et al., 2022). Combining biofertilisers with synthetic pesticides has been shown to allow a 50% reduction in fungicide requirement in wheat production systems in some countries (Spruogis et al., 2017). A previous report for the Plant Health Centre shows the potential for greater integration of biocontrol options into crop disease programmes (Rees et al., 2023). There are new apps being launched to help growers optimise fungicide programmes to control high pressure diseases, such as Potato late Blight and move away from prophylactic regimes[6].

3.5 Arable/ley rotations and livestock integration

Prior to the widespread availability of synthetic fertilisers, grass leys grazed by livestock were a vital component of arable rotations replenishing depleted soil nutrients and building organic matter. Arable leys that incorporate nitrogen-fixing legumes and integrate livestock grazing, are particularly valuable in enhancing soil fertility, building organic matter, and reducing the need for synthetic fertilisers. As a break crop, they have the potential to reduce the prevalence of pests and diseases, and competitive grasses can reduce the weed seed bank. The inclusion of leys in arable rotations can improve soil structure, reduce compaction and enhance soil porosity and water infiltration and retention (Berdeni et al., 2021).

Grazing winter cereals, or oilseed rape by sheep is thought to improve the soil fertility and soil organic matter (Figure 2). Practitioners note that this reduces disease pressures, partly through the removal of diseased leaves. Cover crops established in the autumn can also be grazed by sheep. However, in Scotland, the Ecological Focus Area Green Cover rules means that cover crops cannot be grazed before the 1 January. The opportunities for grazing are also limited due to the typically low biomass of the cover crop. If cover crops are to be grazed, this may influence the choice of species sown. Grass leys and the integration of livestock have the potential to build resilience into farming systems through diversification of outputs (e.g. beef, lamb), improvements to soil health and reducing reliance of agrochemicals.

[6] New Syngenta Blight Hub answers agronomy questions | Syngenta

Figure 2: Sheep grazing winter cereals, Balbirnie Home Farms, Fife

3.5.1 Impacts of Arable/ley rotations and livestock integration on pests and beneficials

The RAE found only one study that looked at the impact of ley rotations on pests (Courson et al., 2022). This study explored how the proportion of grassland at the regional level influenced cereal aphids, slugs and key pests of oilseed rape (i.e. pollen beetles and stem weevils). Slugs which are less host specific, were not impacted by the proportion of grasslands and were primarily driven by weather patterns. Cereal aphids, and oilseed rape pests, on the other hand, decreased in abundance as the proportion of grass increased, thus indicating that grass leys in rotations could help suppress host specific pests (Courson et al., 2022). We assume that the proportion of grassland in a landscape provides a proxy for an increase in grass leys within arable rotations, however, the study focussed on a range of landscapes not simply arable landscapes. No studies were found that directly explored either the impact of arable-ley rotations or livestock integration on pests or natural enemies indicating the need for research in this field.

3.5.2 Impacts of Arable/ley rotations and livestock integration on weeds

The wider literature indicates that livestock integration can be a valuable tool in managing herbicide resistant weeds such as black-grass (Schut et al., 2021). A recent study by SRUC indicated that winter grazing of cereals typically has no impact on weed abundance, although there is some indication that grazing winter cereals in the early autumn may increase weed abundance (R Walker, personal communication).

3.5.3 Impacts of Arable/ley rotations and livestock integration on diseases

The RAE did not identify any literature on the impact of arable leys rotations on disease, although there are benefits from diversifying and extending crop rotations in general. The research by SRUC which collected data from farmer's fields has indicated that the impact of winter grazing by sheep on disease levels in the arable crop is variable (R Walker, personal communication). There was no significant effect for oilseed rape diseases or mildew in cereals. In contrast, the cereal diseases of rust and septoria were reduced by grazing.

3.6 Use of Nitrogen-fixing crops

Grain legumes and forage legumes are nitrogen-fixing crops that can be incorporated into crop rotations. Thus, this measure overlaps with many other options including reducing the reliance on synthetic fertilisers, intercropping, diversification of rotations, and the incorporation of leys or winter cover crops into arable systems.

Figure 3: Crimson clover

3.6.1 Impacts of Nitrogen-fixing crops on pests and natural enemies

Our search terms did not identify any literature on the impact of nitrogen-fixing crops on pests and natural enemies. Nitrogen-fixing crops such as field beans are likely to act as a break crop disrupting pest life cycles and reducing pest burdens. Additionally, through fixing nitrogen, the reliance on inorganic fertilisers by the crop and the following crop is reduced with indirect impacts on pests (see above). Increasing their prevalence in the landscape is, however, likely to result in an increase in the pests that specialise on these species, and while most species are relatively host specific some can also impact on other crops (e.g. potatoes and *Ditylenchus* *dipsaci*). Pests of beans include the black bean aphid (and associated viruses), stem-bulb nematodes *Ditylenchus dipsaci* and *Ditylenchus gigas,* bean seed beetle (*Bruchus rufimanus*), and pea and bean weevil (*Sitona lineatus*) (Processors and Growers Research Organisation, 2024; Musa, 2021). Pea pests include pea aphid *(Acyrthosiphon pisum)* (and associated viruses), pea and bean weevil, pea midge (*Contarinia pisi*) and pea cyst nematode (*Heterodera gottingiana*) (Processors and Growers Research Organisation, 2024). Including nitrogen-fixing crops in rotations can therefore present land managers with new pest challenges. Control measures will vary depending on the crop and pest in question. For example, clean seed and avoiding contaminated fields is crucial in controlling stem bulb nematodes while deep ploughing is recommended for pea midge (Processors and Growers Research Organisation, 2024; AHDB, 2024).

The impact of nitrogen-fixing crops on natural enemies will depend on a range of factors including flower structure and whether the crop is permitted to flower (Cole et al., 2022). The inclusion of nitrogen-fixing crops as a cover crop will provide living roots and soil coverage during winter, however, as these crops are typically destroyed before flowering, they will not provide floral resources for natural enemies such as hoverflies and parasitic wasps (Cole et al., 2020). In providing habitat and ground cover, under-sowing cash crops with nitrogen-fixing crops could also provide resources for natural enemies. Both social and parasitic wasps have been observed foraging on the extra-floral nectaries of winter vetch (L Cole – personal observation) providing an interesting avenue for future research (Jones et al. 2017).

3.6.2 Impacts of Nitrogen-fixing crops on weeds

The rapid assessment did not find any papers relating to the direct impact of nitrogen fixing crops on weeds.

3.6.3 Impacts of Nitrogen-fixing crops on diseases

The rapid assessment did not find any papers relating to the direct impact of nitrogen fixing crops on diseases. As with pests, increasing the prevalence of nitrogen fixing crops will likely see a surge in their associated diseases posing a risk not just to cash crops such as field beans and peas, but also other crops that are susceptible to these diseases. For example, it is known that clover can be attacked by one of the species in the *Sclerotinia* complex but it is believed that the fungus is quite specific and will not cross-infect other crops. Some farmers may not be familiar with these diseases and as such we need to raise awareness of the symptoms, infection sources, factors that enhance risk alongside management actions to reduce risk.

The biggest threat of including new crops in rotation will come from soil borne pathogens with a long survival rate in soil (*Aphanomyces* root rot) and those which attack many crop species. For example, *Fusarium culmorum* attacks bean and pea crops and is also a major cause of root and ear disease in cereal crops. Control of these diseases will rely on rotation and the use of resistant varieties.

While some actions are likely to be universally beneficial (e.g. certified seed/testing) others will depend on context and actions to reduce one disease risks could increase another. For example, while winter beans are more susceptible to chocolate spot, they are less susceptible to wilt disease.

3.7 Diversify crop rotation and break crop rotation period

Monocultures are particularly vulnerable to outbreaks of pests, weeds and diseases. As our climate changes, our cropping systems are likely to become more vulnerable to such pressures.

For example, milder winters could increase the likelihood of pest species surviving overwinter and/or result in their earlier emergence. We may experience new pests, or pathogens, and this could be exacerbated by a reduction in the availability and effectiveness of chemical control measures. Increasing the diversity of crops in the rotation will build resilience and the inclusion of nitrogen-fixing crops such as field beans or peas will provide a nutrient building phase. Root crops, such as potatoes, are an economically important crop in Scotland. However, as they typically involve a high level of soil disturbance increasing the period between such crops in a rotation can help improve soil health. Overall, diverse crop rotations are likely to reduce the need for synthetic inputs, improve soil health, and provide a greater diversity of outputs.

3.7.1 Impacts of diversified crop rotations and increasing break crop rotation period on pests and beneficials

Research exploring the impact of crop diversity on pests was lacking, with only one landscape scale study that explored the impact of diverse crop rotation, and area of pest host crops in the landscape on the prevalence of cabbage pests (Scheiner & Martin, 2020). This study found that crop rotation diversity had no impact the abundance of key pests (i.e. aphids, flea beetles and lepidopteran caterpillars).

Diverse crop rotations provide a wider variety of niches and alternative prey items and thus may be expected to enhance natural enemies. The research, however, was inconsistent with impacts of diversified crop rotations varying between studies and taxa. Scheiner & Martin, (2020) found that landscapes with higher crop rotation diversity had higher rates of aphid parasitism indicating positive impacts on parasitoids (Scheiner & Martin, 2020). Puliga et al. (2021), on the other hand, found no impact of rotational diversity on the abundance of spiders and carabids, nor impacts on predation rates. Lack of impact could be due to crops included in the rotation having similar functional traits, highlighting that considering functional trait diversity within rotations could optimise the benefits gained (e.g. nitrogen-fixing crops, grass leys).

3.7.2 Impacts of diversified crop rotations and increasing break crop rotation period on weeds

Regardless of the inputs of fertiliser and synthetic pesticides, moving from a monoculture to a diversified crop rotation increased the number of dicot weeds (Schwarz, 2018). However, there is limited evidence of the effect of crop rotations on weeds. It is likely that the greatest benefits will be achieved where rotations select crops with very different cultivation timings, challenging weeds by providing different growing conditions each year (Riemens, et al. 2021). Liebman and Dyck's (1993) review indicated that more diverse rotations typically suppressed weed densities. This concurs with more local experience in Scotland where cereal dominant rotations are linked to an increase in grassweed pressure, particularly in oat crops where herbicide options are limited.

3.7.3 Impacts of diversified crop rotations and increasing break crop rotation period on diseases

Rotations break disease life cycles and therefore should help to protect crops. The inclusion of break crops or adopting a diversified rotation could reduce soil and trash borne disease for wheat crops compared to a continuous cereal rotation (Winter et al., 2014). Introducing a root crop was shown to reduce soil fungal biodiversity and this also included fungi antagonistic to crop diseases (Mielniczuk et al., 2020). The situation was not as clear cut for oilseed rape, where a trash borne and a foliar disease were reduced but other foliar diseases increased following a 4-year break from oilseeds (Cwalina-Ambroziak et al., 2016). Clubroot is prevalent in Scottish arable soils but is an example where extended rotations are known to be beneficial in reducing the disease.

3.8 Enhancement of existing hedgerows

Targeting the quality of the hedgerow is a measure that aims to enhance the biodiversity and carbon value of hedgerows in arable landscapes. Hedgerows provide shelter, nesting sites, and forage for a range of species. Acting as ecological corridors that connect pockets of semi-natural habitats; hedgerows play a key role in helping the SG deliver its vision of creating nature networks throughout Scotland.

3.8.1 Impacts of enhancing existing hedgerows on pests and natural enemies

Research indicates that the impact of hedgerow enhancement on pests varied with taxa (Courson et al., 2022; Fusser et al., 2017; M. Ramsden et al., 2017; Tougeron et al., 2022). The prevalence of aphids (Courson et al., 2022; M. Ramsden et al., 2017; Tougeron et al., 2022), or oilseed rape pests (i.e. stem weevil and pollen beetle: Courson et al., 2022) were not impacted by the presence of hedgerows. However, higher incidences of slug damage were recorded in landscapes with a higher proportion of hedgerows (Courson et al. 2022). In agreement with these findings, slugs were more abundant in cereal fields adjacent to hedgerows than those adjacent to grassy field margins (Tougeron et al., 2022). However, Fusser et al. (2017) found impacts were not consistent across slug species, with *Arion* spp. being more abundant in fields bounded by hedgerows while the grey field slug *Deroceras reticulatum* was not influenced by boundary type. Tougeron et al. (2022) found that impacts of hedgerows on slugs tended to diminish towards the field centre indicating adverse impacts are restricted to the outer field edges. Contrasting findings across taxa can, in part, be explained by differences in ecology. In contrast to slugs which are generic feeders, aphids and stem weevils are host specific and hedgerows are unlikely to provide suitable alternative host plants for them. Slugs are also very susceptible to desiccation and hedgerows may provide harbourage during dry periods. It is possible that the grey field slug, which is the most abundant species in arable fields is more adapted to seeking refuge in fields.

Figure 4: Hedgerow

The rapid evidence assessment highlighted several studies that explored the impact of hedgerows on natural enemies. When exploring predation rates, or the role natural enemies played in herbivore suppression, positive impacts of hedgerows were found (Ferrante et al., 2024; Lajos et al., 2020). Impacts on specific taxa, however, varied between studies, crops and the taxa under investigation, and no study found hedgerows increased the abundance or richness of key taxa. Natural enemy abundance (Puliga et al., 2023), parasitic wasp abundance (Tougeron et al., 2022), predatory wasp abundance (Holzschuh et al., 2009) and ground beetle richness (Fusser et al., 2017; Pecheur et al., 2020; Tougeron et al., 2022) were not influenced by the presence of hedgerows. Both neutral (Fusser et al., 2017) and negative impacts (Pecheur et al., 2020; Tougeron et al., 2022) were, however, found for ground beetle abundance with impacts varying between crops and functional groups (Aviron et al., 2018). Negative impacts of hedgerows were also found for spider abundance and richness (Tougeron et al., 2022). It is, however, important to note that these surveys focussed on the peak activity period (i.e. April to September) and thus did not explore the value of hedgerows as an overwintering habitat. This value was highlighted in a study by (Mestre et al., 2018) who found greater densities and richer communities of spiders overwintering in hedgerows when compared to arable fields.

3.8.2 Impacts of enhancing existing hedgerows on weeds

No papers were found that described the effect of hedgerows on weeds. Nevertheless, a study in Brittany suggested that the enhancement of hedgerows has no significant impact on troublesome weeds, although there is an indication that wider field margins will reduce the area of these weeds (Boinot & Alignier, 2022). Troublesome weeds are those weeds that could potentially reduce yields, increase the impurities in the yield or lead to harvesting problems.

3.8.3 Impacts of enhancing existing hedgerows on diseases

No papers were found describing the impact of hedgerows on diseases. Nevertheless, the evidence from the grey literature suggests that structurally sound hedgerows offer some protection from adverse weather, particularly strong winds. Hedges could protect crops with stem-based diseases, which are prone to bending and lodging leading to harvest problems, from these strong winds. Conversely, local experience suggests that some foliar pathogens such as yellow rust can be more favoured in sheltered field margins. There is no evidence to suggest that hedgerows have a positive impact on earthworm populations (Prendergast-Miller et al., 2021).

3.9 Retain and enhance in-field biodiversity cropping and features

This measure includes field margins, beetle banks, and wild bird cover. The search terms included in our rapid evidence assessment aimed to capture the breadth of biodiversity enhancing measures included in this option (see search term in Annex 1 for details). However, the research identified primarily focussed on field margins (i.e. both floral-rich pollinator strips and grassy margins).

3.9.1 Impacts of retaining and enhancing in field biodiversity cropping and features on pests and beneficials

A recent global meta-analysis found that when compared to grassy margins, floral-rich field margins had lower abundances of invertebrate pests and reduced pest damage (Crowther et al., 2023). In agreement with this meta-analysis, Woodcock et al. (2016) reported floral-rich margins were more effective at reducing in-field aphid populations than grassy margins. In contrast, Török et al. (2021) found higher abundances of aphids (but not cereal leaf beetle larvae) in fields with floral-rich margins than those without margins, indicating a potential disservice. Floral-rich field margins were also found to support higher slug densities compared to heavily mown grassy margins, indicating floral margins provided resources such as harbourage and detritus (Eggenschwiler et al., 2013). Grassy field margins, however, are not typically frequently mown in Scotland and harbourage and detritus are likely to be similar to floral-rich margins. Impacts (i.e. both positive and negative) were largely constrained to the margin or outer crop edge and diminished towards the field centre (Eggenschwiler et al., 2013; Woodcock et al., 2016), thus indicating impacts on pest populations may not necessarily result in significant yield declines.

When it comes to natural enemies, a global meta-analysis found floral-rich margins supported higher natural enemy populations than grassy margins (Crowther et al., 2023). A second meta-analysis focused on North America, Europe and New Zealand found floral-rich strips (but not hedgerows) increased pest control services in adjacent fields by, on average, 16% (Albrecht et al. 2020). Several studies (Török et al., 2021; Tschumi et al., 2016) showed the impact of field margins on natural enemies tended to be either neutral or positive. Fields with floral-rich margins had higher abundances of spiders (Török et al., 2021), lacewings (Török et al., 2021; Tschumi et al., 2016), ladybirds (Török et al., 2021), and hoverflies (Török et al., 2021;Tschumi et al., 2016). Tschumi et al. (2016), found that increased pressure from natural enemies reduced aphid populations. However, Török et al. (2021) found higher aphid populations in fields with floral-rich margins indicating that elevated natural enemy populations were failing to control aphids.

There was evidence that the impact of margin type (i.e. grassy versus floral-rich) differed between natural enemy functional groups. Canopy active natural enemies benefited from floral-rich margins (e.g. parasitic wasps, and hoverflies) (Mansion-Vaquié et al., 2017; M. W.

Ramsden et al., 2015; Woodcock et al., 2016), whereas ground active natural enemies (e.g. ground beetles, rove beetles and wolf spiders) were either not impacted (Anjum-Zubair et al., 2010; Rischen et al., 2022; Woodcock et al., 2016) or were more abundant in grassy field margins (Mansion-Vaquié et al., 2017). Differences can be attributed to the resource requirements, with parasitic wasps and hoverflies reliant on floral resources as adults, while ground beetles and spiders utilise undisturbed grassy margins as overwintering habitat (Ganser et al., 2019; Mestre et al., 2018; Sarthou et al., 2014). With some natural enemies using field margins as overwintering habitat, annually ploughed floral-rich margins and wild bird cover could act as an ecological trap (Ganser et al., 2019; Pecheur et al., 2020). To reduce the need to replant, management to prolong the life of floral strips (e.g. mowing and inclusion of yellow rattle a hemi-parasite of grass) is recommended.

Figure 5: Floral-rich and grassy field margins

3.9.2 Impacts of retaining and enhancing in field biodiversity cropping and features on weeds

No papers were found in the rapid evidence assessment describing an impact of field margins on weeds. In wider literature, there is evidence from France that field margins will increase the predation rate of weeds seeds (Petit et al., 2023), and hence are likely to reduce the weeds in the arable crop.

3.9.3 Impacts of retaining and enhancing in field biodiversity cropping and features on diseases

No papers were found in the rapid evidence assessment describing an impact of field biodiversity on disease.

3.10 Inter-cropping, under-cropping and mixed cropping

This category includes variety mixtures of the same species, intercrops of two or more species, understories sown as living mulches, and companion crops sown alongside the main crop.

3.10.1 Impacts of inter-cropping, under-cropping and mixed cropping on pests and natural enemies

Several studies identified that intercropping reduced pest populations, in particular this was demonstrated for aphids (Lopes et al., 2015), nematodes (Boetzl et al., 2023) and key oilseed rape pests (i.e., cabbage stem flea beetle, cabbage stem weevil and pollen beetle: Breitenmoser et al., 2022). No impact was, however, found for cereal leaf beetles (Boetzl et al., 2023). Impacts varied depending on the crop species combination, with cereal-oilseed intercrops (i.e. wheat, oats or rye sown with oilseeds) tending to be more effective at reducing flea beetle populations than planting berseem clover-oilseed combinations or trap crops of turnip rape (Seimandi-Corda et al., 2024). Wheat-pea intercrops supported lower abundances of aphids than straight pea crops, although abundances in the intercrop were similar to straight wheat crops (Lopes et al., 2015). Scottish field trials undertaken as part of the trans-European project DIVERSify (Designing InnoVative plant teams for Ecosystem Resilience and agricultural Sustainability) found that when compared to monocultures, aphid infestations were suppressed in the pea component of a pea/barley intercrop but were more abundant in the barley component, suggesting that effects can vary between the component crops. With intercrops directly impacting on the biomass of host plants, reduction in pests could simply be due to differences in plant biomass.

There was a lack of consensus regarding the impacts of intercropping on natural enemies and impacts varied between functional groups, crops and mixtures. Under-sowing oats with clover did not influence ground beetles, rove beetles or predatory nematodes, however, negative impacts on spider populations were found (Boetzl et al., 2023). Contrary to this, Puliga et al. (2023) found wheat-pea intercrops supported higher abundances of ground active predators (i.e. spiders, ground beetles) and natural enemy predation rates than straight wheat crops. Hoverfly trends differed between crop type and between intercrops planted as mixes and as strips. Hoverflies were more abundant in wheat-pea intercrops established as a mix than straight pea crops, but not straight wheat crops. On the other hand, wheat-pea intercrops established in alternating strips supported similar hoverfly abundances to straight pea crops, but fewer hoverflies than straight wheat crops (Lopes et al., 2015). This study found that the highly mobile ladybirds and hoverflies were primarily driven by the abundance of aphids and were simply attracted to areas of high aphid densities (Lopes et al., 2015).

3.10.2 Impacts of inter-cropping, under-cropping and mixed cropping on weeds

There is limited evidence of the impact of living mulches and companion cropping on weeds. Living mulches typically have no impact on the weed biomass (Boetzl et al., 2023; Lorin et al., 2015). Although companion cropping reduced weeds and increased crop yield relative to weeding, it was less effective than spraying with an herbicide (Gruszecki et al., 2015). Findings of DIVERSify indicated that intercropping peas and beans with cereals suppressed weeds and resulted in high-yielding crop mixtures (Karley et al., 2019).

3.10.3 Impacts of inter-cropping, under-cropping and mixed cropping on diseases

One older study looking at pea-wheat intercrops found reduced levels of Ascochyta in pea crops on stems and pods but similar levels on stipules (Schoeny et al., 2010). A more recent study from Sweden showed that undercropping clover with oats had no effect on root disease levels (Boetzl et al., 2023). A meta-analysis of the effect on disease of intercropping faba bean and cereal focussing on research conducted in China, found a significant reduction in yellow rust and mildew in wheat and chocolate spot and Fusarium wilt in faba bean (Zhang et al, 2019). In the same study, there was an indication that yellow rust in barley also declined, but there was no impact on bean rust. Mixtures of cereal varieties typically reduce disease levels in the crop (Newton and Guy, 2009).

Figure 6: Vetch/Field bean intercrop

3.11 Silvo-arable systems

Silvo-arable systems are systems where the crops are grown beneath trees, which are planted in wide alleys. Fruit trees, trees grown for medicinal purposes or for biomass production can be part of a silvo-arable system.

3.11.1 Impacts of silvo-arable systems on pests and beneficials

Our rapid evidence assessment only identified two research papers exploring the impact of silvo-arable systems on pests and natural enemies. Boinot et al. (2019b) reported that integrating trees reduced the abundance of a range of pests including aphids, click beetles and slugs, with only snails bucking this trend. Contrary to these results, Smits et al. (2012) found silvo-arable fields had no impact on aphid populations. This study, however, had low replication (3 fields) and the straight wheat treatments were adjacent to agroforestry treatments. Mobile species such as aphids and their predators operate beyond the field scale and consequently impacts at the field scale are less likely to be detected.

The impact of silvo-arable systems on natural enemies varied between taxa and studies. Boinot et al. (2019b) found canopy active predators (i.e. ladybirds, wasps and lacewings) and spiders benefitted from silvo-arable systems with the undisturbed vegetation along the agroforestry strip providing overwintering habitat. Contrary to these findings, Smits et al. (2012) found no impact on populations of canopy active predators (i.e. ladybirds, lacewings and hoverflies). Although, as mentioned above, lack of replication and the proximity of agroforestry and straight wheat plots means these results should be interpreted with caution. Abundances of ground beetles and rove beetles were greater in the cropped field than the agroforestry strip

(Boinot, Poulmarc'h, et al., 2019). Trends, however, differed between species, with carabid species that are sensitive to agricultural disturbance more abundant in the agroforestry strips.

3.11.2 Impacts of silvo-arable systems on weeds

No papers were found that explored the impact of silvo-arable systems on weeds. A meta-analysis of silvo-arable systems in Europe and North America sourced only two papers that assessed weeds (Kletty et al. 2023). The study conducted in France, showed that there was no difference between an arable system and a silvo-arable system for conventional cropping systems, but weed cover was reduced in organic silvo-arable systems (Boinot, Fried, et al., 2019). However, in a silvo-arable system in the UK, weeds increased (Staton et al., 2021).

3.11.3 Impacts of silvo-arable systems on diseases

No papers were found in the REA describing an impact of silvo-arable on disease.

3.12 Water margins

The main purpose of this measure is to protect watercourses from pollution. The permanent vegetation intercepts soil borne pollutants mitigating diffuse pollution. Additionally, water margins provide habitat for a range of species and can provide ecological corridors through the farmed environment. In this respect, water margins share many of the characteristics of in-field margins.

3.12.1 Impacts of water margins on pests and natural enemies

Research exploring the impact of water margins on pest populations in arable systems was lacking and only a single paper explored their impact on natural enemies. This paper found that the presence of water margins increased the diversity of ground beetles, but did not impact on abundance. While research is lacking, water margins will provide similar resources to non-riparian field margins including floral resources (Cole et al. 2015) and overwintering habitat (Cole et al. 2020) and as such we may expect similar impacts on natural enemies and pest populations.

3.12.2 Impacts of water margins systems on weeds

No papers were found in the rapid evidence assessment describing an impact of water margins on weeds. However, it is expected that the effect of water margins on weeds will be similar to non-riparian field margins.

3.12.3 Impacts of water margins systems on diseases

No papers were found in the rapid evidence assessment describing an impact of water margins on disease.

4 Farmer perception of the impact of the policy reforms on plant health

4.1.1 The views of the farmers

Farmers perceptions regarding plant health threats for eight of the policy reforms were gathered through surveys (Annex 3). The policy reforms considered were i) diversified crop rotation, ii) winter cover crops, iii) minimum tillage, iv) nitrogen fixing crops, v) arable/ley rotations, vi) intercropping, vii) enhancing field biodiversity and viii) enhancing hedgerows. These surveys were distributed at three farmer events in Fife, Aberdeenshire and Angus.

The measure with the greatest expectation of improving the management of pest problems was diversifying crop rotation (Figure 7). There was also a belief that arable/ley rotations, intercropping and more habitat for wildlife would improve pest control. In contrast, a switch to minimum/no tillage was considered likely to increase pest issues in crops. For weed problems, the measure with the greatest potential to control weeds was again diversifying crop rotation, with arable / ley rotations close behind. In general, there were more neutral responses in terms of weed issues (Figure 8). As with pests, a switch to minimum/no tillage was expected to pose the biggest risk with respect to weeds. With respect to plant disease, farmers perceptions were similar to pests and weeds, with diversifying crop rotation seen as having the most potential to control diseases (Figure 9). Nitrogen fixing crops, arable / ley rotations and intercropping were also seen in a very positive light. A switch to minimum tillage remained the greatest concern amongst farmers, although responses relating to disease were more neutral than pests or weeds.

4.1.2 Willingness to uptake

To explore the willingness of arable farmers to uptake specific agroecological approaches, we drew on data derived from previous workshops held in January 2024. Workshops formed part of the AHDB/FAS Agronomy Roadshows held in the Borders, Perth and Kinross and Aberdeenshire (January 2024), thus providing a good geographical spread of participants. Over 90 people participated in the workshops with approximately 30 participants at each location. Participants were primarily arable farmers, but also included advisors, and suppliers.

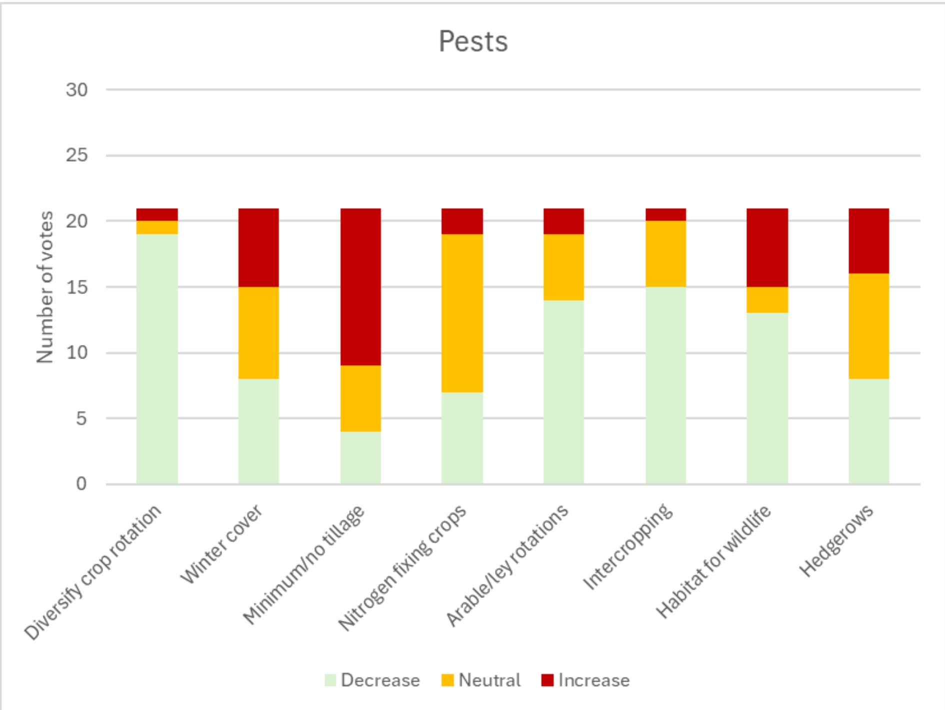

Figure 7: Farmer perception of pest threats

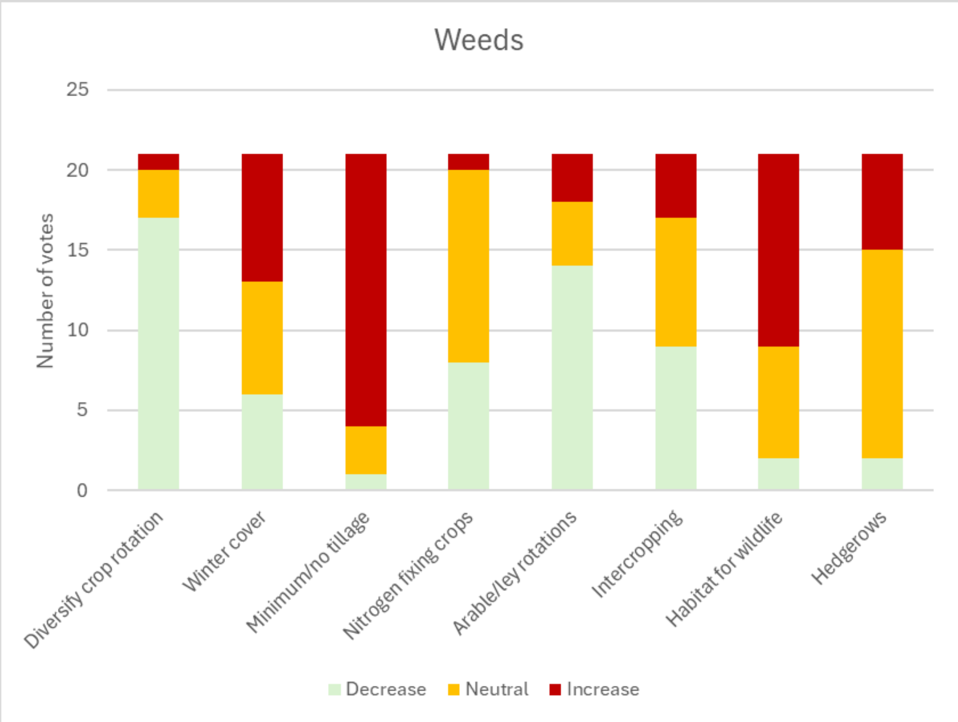

Figure 8: Farmer perception of weed threats

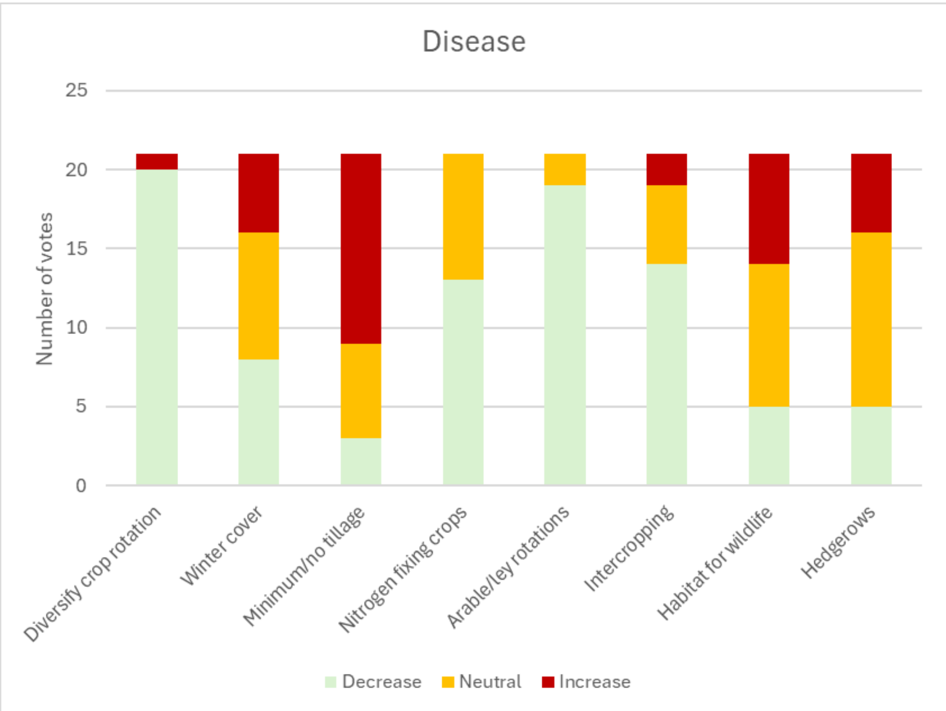

Figure 9: Farmer perception of disease threats

During each workshop, participants were asked to hold up coloured cards to demonstrate their willingness to implement eight measures (winter cover, diversified crop rotations, nitrogen-fixing crops, minimum/no tillage, intercropping, livestock integration, enhanced hedgerows and pollinator strips). Green cards indicated that the participant was already implementing the measure, amber cards indicated a willingness to implement the measure, and red indicated that the measure would not fit their farming system.

Farmers were typically either already implementing the measures explored or were willing to consider implementing them (Figure 10). Participants reported least resistance to the uptake of pollinator strips, diversified rotations and nitrogen-fixing crops. This indicates these measures could have the greatest uptake and consideration should be given to their plant health risks. Participants showed greatest resistance to intercropping in all regions (primarily due to difficulties in processing intercrops for high commodity markets).

Some regional differences in willingness to uptake were observed and these could largely be aligned with the current farming system (e.g. livestock integration had least resistance in Perth and Kinross where mixed farming systems are still common), or environmental conditions (e.g. less resistance to reduced tillage in the Borders). To ensure a just transition, it is important that geographical differences (e.g. topography, land capability and climate) that impact on the feasibility of implementing these measures are considered. Involving farmers and stakeholders in the regional tailoring of policies was a key recommendation of the Scottish Government's (2018) *Future Strategy Report* and our findings highlight that this is relevant to the implementation of enhanced conditionality.

With many arable farmers planning crop rotations five years or more in advance, there was considerable concern over the lack of clarity on how the proposed Tier 2 support would be administered. The costs of transitioning were frequently mentioned as a barrier to implementation. It was clear that while farmers generally demonstrated willingness to consider implementing changes, that this would clearly depend on financial returns and in some instances capital investment requirements (e.g. changes to farm infrastructure to permit livestock integration, direct drill machinery). Farmers also highlighted the importance of flexibility, for example measures may not be viable across all fields/crops on a farm and thus a whole farm approach to implementation would not be appropriate. For example, cover crops may be more difficult to implement in fields with heavy soils, or reduced tillage would not be viable in potato fields. Implementing these measures over a certain percentage of the farm would provide flexibility and ensure viability. Additionally, farmers should be permitted to adapt what they do in response to weather conditions (e.g. it may not be viable to implement cover crops if harvest is delayed). It is important to recognise that farmers that attend such stakeholder events tend to be more forward-looking and consequently workshop outcomes may not reflect the view of the wider population of arable farmers across Scotland.

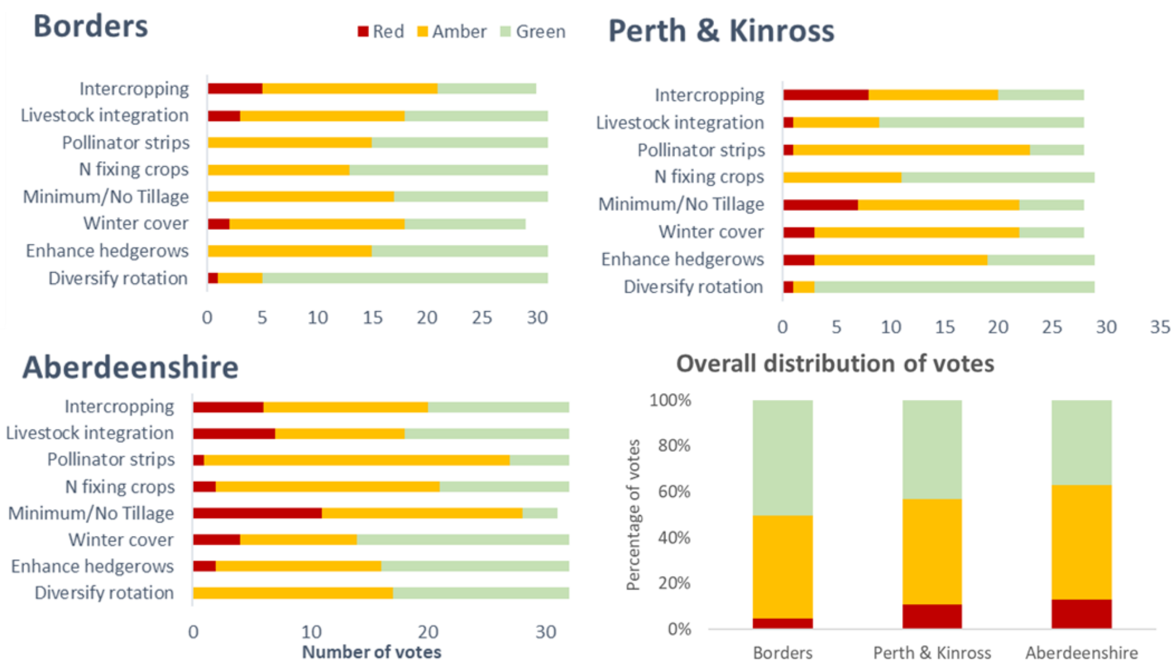

Figure 10: The willingness of farmers to implement the measure (green – already implementing, amber indicated a willingness to implement the measure, red not fit for their farming system.

5 Potential regulatory options

With changes in agricultural practices driven by policy reform, it is reasonable to assume that the risk posed by some pests and diseases may change, and that plant health regulations may need to be revised to address this. These regulatory changes may be relevant for changes in statutory, basic or enhanced practices.

This project engaged with SASA (the relevant Plant Health Authority in Scotland) which regulates on pesticide use, and supports farmers with IPM, to clarify what changes the proposed agricultural reform may have on plant health risks.

These conversations revealed that it is not foreseen that the proposed agricultural reform measures will require changes to the plant health frameworks already in place, e.g., import regulations (including for seed sowing), plant passports and phytosanitary certificates, plant health authorisation (licences and registration for professional operator status), seed and soil testing requirements, protected zone status, quarantine pests and pathogens lists, annual surveying requirements, and outbreak contingency planning.

It is expected that current regulations are sufficient to enable farmers to manage potential changes in plant health risks through continued IPM approaches once the proposed agricultural reforms have come into practice (e.g., pesticide regulations (EPRS, 2018)). In the unlikely event that there is a negative impact on plant health due to the measures, this would be detected through current pest, weed and disease surveillance and a review would be triggered explore drivers and identify solutions.

6 Discussion

The evidence from the REA was inconclusive for impacts of many of the proposed Agricultural Measures on plant health, Table 1. Furthermore, it is worth noting that in many cases, the evidence was limited and varied between studies, taxa and crops. In some cases, the evidence would suggest that the measure is potentially positive for one type of natural enemy or pest but could have negative impacts on others. Equally, the evidence suggests similar conclusions for diseases. The overall outcome will be dependent on the ecological interactions between the crop and the pest, natural enemy, weed or disease that take place and the importance of these interactions on plant health. It should be recognised that some of the measures will be implemented as a package, and therefore there will be interactions between individual measures, which may be positive or negative. The results of the REA also suggest that field management, crop choice, soil, climate interactions will all affect the overall impact of both the success of the measure and the effect the measure has on plant health.

Several measures (e.g. nitrogen-fixing crops and cover crops) could result in farmers growing new crops and consequently encountering unfamiliar pests, weeds and diseases. Increasing awareness in recognition, life-cycles, factors impacting risk, and building knowledge on actions to mitigate risks are key. Control measures will vary depending on both crop and plant health risk and while some actions are likely to be universally beneficial (e.g. certified seeds, removal of plant trash) others will depend on context and actions to reduce one risk could increase another. For example, while winter sown beans reduce risk of black bean aphid the susceptibility to chocolate spot is increased. Actions to mitigate risks will therefore be context specific depending on local risks and factors that impact those risks (e.g. previous crop, weather conditions).

The farmers surveyed had diverse opinions as to whether the measures would have positive or negative impacts on animal pests, weeds and diseases, and enterprise viability. Nevertheless, in general, the farmers view diversified crop rotation and the incorporation of leys into arable systems as likely to reduce the incidence of pests, weeds and diseases. They also thought that while intercropping would reduce pests and diseases, they were less confident of its impact on weeds. However, intercropping and minimum tillage were the options that the farmers were least likely to adopt due to financial implications.

In summary, although the REA was inconclusive, and very case and organism specific, there was no evidence to suggest that the measures proposed would result in obvious or major risks for plant health. Implementation of enhanced conditionality is, however, expected to result in widespread changes to the farmed landscape. Additionally, climate change will impact on the type and extent of crops grown and could increase the risk of new pests, weeds and diseases establishing in the UK (Bebber et al. 2024). Consequently, it is vital that we continue to monitor plant health both at the farm and country level to ensure early detection of emerging threats. This alongside the establishment of best practice will ensure that risks are reduced and identified at an early stage, allowing for mitigation measures to be promptly out in place. The inconclusive evidence would suggest how the management practice is implemented effects the outcome. Therefore, it is important that knowledge exchange and guidance towards best practices is provided to the arable sector to complement the introduction of the proposed measures. Best practices of the measures will need to be provided by the technical advisors/consultants. The advice may be geo-location specific and will be based on existing and developing knowledge. There are also knowledge exchange messages that can be developed where farmer perceptions of risk differ widely from the more inconclusive or neutral findings in the REA. Minimum tillage and habitats for wildlife being two examples where famer perceptions are of increased weed and pest pressures.

Table 1 Impact of measures on plant health identified from the REA[1]

	pests	natural enemies	weeds	diseases
winter cover	+/-[1]	+/=	=/-	+
tillage	-	+/=	+	+/-
reduced fertiliser	=	=	+/=	+/-
replace with organic fertiliser	+/=	=		
reduced pesticides	-		=/-	+
arable/ley rotations	+/=		+/-	=/-
nitrogen fixing crops		+		
diversified rotations	=	+/=	+/-	+/-
hedgerows	=/-	+/-	=	-
in-field biodiversity	+/-	+/=	-	
intercropping	=/-	+/-	=/-	+/=
silvo-arable	+/-	+/-	+/-	
water margins		+		

[1] + represents a positive impact (i.e. decrease in pests, weeds, disease or increase in natural enemies), = represents no change, - represents adverse impacts (i.e. increase in pests, weeds, disease or decrease in natural enemies), blank cells mean that there is no evidence

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Annex 1

Table A1 – Overview of the Scottish Government's list of measures relevant to arable systems.

Package	
Winter cover	Retain stubbles from a combinable crop over the winter. Stubble area to be left ungrazed, unsprayed, and undisturbed before 1 March following harvest. Retaining the stubble helps to protect the soil, retain organic matter, and will improve mitigation and adaptation to the effects of climate change. Leaving stubble until early spring will also allow a variety of arable plants to develop, providing food and cover for insects, birds and small mammals. Implementation could be extended by keeping living roots in the soil using cover crops: plant specific species mix after summer harvest to keep living roots in the soil, thus providing soil cover to prevent damage and erosion, taking up excess nitrogen (catch crop function), providing nitrogen for the next crop (vetch, clover, or other legumes), improving soil structure (deeper rooting species such as rye or tillage radish), providing above ground resources for pollinator insects, birds and small mammals (e.g. radish, buckwheat, brassicas) but also root exudates to feed a diverse soil biodiversity.
Minimum/No Tillage	Minimise soil disturbance, avoid inversion and avoid deep ploughing (if no major compaction or large weed burden) by using a direct drill, discs, or different machinery. This will keep soil structure and its biodiversity, avoid organic matter oxidation and disruption of soil biodiversity. Minimum / no tillage will not be suitable for all soil types or crops, and may be affected by other constraints such as compaction, weed burden etc.
Efficient / Reduced use of inorganic fertilisers and lime	Use your soil analysis recommendation and crop agronomic advice to apply only where and as little as necessary or extenuating circumstances require a dispensation. Apply inorganic fertilisers and lime as per soil analysis and crop requirement with variable rate using precision spreading based on mapping and crop monitoring where available. Implementation could be extended by increase the use of legumes in the rotation, use green manure, use animal manure or livestock grazing, compost and digestate. To protect soil health and water quality and protect habitat conditions for pollinating insects, wild birds and small mammals.
Efficient / Reduced use of synthetic pesticides	Using an Integrated Management approach, you will only apply synthetic pesticides if economic threshold of pest/disease is reached or extenuating circumstances require a dispensation. To protect soil health and water quality and protect habitat conditions for pollinating insects, wild birds and small mammals. Implementation could be further extended by use of GPS enabled technology, where available, to apply variable rates.
Use of N fixing crops	Add legumes such as peas or field beans into the cropping rotation, and other appropriate catch/cover/green manure/soil improver crops including pasture legumes. To improve soil health and water quality and

	improve habitat conditions for pollinating insects, wild birds and small mammals.
Diversify crop rotation and break crop rotation period (esp. for root crop)	Use a number of different crops in an arable rotation depending on soil type and land capability e.g. oilseed rape, peas, beans, vegetables, potatoes, linseed, oats, forage brassica, forage maize, buckwheat. A varied crop rotation can enhance biodiversity, improve soil organic matter and climate impact resilience. Soil erosion is minimised, pest and disease burdens are reduced. Especially, leave a longer break between soil damaging root crops to improve soil recovery (ex: aim for 8 years for potatoes). To improve soil health and water quality and improve habitat conditions for pollinating insects, wild birds and small mammals.
Inter-cropping, under-cropping and mixed cropping (e.g. peas and barley) and avoid monoculture	To avoid monocultures and improve within field species diversity, plant several crops together (mixed cropping ex: peas and barley, to improve protein content of silage in winter feed and decrease the need for purchased protein), undersow cash crops with undercrop (ex: using clover for N fixing, pest protection and outcompete weeds or grass for low input winter grazing), inter-crop cash crop with flowering mix for Integrated Pest Management (IPM) or with any companion crop that can create synergies and improve yield. To improve soil health and water quality and improve habitat conditions for pollinating insects, wild birds and small mammals.
Arable/ley rotations (transition from arable to arable/livestock mix)	Add grass or fodder crops into the cropping rotation to allow introduction of grazing animals on arable land. Can also include use of livestock to graze winter cereals to reduce reliance on synthetic inputs. To improve soil health and water quality and improve habitat conditions for pollinating insects, wild birds and small mammals.
Silvo-arable systems	Plant trees at suitable interval for machinery in arable field to create silvo-arable systems, in order to improve carbon sequestration, minimise soil erosion, improve drainage, support more biodiversity. Species for coppicing, fruits, nuts or timber can provide marketable products will also improve profitability. To improve soil health and water quality and improve habitat conditions for pollinating insects, wild birds and small mammals.
Retain and Enhance in Field Biodiversity Cropping and Features	Options include • Beetle banks • Wild bird cover • Flower rich margins • Grass field margins • Hedgerows
Water Margins	Manage existing fenced and unfenced water margins and buffer strips. Cut or grazed annually to maintain species and structure diversity. If wider than 6m, grazing is possible. To improve water quality, protect ponds and freshwater habitats to benefit insects, fish, and amphibians and create river corridors. Implementation could be extended by unfenced water margins fenced off to exclude stock. Min 6m margins depending on water course width (12m adjacent to still water). Manage to increase diversity of species and structure, as well as connectivity. To improve water quality, protect

	ponds and freshwater habitats to benefit insects, fish, and amphibians and create river corridors.
Enhance existing Hedgerows	Allow hedge to grow to minimum 1.5m height and width and maintain its 2m GAEC margins, Plant 10% of gaps larger than 5m. Leave hedgerow trees to reach maturity and full height every 50-100m. Implementation could be extended by allowing hedge to grow beyond 1.5m height and width and leave hedgerows trees to reach maturity every 50-100m. Widen the margin to minimum 4m on one side. Trimmed once every 2 years in winter. Introduce native trees and shrubs and plant all gaps larger than 5m. Implementation could be further extended by allowing hedge to grow beyond 3m height and width and leave hedgerows trees to reach maturity every 50-100m. Widen the margin to minimum 4m on both sides where practicable. Fence grassland hedge margins. Trimmed once every 3-5 years in winter. Introduce native trees and shrubs and plant all gaps larger than 5m. Connect hedgerows across the farm.

Annex 2

A Rapid Evidence Assessment (REA) approach was adopted to assess the current state of the evidence of the impact of the proposed agricultural reforms on plant health. While a REA is not as comprehensive as a systematic review, the REA is designed to be rigorous, transparent and minimise bias (Barends et al. 2017).

The search used to identify the literature was constrained to post 1999, and was:

> TS=((crop* OR arable OR wheat OR barley OR potato* OR OSR OR oilseed OR cereal*) AND ("plant health" OR disease* OR pest*) AND ((((("Winter cover" OR "winter stubble" OR "cover crops" OR "green cover" OR "green manure" OR "catch crop" OR "soil cover" OR “minimum tillage” OR “conservation tillage” OR “direct drill” OR “reduced tillage” OR “conservation crop*” OR “reduced fertiliser” OR ((reduced OR minimum) AND (synthetic* OR fertiliser OR herbicid* OR pesticid* OR fungici* OR insecticid*)) OR “precision agricult*” OR “nutrient budget” OR “input efficienc*” OR “plant protection product*” OR “nitrogen fix*” OR nitrogen-fix* OR legume* OR clover* OR “field beans” OR peas OR vetch OR “diverse crop rotation*” OR “break crop* OR “diverse rotation*” OR “novel crop*” OR intercrop* OR undersown OR under-crop* OR “plant teams” OR “mixed crop*” OR “under crop* OR “inter crop*” OR inter-crop* OR “livestock integration*” OR “conservation headland*” OR "skylark plot*" OR “alley crop*” OR agroforestry OR silvo-arable OR “conservation mow*” OR “conservation harvest” OR “mowing technique*” OR “machinery width” OR (refuge NEAR/2 harvest) OR “water margin*” OR bufferstrip* OR “buffer strip*” OR “riparian buffer*” OR “flood plain” OR “arable conservation” OR (buffer NEAR/2 wetland) OR “beetle bank*” OR “infield strip*” OR “bird cover” OR “bird seed” OR “cover mix*” OR (bird NEAR/2 forage) OR wildflower OR “nectar mix” OR “pollen mix” OR “pollinator mix” OR “flower-rich strip*” OR “flower-rich margin*” OR “flower strip*” OR “flower margin*” OR “pollinator margin*” OR “pollinator strip*” OR ((grass OR regenerated OR field) AND margin) OR hedge*)))))) NOT ALL=(((USA OR america OR chin* OR asia* OR africa OR brazil OR "south america" OR india* OR mediterran* OR subtropi* OR tropi* OR Thailand OR "ecological status" OR model* OR lab* OR "sewage sludge*" OR biochar OR fish* OR aqua* OR viticul* OR rice OR vine* OR olive* OR millet* OR groundnut OR cassava* OR marine* OR chroma* OR "food securit*" OR "in vitro" OR "in silico" OR sprayer* OR regulat* OR legislat* OR resistance OR software* OR Ecotoxicol* OR "human health*" OR cloth* OR worker* OR employ* OR farmer* OR colorado* OR orchard* OR tomato* OR raspberr* OR strawberr* OR fruit*))) and English (Languages) and IRAN or MEXICO or EGYPT or ARGENTINA or RUSSIA or PAKISTAN or SAUDI ARABIA or SOUTH KOREA or TURKEY or JAPAN or COLOMBIA or ISRAEL or ETHIOPIA or INDONESIA or TAIWAN or BANGLADESH or ECUADOR or MALAYSIA or CAMEROON or CUBA or KENYA or SRI LANKA or TUNISIA or IRAQ or ZAMBIA or VENEZUELA or SINGAPORE orQATAR or U ARAB EMIRATES or PHILIPPINES or NAMIBIA or LIBYA or KUWAIT or KAZAKHSTAN or GHANA or COSTA RICA or ALGERIA or ALBANIA or URUGUAY or PERU or MOROCCO or JORDAN or CHILE or BURKINA FASO (Exclude – Countries / Regions) and NIGERIA or VIETNAM or CANADA or AUSTRALIA or GREECE or NEW ZEALAND or SERBIA or PORTUGAL or ITALY or SPAIN or FINLAND or NEPAL or MOLDOVA or MACEDONIA or NORWAY(Exclude – Countries/Regions)

The search identified 490 potential papers and was conducted on 2 April 2024 in Web of Science. Sources were screened firstly on the basis of title and abstract, then secondly by scanning the full text. At each stage, sources were progressed unless it was apparent that an objective reason existed for it to be excluded from the study (exclusion rule). To be included, the papers had to assess the effect of management practices on an aspect of plant health. Sources were subsequently assessed for suitability. A total of 93 papers were assessed as sufficiently relevant for data extraction and inclusion in the review. In total, 578 lines of data were extracted from the 93 papers. The REA has focused on assessing the direction of change and has not quantified absolute values. In addition, where evidence was lacking, information has been sourced from the grey literature.

Annex 3

The survey was distributed to the farmers at AHDB Strategic Farm (Balbirnie) event (18/June/24), SRUC Kirkton trials evening (27/June/24) and Arable Scotland event (02/July/24)/. Each respondent was asked to consider the effect of one of eight measures on weeds pest and disease problems on their farm. They were asked to select a response to indicate of they considered a change would increase the problem (upwards arrow), have no significant effect (equal sign), or decrease the risk from the problem (downwards arrow).

Help us determine the potential impacts of implementing practices aimed to improve the environment performance of farms

SRUC

Participant information sheet and Consent statement: 15/06/2024 – 31/07/2024

During this roadshow you are being invited to participate in a questionnaire (5 mins). Participation is on a voluntary basis.

The purpose of this study (led by Kairsty Topp, Kairsty.Topp@sruc.ac.uk), funded by the Plant Health Centre, is to identify potential risks and benefits to plant health that may result from the implementation of actions outlined in the Scottish Government's list of measures. The data will help us fill evidence gaps with respect to the agronomic impacts (both positive and negative) of implementing these practices. The findings of this study will be communicated back to the Scottish Government in a report to the Plant Health Centre. This will help to ensure future policy is fit for purpose in the real-world. The findings will be published in a peer-reviewed academic journal.

Please note all information gained within this workshop/questionnaire will be kept strictly confidential and no question will allow you to be identified. Your response will be held in our records for a period of no longer than 5 years and will not be passed on to any third parties. Data collected will be stored securely and will abide by SRUC's data handling and privacy policy. By participating you are consenting to these terms of data storage and use which have been approved by the SRUC's Ethics Committee.

Please tick here to show that you are willing to participate in this anonymous study ☐

Please circle your farm size	< 150 ha	150-250 ha	> 250 ha

Please circle the key crops grown on your farm	Cereals	Oilseed rape	Grain legumes	Field vegetables

Are you involved in any agri-environment schemes (e.g. organic, AECS)	Yes/No
Do you use precision agriculture technology (e.g. variable seed rate, variable applications)	Yes/No

PTO for survey

Help us determine the potential impacts of implementing practices aimed to improve the environment performance of farms

SRUC

For each practice identified below please indicate how you feel the widespread implementation of that practice in arable land would impact on pests, weeds and diseases. Circle the most appropriate icon.

↑ Increases pests/ weeds/diseases.   = No impact on pests, weeds, diseases.   ↓ Decreases pests/ weeds/diseases.

Practices	Pests	Weeds	Diseases
Diversify crop rotation and break crop rotation period: Use several different crops in the rotation. Leave a longer break between soil damaging root crops(e.g. potatoes) to improve soil recovery.	↑ = ↓	↑ = ↓	↑ = ↓
Winter cover: retain stubble over winter and leave undisturbed until 1st March. Could be extended to include cover crops.	↑ = ↓	↑ = ↓	↑ = ↓
Minimum/No Tillage: Minimise soil disturbance, avoid inversion/deep ploughing e.g. using direct drilling where feasible (e.g. no issues with compaction or large weed burden).	↑ = ↓	↑ = ↓	↑ = ↓
Use of Nitrogen fixing crops: Include legumes such as peas or field beans into the cropping rotation, and other appropriate catch/green manures.	↑ = ↓	↑ = ↓	↑ = ↓
Arable/ley rotations: Add grass or fodder crops into the cropping rotation and graze animals on arable land. Can also include grazing livestock on winter cereals or cover crops.	↑ = ↓	↑ = ↓	↑ = ↓
Inter-cropping, under-cropping: Avoid monocultures and improve within field species diversity, plant several crops together, undersown cash crops.	↑ = ↓	↑ = ↓	↑ = ↓
Enhance habitat for wildlife: Beetle banks, pollinator strips, in field trees, etc.	↑ = ↓	↑ = ↓	↑ = ↓
Enhance existing Hedgerows: Allow hedge to grow to minimum 1.5m height and width, plant gaps and leave some trees to reach maturity.	↑ = ↓	↑ = ↓	↑ = ↓

Comments:

This work is funded by The Plant Health Centre

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