Crop protection priorities for grass and forage crops in light of proposed EU pesticide regulations and other changes

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Submitted to:

Mary Vickers (EBLEX)

Elizabeth Berry (DairyCo)

Prepared by:

Sarah Wynn, John Garstang, Peter Gladders, Steve Ellis, James Clarke and Susan Twining

ADAS UK Ltd

Boxworth

Cambridge

CB23 4NN

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Executive Summary

Changing pesticide legislation

Pesticides are an important tool for protecting grass and forage crops. They provide a relatively cheap and efficient way of controlling the major weeds, pests and diseases that affect grass and forage crops. These pesticides are currently under pressure as a result of changing approvals legislation in Europe (revision of 91/414/EEC) and the implementation of the Water Framework Directive (WFD). Other pressures are also being applied in the form of increasingly resistant target organisms and the presence of pesticide residues in food products. These pressures are all leading to potential reductions in the availability of pesticides for the control of organisms harmful to plant health.

This report reviews the most important scenarios that could affect the availability of pesticides for use in permanent grass, temporary grass, white clover, red clover, lucerne, lupins, maize, stubble turnips, kale, forage rape, fodder beet and chicory – it also summarises the impacts of pesticide losses on oilseeds and cereals (from HGCA report) and pulses (from PGRO report). It looks at the effects of the losses of pesticides on the weeds, pests and diseases they control and the resultant level of production and feed value that the crop could achieve.

ADAS experts determined the most important weeds, pests and diseases that affect each of the crops, and the proportion of crops affected by each. This was done through expert knowledge and the use of survey information. For each weed, pest or disease group estimates of total yield impact in ‘business as usual’ and untreated situations were established, on an area weighted basis, using survey information and trials data supported by expert knowledge. ADAS experts then used their knowledge of the weed, pest or disease, supported by any relevant trials information to determine the effects of pesticide losses on yields in each of the scenarios.

It is uncertain as to exactly what the revision of 91/414/EEC will lead to as the final implementation has not been finalised, although there are clear indications that the losses of pesticides will not be as severe as was once forecast. In this report a number of scenarios, based on a PSD (now CRD) report released in December 2008, were assessed to determine the effect on grass and forage crops. After a vote in the European Parliament (13th January 2009), it is likely that the least severe of the four PSD (now CRD) scenarios (scenario 2c) will be close to the final outcome, however, much will depend on final implementation. If scenario 2c is the most likely scenario it would result in the loss of about 23 active ingredients, of which only 20 are approved for use in the UK. Of these 20 active ingredients, 8 are used in the production of grass or forage crops. Of the UK approved actives that are at risk 11 are fungicides, 6 herbicides, 2 insecticides and 1 rodenticide.

The impacts of the revision of 91/414/EEC on grass and forage crops are relatively minor as most of the actives affected are either not widely used or there are alternative actives that can carry out a similar role. It is predicted, however, to have an impact on the production of cereal crops used to feed livestock, as key black-grass control from pendimethalin will be lost. Availability and cost of cereals may be affected due to reduced yields. Where the revision of 91/414/EEC will have a greater impact on grass and forage crops is if there are losses to the Water Framework Directive (WFD) that are in similar areas, so the combination of losses due to revision of 91/414/EEC and WFD may be greater than the losses to the two scenarios in isolation.

The implementation of the Water Framework Directive (WFD) is likely to impact on a number of important active substances. The active substances that are most likely to be affected are those that are used on a large area, such as grass land, and or used at high rates. This makes herbicides particularly vulnerable as large areas of grassland can have high rates of active substance applied to them. As a result, about 10 herbicides are causing concern with relation to the WFD. This includes a number of important, clover safe, actives for the control of broadleaved weeds in grass and legumes (MCPA, MCPB and 2,4-DB). If restrictions or withdrawals for the use of these chemicals occur it could make the control of broadleaved weeds in grassland more difficult, especially if the sward contains clover. The list of chemicals for which there is concern also includes important herbicides for the control of grass weeds in forage crops and oilseed rape (propyzamide, carbetamide and metazachlor). The impacts of the loss of propyzamide, carbetamide and metazachlor, in forage crops would be relatively small on an industry scale. It would potentially make the production of winter forage brassicas more expensive due to higher costs in herbicides and lowered feed value. However, the impacts in the arable sector are far greater with the potential for oilseed rape crops to be hard hit resulting in significant yield reductions, and possibly reduced crop area. The knock on effect of this could be a reduced availability of cheap rape meal to use as a supplementary protein source in livestock rations.

The poor control of weeds, especially black-grass in rape could have implications for its control in cereal crops too. The rape herbicides that are ‘at risk’ from the WFD are currently key tools in resistance management strategies. The loss of them and their ‘cleaning’ potential in rape crops could lead to reduced control of grass weeds in wheat, resulting in lower average yields and corresponding reduced availability of cereals to the stock feed industry.

Many of the insecticides are likely to be at risk from the WFD. As a result there could potentially be very limited options for the control of some pest species. However, very little insecticide spraying actually occurs on grass and forage crops so this is unlikely to have a serious impact upon production. The loss of active substances to the WFD will be additional to any losses from the revision of 91/414/EEC. This could lead to larger impacts when combined as compared to when looked at in isolation.

Other reasons for loss of existing active substances include them failing to achieve Annex 1 listing before end December 2010, concern over residue levels in food or market acceptability, and development of resistance.

Under 91/414/EEC all active substances had to be reassessed for approval onto Annex 1. There are a number of active substances that are still going through this process. These substances have yet to provide sufficient data to meet the criteria required for inclusion in Annex 1. Companies have until June 2009 to provide data for the active substances affected, or they will not be assessed. If active substances are not included in Annex 1 before the end December 2010 they will cease to be approved. Notable active substances affected include a range of older grass weed herbicides, used in the control of volunteer cereals; metaldehyde, used for the control of slugs; and asulam used for the control of bracken.

New products and options will become available. There are some new herbicides (ethametasulfuron), insecticides (indoxacarb, rynaxypyr, cyazapyr & spirotetramat) and fungicides (carboxamides) that are due to come on to the market within the next few years. Provided these pass the new approval requirements they will provide additional options for the control of charlock and cranesbill in OSR. The relatively small usage of insecticide and fungicides in grass and forage crops means that the majority of these new actives will have little influence on these crops.

ES Table 1- Key reasons for change in availability of crop protection options, the major substances at risk, their impact and likely timescale

Measure	Major active substances at risk	Key impacts	Timescale
Revision of 91/414/EEC	pendimethalin linuron	Grass-weeds	2011-2020
	epoxiconazole and some other triazoles	Foliar disease control	2011-2020
Failure to achieve Annex 1 listing	metaldehyde	Slugs	By December 2010
	asulam Older grass weed herbicides	Bracken control in rough grazing Volunteer cereal control	
WFD	propyzamide carbetamide metazachlor	Grass-weeds in forage brassicas (and oilseed rape)	2009 onwards
	metaldehyde	Slugs	Now
	MCPA, MCPB, 2,4-DB, 2,4-D clopyralid glyphosate	Clover safe broadleaved weed control in grassland Thistle control Control of perennial weeds prior to establishment of crop	2009 onwards

The main economic impacts of the important weeds, pest and diseases to the industry, are summarised in Table ES2, whilst Table ES3 summarises the impacts per hectare.

The major impacts are in grassland, because of its large area. Totalled across all grass and forage crops the following potential impacts (£M per year) have been identified:

- Improvements over Business as Usual – assuming no current options are lost
  - Improved disease control in grassland (permanent - £422M and temporary – £292M).
- Losses due to revision on 91/414/EEC
  - Fusarium control in maize (£8.6M)
  - Loss of herbicides minimal on their own, would compound any losses from WFD
- Water Framework Directive – could potentially have the most significant impact:
  - Reduction in clover safe broadleaved weed control (£45M in mixed clover grassland) in increased fertiliser requirements, cost to individual growers of small area crops could be significant
  - Loss of herbicides would result in reduced feed value of forage legumes due to contamination and yield reductions and increased costs – resulting in reduced value of crop ranging from £102/ha in lupins to £250/ha in lucerne

Climate change

With temperature rises of a little over 2^{o}C and warmer drier summers and less cold and wetter winters the impact of climate change on weeds, pests and diseases will be akin to the UK being several degrees of latitude further south. How this is affected by changes in pesticide availability will depend more on future rather than the current pesticide reviews. However where day length triggers a specific problem the timing of the occurrence will remain similar even though the severity may increase with temperature.

The risk of more poaching due to milder conditions allowing longer periods at grass and with more rain, alternating with drier summers may lead to significant increases in *Poa annua* ingress into swards. Even with changes to pesticide availability controlling this problem will remain an issue for grazing management rather than pesticide use.

The warmer weather may increase the contribution legumes can make to UK grassland. Higher temperatures favouring more rhizobial activity, whilst a backdrop of rising energy / carbon prices make nitrogen fixed by legumes a more valuable commodity. These potential benefits make the possible shortage of clover safe herbicides identified earlier of some concern. The scope for stitching-in or oversowing clover needs more research, not only to cover the impact of herbicide losses, but also because of the likely increase in the general value of legumes.

The warmer climate and improvements in maize varieties will increase the scope for grain maize production. This is unlikely to be affected by changes in pesticide availability as the crop is already well support by a stream of modern products developed in warmer climatic regions.

Warming is likely to have pronounced effects on the status, distribution and severity of grassland and forage pests. Grassland may have to contend with increased incidence of attack by stem nematode (*Ditylenchus dipsaci*) and Marsh crane fly (*Tipula oleracea*)), whilst September crane fly (*Tipula paludosa*) may decrease in severity.

Warmer drier conditions for maize establishment should ease the slug burden, but Corn rootworm (*Diabrotica* spp.) and the European cornborer (*Ostrinia nubilalis*) may well increase. *Diabrotica* species have already been found in sporadic outbreaks in the warmer parts of southern England.

Brassica crops face increased threat from peach-potato aphids (*Myzus persicae*), cabbage stem flea beetle (*Psylliodes chrysocephala*) and Diamond back moth (*Plutella xylostella*) amongst a range of pests. Improved weather conditions for the reproduction and survival of pests will increase the need for careful product husbandry to avoid poor control and increasing levels of pesticide resistance developing. The current and future reviews of pesticide options will need to bear this in mind as climate change swings in favour of certain pests.

This report shows there is scope for considerable lost production from grassland due to disease. As this is a complex of different viruses and fungal pathogens occurring at different times and on varying hosts it is both likely to be increased by the anticipated climate changes, and unlikely to be amenable to effective treatment by current pesticides.

Crown rusts (*Puccinia coronata*) on grassland are likely to increase, whilst Dreschlera and *Rhynchosporium* leaf spots are likely to increase in summer, although *Mastigosporium* leaf spots in winter are like to decrease.

On maize the warmer weather will increase Fusarium stalk and cob rots (*Fusarium spp*), eyespot (*Kabatiella zeae*) and widen the range of Northern leaf blight (*Setosphaeria turcica*).

In addition to the increased pests mentioned above Brassica crops will face increased challenges from clubroot (*Plasmodiophora brassicae*), powdery mildew (*Erysiphe cruciferarum*), stem canker (*Leptosphaeria maculans*) and stem rot (*Sclerotinia sclerotiorum*). By way of consolation light leaf spot (*Pyrenopeziza brassicae*) is unlikely to get worse. Increases in wilts (*Verticillium* spp.) and *Phytoplasmas* are likely to add to the general disease burden.

As the climate changes and the pesticide portfolio is continuously reviewed the issue of disease, particularly on grassland will need to be kept under review. Initially at least surveys of the severity of the problem will allow unforeseen increases in losses to be addressed.

ES Table 2. Pesticide losses economic impacts – Loss to industry (relative feed value) £M (cream £100-250M, yellow over £250M)

Losses to industry £M		Weeds			Pests		Diseases						
Crop	Scenario	Grass weeds	BLW	Bracken	Leather Jackets	Frit Fly	All diseases	Rusts (inc Crown rust)	Foliar Diseases	Ergot	Viruses	Leaf Spots	Fusarium
Grass Permanent	Revision 91/414/EEC (2c)	-	-	-	-	-	-	-	-	-	-	-	-
	WFD	-	-61.5	-	-	-	-	-	-	-	-	-	-
	91/414/EEC & WFD	-	-61.5	-	-	-	-	-	-	-	-	-	-
	Untreated	-	-382.7	-267.1	-2.5	-25.3	-422.5	-	-	-	-	-	-
	Business as usual	-	-	-220.9	-2.5	-25.3	-422.5	-	-	-	-	-	-
Grass Temporary	Revision 91/414/EEC (2c)	-	-	-	-	-	-	-	-	-	-	-	-
	WFD	-	-17.3	-	-	-	-	-	-	-	-	-	-
	91/414/EEC & WFD	-	-20.0	-	-	-	-	-	-	-	-	-	-
	Untreated	-	-89.3	-	-10.2	-10.2	-	-147.3	-75.2	-4.5	-70.5	-	-
	Business as usual	-	-	-	-10.2	-10.2	-	-147.3	-69.4	-4.5	-70.5	-	-
White Clover	Revision 91/414/EEC (2c)	-	-	-	-	-	-	-	-	-	-	-	-
	WFD	-	-44.6	-	-	-	-	-	-	-	-	-	-
	91/414/EEC & WFD	-	-44.6	-	-	-	-	-	-	-	-	-	-
	Untreated	-	-44.6	-	-	-	-	-	-16.2	-	-1.3	-	-
	Business as usual	-	-	-	-	-	-	-	-16.2	-	-1.3	-	-
Red Clover	Revision 91/414/EEC (2c)	-	-	-	-	-	-	-	-	-	-	-	-
	WFD	-	-2.2	-	-	-	-	-	-	-	-	-	-
	91/414/EEC & WFD	-	-2.2	-	-	-	-	-	-	-	-	-	-
	Untreated	-	-2.2	-	-	-	-	-	-	-	-	-	-
	Business as usual	-	-	-	-	-	-	-	-	-	-	-	-
Lucerne	Revision 91/414/EEC (2c)	-	-	-	-	-	-	-	-	-	-	-	-
	WFD	-	-	-	-	-	-	-	-	-	-	-	-
	91/414/EEC & WFD	-	-	-	-	-	-	-	-	-	-	-	-
	Untreated	-	-	-	-	-	-	-	-	-	-	-	-
	Business as usual	-	-	-	-	-	-	-	-	-	-	-	-
Lupins	Revision 91/414/EEC (2c)	-	-	-	-	-	-	-	-	-	-	-	-
	WFD	-	-	-	-	-	-	-	-	-	-	-	-
	91/414/EEC & WFD	-	-	-	-	-	-	-	-	-	-	-	-
	Untreated	-	-	-	-	-	-	-	-	-	-	-	-
	Business as usual	-	-	-	-	-	-	-	-	-	-	-	-
Maize	Revision 91/414/EEC (2c)	-	-	-	-	-	-	-	-	-	-	-	-8.6
	WFD	-	-	-	-	-	-	-	-	-	-	-	-
	91/414/EEC & WFD	-	-	-	-	-	-	-	-	-	-	-	-8.6
	Untreated	-151.2	-	-	-	-	-	-	-6.7	-	-	-	-12.6
	Business as usual	-	-	-	-	-	-	-	-5.9	-	-	-	-9.4
Stubble turnips	Revision 91/414/EEC (2c)	-	-	-	-	-	-	-	-	-	-	-	-
	WFD	-	-	-	-	-	-	-	-	-	-	-	-
	91/414/EEC & WFD	-	-	-	-	-	-	-	-	-	-	-	-
	Untreated	-1.1	-1.8	-	-	-	-	-	-1.3	-	-	-	-
	Business as usual	-	-	-	-	-	-	-	-1.3	-	-	-	-
Kale	Revision 91/414/EEC (2c)	-	-	-	-	-	-	-	-	-	-	-	-
	WFD	-	-	-	-	-	-	-	-	-	-	-	-
	91/414/EEC & WFD	-	-	-	-	-	-	-	-	-	-	-	-
	Untreated	-	-	-	-	-	-	-	-	-	-	-	-
	Business as usual	-	-	-	-	-	-	-	-	-	-	-	-
Forage rape	Revision 91/414/EEC (2c)	-	-	-	-	-	-	-	-	-	-	-	-
	WFD	-	-	-	-	-	-	-	-	-	-	-	-
	91/414/EEC & WFD	-	-	-	-	-	-	-	-	-	-	-	-
	Untreated	-	-	-	-	-	-	-	-	-	-	-	-
	Business as usual	-	-	-	-	-	-	-	-	-	-	-	-
Fodder beet	Revision 91/414/EEC (2c)	-	-	-	-	-	-	-	-	-	-	-	-
	WFD	-	-	-	-	-	-	-	-	-	-	-	-
	91/414/EEC & WFD	-	-	-	-	-	-	-	-	-	-	-	-
	Untreated	-6.4	-	-	-	-	-	-	-	-	-	-	-
	Business as usual	-	-	-	-	-	-	-	-	-	-	-	-
Chicory	Revision 91/414/EEC (2c)	-	-	-	-	-	-	-	-	-	-	-	-
	WFD	-	-	-	-	-	-	-	-	-	-	-	-
	91/414/EEC & WFD	-	-	-	-	-	-	-	-	-	-	-	-
	Untreated	-	-13.1	-	-	-	-2.2	-	-	-	-	-	-
	Business as usual	-	-	-	-	-	-2.2	-	-	-	-	-	-

ES Table 3. Loss of value (£/ha) associated with pesticide availability in five scenarios, across forage and feed crops for a range as a result of a range of weeds, pests and diseases. (-£50-100, -£100-200, -£200+ /ha)

Losses to £/ha		Weeds		Pests						Diseases						
Crop	Scenario	Grass weeds	BLW	Leather Jackets	Frit Fly	Wire Worm	Slugs	Flea Beetle	Aphids	All diseases	Rusts (inc Crown	Foliar Diseases	Viruses	Leaf Spots	Soil Borne diseases	Fusarium
	Revision 91/414/EEC (2c)															
	WFD		-10													
Grass Permanent*	91/414/EEC & WFD		-10													
	Untreated		-63	0	-4					-70						
	Business as usual			0	-4					-70						
	Revision 91/414/EEC (2c)															
	WFD		-15													
Grass Temporary*	91/414/EEC & WFD		-18													
	Untreated		-78	-9	-9		0				-129	-66	-62			
	Business as usual			-9	-9		0				-129	-61	-62			
	Revision 91/414/EEC (2c)															
	WFD		-180													
White Clover ****	91/414/EEC & WFD		-180													
	Untreated		-180									-66	-5			
	Business as usual											-66	-5			
	Revision 91/414/EEC (2c)															
	WFD		-554													
Red Clover ****	91/414/EEC & WFD		-554													
	Untreated		-554									-228				
	Business as usual											-185				
	Revision 91/414/EEC (2c)															
	WFD		-250													
Lucerne ****	91/414/EEC & WFD		-250													
	Untreated		-250									-156				
	Business as usual											-156				
	Revision 91/414/EEC (2c)		-20													
	WFD		-20													
Lupins***	91/414/EEC & WFD		-34													
	Untreated		-34										-16	-112		
	Business as usual												-16	-84		
	Revision 91/414/EEC (2c)											-6				-56
	WFD			0	0	0										
Maize*	91/414/EEC & WFD			0	0	0						-6				-56
	Untreated	-990		-1	-1	0	0					-44				-82
	Business as usual			0	0		0					-39				-61
	Revision 91/414/EEC (2c)															
	WFD	-15	-16	0												
Stubble turnips**	91/414/EEC & WFD	-15	-16	0												
	Untreated	-60	-96	0		-1		-10				-70	-15		-10	
	Business as usual			0		0		-2				-70	-15		-10	
	Revision 91/414/EEC (2c)	-21										-75				
	WFD	-43	-37													
Kale**	91/414/EEC & WFD	-43	-52									-75				
	Untreated	-43	-52	0			0	-7	-1			-122	-5		-8	
	Business as usual							-2	0			-54	-5		-8	
	Revision 91/414/EEC (2c)															
	WFD		-44													
Forage rape**	91/414/EEC & WFD		-44													
	Untreated		-44									-36	-5		-1	
	Business as usual											-36	-5		-1	
	Revision 91/414/EEC (2c)										-4	-10				
	WFD		-5													
Fodder beet**	91/414/EEC & WFD		-5								-4	-10				
	Untreated	-1108	-5	0				-1	-1		-87	-52	-20			
	Business as usual							-1	-1		-78	-42	-20			
	Revision 91/414/EEC (2c)															
	WFD															
Chicory ****	91/414/EEC & WFD															
	Untreated		-657							-110						
	Business as usual									-110						

Table ES4 summarises in a matrix the major areas of loss and priorities for EBLEX and DairyCo research and knowledge transfer activities. This table includes the major implications, which we have prioritised using 1-3 scale based on importance and likelihood of success. The relevant research and knowledge transfer opportunities are included.

ES Table 4. EBLEX and DairyCo research and knowledge transfer priorities on grass and forage crops

Crop	Importance to industry	Weeds	Pests	Diseases	R&D priorities	KT priorities
Permanent grass	Large area	1		2	Improve weed management in long-term grass	Improve long-term grassland management
	a high proportion on land that can not be ploughed				Develop tools to ensure total herbicide use in a catchment meets both efficacy and water quality requirements	Promote existing knowledge on herbicide use and water risk to farmers. Link messages on production efficacy with water quality.
					Develop and test opportunities to improve disease control in long-term grass	
Temporary grass	Large area	1	2	2	Improve weed management in temporary grass	Improve temporary grassland management
					Develop tools to ensure total herbicide use in a catchment meets both efficacy and water quality requirements	Promote existing knowledge on herbicide use and water risk to farmers. Link messages on production efficacy with water quality.
					Develop and test opportunities to improve pest and disease control in temporary grassland	
White clover	Reduces N use	1		2	Improve weed management in white clover	Improve white clover management
	Increases growth rates in cattle and sheep				Develop tools to ensure total herbicide use in a catchment meets both efficacy and water quality requirements	Promote existing knowledge on herbicide use and water risk to farmers. Link messages on production efficacy with water quality.
					Develop and test opportunities to improve disease control in white clover	
Red clover	Reduces N use	1		2	Improve weed management in red clover	Improve red clover management
	High protein content silage Good animal performance				Develop tools to ensure total herbicide use in a catchment meets both efficacy and water quality requirements	Promote existing knowledge on herbicide use and water risk to farmers. Link messages on production efficacy with water quality.
	Drought resitant				Develop and test opportunities to improve disease control in red clover	
Lucerne	Drought tolerant	1		2	Improve weed management in lucerne	Promote best practice in weed control in lucerne
					Develop and test opportunities to improve disease control in lucerne	
Lupins	Good protein source	2		2	Improve weed management in lupins	Promote best practice in weed control in lupins
	(replacement for soya meal)				Develop and test opportunities to improve disease control in lupins	
Maize				3	Develop and test opportunities to improve disease control in maize	
Stubble turnips	Fills gap in autumn / winter when grass not growing	3		3	Improve weed management in stubble turnips and share information from other brassica crops	Promote best practice in weed control in stubble turnips
					Develop and test opportunities to improve disease control in stubble turnips and share information from disease control on other brassica crops	
Kale	Winter forage Good growth rates	2		3	Improve weed management in kale and share information from other brassica crops	Promote best practice in weed control in kale. Integrate messages with weed control in oilseed rape activities
					Develop and test opportunities to improve disease control in kale and share information from disease control on other brassica crops	
Forage rape	Winter forage Good growth rates	2		3	Improve weed management in stubble turnips and share information from other brassica crops	Promote best practice in weed control in forage rape. Integrate messages with weed control in oilseed rape activities
					Develop and test opportunities to improve disease control in forage rape and share information from disease control on other brassica crops	
Fodder beet	High yielding High energy			3	Develop and test opportunities to in fodder beet and share information from sugar beet	

KEY
based on economic impact and likelihood of achievement

1 **First priority** 2 **Second priority** 3 **Third priority**

* **Existing work** ? **Needs discussion**

ES Table 5. EBLEX and DairyCo research and knowledge transfer priorities on cereal and pulse crops

Crop	Importance to industry	Weeds	Pests	Diseases	Main issue	Action priorities
Peas	Protein source	High	Low	Low	Increasingly chalenging to grow, although grass weed control my be less affected there will be fewer broadleaved weed control options.	Monitor rotational/cropping changes and be prepared to switch to alternative protein sources, maintain liaison with PGRO
Beans	Protein source	High	Low	Low	Increasingly chalenging to grow, although grass weed control my be less affected there will be fewer broadleaved weed control options.	Monitor rotational/cropping changes and be prepared to switch to alternative protein sources, maintain liaison with PGRO
Wheat		Medium	Low	Medium	Risk of herbicide resitrictions reducing overall production. Impact of disease control unclear until endocrine disruption impacts clearer	Monitor implications and retain close contact with HGCA
Barley		Medium	Low	Low	Herbicide restrictions or unavailability will lead to lower production due to higher weed pressures	Monitor implications and retain close contact with HGCA
Oats		Low	Low	Low	Unlikely to have significant impacts as oats tend to be grown in areas were there are few, or no, grass weeds	
Oilseed rape	Protein source	High	Medium	Medium	Future of UK OSR at risk from herbicides and molluscicides appearing in water	Monitor rotational/cropping changes and be prepared to switch to alternative protein sources. Maintain close contact with HGCA

KEY
High = risk of impact on feed availability could be immediate and requires action or monitoring
Low = likelihood of implications on feed availability are small based on current knowledge of impacts

The majority of the research priorities for cereals and pulses will fall under other levy boards (HGCA and PGRO) but EBLEX and DairyCo should be aware of where the problems are likely to occur and why. Reductions in availability of grains, pulses and rape meal will impact on livestock producers so knowledge transfer activities will be require to ensure livestock producers understand the likely implications on their businesses.

1. Introduction

The ruminant livestock sectors of UK agriculture rely on a sustained supply of high quality grazing and conserved forage to maintain their profitability. This is supplemented to varying degrees with other home grown forage crops such maize, lucerne, stubble turnips and fodder beet and additional protein feed sources from cereals, pulses and co-products from industrial uses such as rape meal and distillers grain.

Both a strength and weakness of forage crops is their ability to continue growth even in the presence of weeds, pests and diseases. Plant Protection Products (PPPs) can play a significant role in maintaining pasture productivity. Their role may be crucial during the establishment phase of the grass crop, particularly for temporary grass. Equally the relatively short utilisation period of other forage crops make them vulnerable to losses caused by weeds, pests and diseases at establishment and during the utilisation phase.

The availability, suitability and efficacy of PPPs for use on grass and forage crops is likely to change in the near future. Switching from a risk based to a hazard based approval system means that the future EU pesticide legislation will limit pesticide choice compared to the current situation. Further legislation like the Water Framework Directive may also lead to reduced availability in order to meet EU water quality targets. The wide usage of relatively few active substances on grassland, several of which have been found in water supplies, make the sector vulnerable to such changes.

2. Objectives

The overall aim of the project was to identify the most economically significant threats to production, in grass and forage crops, due to the reduced availability of pesticides in the next 5-10 years, in order to inform priorities for levy investments.

Specific objectives include:

1. Estimation of current economic impact of weeds, pests and diseases on grass and forage crops.

2. Assessment of likely future status of key pesticides over a 5-10 year timescale.

3. Evaluation of alternative control methods whether currently available or in development, and their cost-effectiveness

4. Using this information, identify the most significant combinations of economic importance, risk of loss of current control measures and absence of alternative control methods. The implications of climate change on priorities are considered.

3. Approach

The approach was similar to that used in previous studies on the arable sector[1],[2], but there are some important differences in the usage of pesticides in grass and forage crops. Nationally the 1018 tonnes of PPPs used on grass and forage crops is only about 6.5% of that used in the arable sector[3]. Only 2.7% of the total pesticide usage in the UK is applied to grass and forage.

Most established grassland receives little or no pesticide, whilst the sowing of grass leys and forage crops are essentially arable operations which involve greater use of pesticides. This makes pesticide use more patchy geographically. In a similar way the periodic need to clear perennial weeds like docks and thistle leads farmers to have occasional campaigns of more intense herbicide use that are stopped once the problem has been eradicated or reduced to manageable proportions. Thus the losses from impaired pesticide supplies will tend to be just as serious for individuals using them, but the impact will be neither widespread on an annual basis nor repeated annually except where annual forage crops are produced.

Because of the perennial production cycle of grass, clovers and lucerne these crops will continue to deliver poor returns if weeds, pests and diseases affect their initial establishment. The impact assessments have considered these knock-on effects where experience shows recovery takes some time.

Unlike arable crops and grazed/cut forage crops utilised in a single operation, perennial forage crops allow the use of grazing, and its integration with mowing and pesticide use. Well managed this combination of methods gives grassland farmers one of the most effective integrated farming techniques in agriculture.

3.1. Impacts of key weeds, pests and diseases

The physical and economic losses due to the principal weeds, pests and diseases in permanent grassland, temporary grassland, white clover (as a component of mixed swards), red clover, lucerne, peas, beans, lupins, maize, stubble turnips, kale, forage rape, fodder beet and chicory were reviewed. The losses were considered through their effect on dry matter (DM) yield and relative feed value, i.e. their impact on the financial value of livestock feed produced. Where appropriate, estimates of the loss of quality (feed value) as well as the effects on DM yield were included. The ability of existing pesticides to prevent these losses was taken as a measure of their worth, or the cost of their loss where legislative and regulatory changes threaten their continued use.

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[1] Clarke J, Green K, Gladders G, Lole M and Wynn S (2008) Evaluation of the impact on UK agriculture of the proposal for a regulation of the European Parliament and of the council concerning the placing of plant protection products on the market. Reports for ECPA June 2008

[2] Clarke, J.; Wynn, S.; Twining, S.; Berry, P.; Cook, S.; Ellis, S.; Gladders, P. (2009) Pesticide availability for cereals and oilseeds following revision of Directive 91/414/EEC; effects of losses and new research priorities (HGCA Project 3513). *Research Review 70*. HGCA: London, 127pp. Also available at http://www.hgca.com/publink.aspx?id=5850..

[3] Pesticide Usage Surveys 2005 (Grassland), 2006 (Arable Crops)

3.2. Assessment of future status of pesticide availability

Revisions of the legislative and regulatory changes are ongoing but the active substances and products currently at risk from both the revision of 91/414/EEC and the Water Framework Directive are listed. The information on active ingredients affected by the revision of 91/414/EEC was obtained from the PSD (now CRD) report published in December 2008[4], whilst the actives affected by the Water Framework Directive were an expert assessment conducted by ADAS based on the ecological characteristics or chemical properties or the active and whether or not it was already being detected in water. This ensured the evaluation of alternative control measures covered all the significant potential losses. In addition some categories of active substance are affected by the development of resistance in their target organism be it weeds, pests or diseases.

3.3. Analysis framework

The analysis framework for this study enabled data to be updated as more information became available or to test different scenarios. The analysis framework had separate assessments for the main crop groups – permanent grassland, temporary grassland, white clover (as a component of mixed swards), red clover, lucerne, peas, beans, lupins, maize, stubble turnips, kale, forage rape, fodder beet and chicory. Their outputs were valued per tonne of dry matter ex-field, with the feed value based on dry matter (DM), metabolisable energy (ME) and crude protein (CP) content (with relative feed values calculated as the cost to replace with the equivalent amount of feed barley priced at £105 t). For each crop there was an analysis for the most important weed, pest and disease impacts based on information from research literature, statistic publications and expert opinion.

Each analysis was conducted at an industry level covering the following aspects:

- Standard gross margin using fertiliser, pesticides and cultivation costs[5] to determine the margin of the feed production enterprise, rather than the gross margin of the utilisation enterprise
- Yield impact for each weed, pest or disease, expressed as % yield loss at UK level.
- Quality impacts for each weed, pest or disease, in terms of reduced feed value
- Changes to input costs in order to mitigate impacts of weed, pest or disease.

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[4] PSD (2008) Revised assessment of the impact on crop protection in the UK of the ‘cut-off criteria’ and substitution provisions in the proposed regulation of the European Parliament and of the Council concerning the placing of plant protection products in the market. http://www.pesticides.gov.uk/environment.asp?id=1980&link=%2Fuploadedfiles%2FWeb%5FAssets%2FPSD%2FRevised%5FImpact%5FReport%5F1%5FDec%5F2008%28final%29%2Epdf

- Overall impact on total yield and % change.

- Overall impact on total gross margin.

The yield and quality impacts of individual weeds, pests and diseases were assessed and compared under four scenarios.

- 'business as usual' – These are the current losses that are sustained, despite currently available pesticides. Figures that are presented are, therefore, the possible improvement in yield or financial value that could be achieved if perfect control could be achieved.

- Untreated – These are the losses that would occur if no pesticides for that target organism were applied.

- Replacement of 91/414/EEC – Council Common Position: 2C Swedish Criteria[4]

- Water Framework Directive impacts: Restrictions based on chemical or ecological considerations (ADAS assessment of actives affected)

Whilst looking at the above scenarios developing resistance to pesticides, reduced pesticide availability through market acceptability, and other activities like improved grazing management or defoliation practices were taken into account.

Information from the individual effects was collated into a summary sheet for each of the crops and comparisons made in terms of yield and economic impact of individual weeds, pests and diseases.

To assess mixed grass and clover swards it was assumed that swards containing white clover were 30% clover and 70% grass species and swards containing red clover or lucerne were 30% clover/lucerne and 70% grass.

3.3.1. Identifying area affected and yield impacts

Specialists identified the most important weeds, pests and diseases affecting the feed and forage crops. Evidence was gathered from surveys, research projects and expert opinion, to identify the area of each crop affected by a particular problem and the typical yield impacts.

Once the base line figures were established for treated and untreated yield losses, trials data and expert opinion were used to calculate the change in percentage yield loss, from the baseline level, caused as a result of losses of pesticides in each of the different scenarios. These figures for yield losses were then used in calculations to determine the loss of production, from each weed, pest or disease in each of the scenarios.

3.3.2. Economic analysis

For each crop a 'business as usual' gross margin was developed based on costs from J. Nix (2009)[5] and the Defra crop area statistics see table 1 for the basic gross margin information used in this report.

Table 1. Area, yield, feed value, variable costs and Gross Margins of grass and fodder crops.

	Crop area	Typical yield	Relative feed value	Seed costs	Fertiliser costs	Spray costs	GM
	ha	tDM/ha	£/t DM	£/ha	£/ha	£/ha	£/ha
Grass Permanent	6,035,000	10.0	140	7	227	7	1,159
Grass Temporary	1,141,000	15.0	170	20	313	10	2,212
White Clover	248,000*	8.0	170	37	78	12	1,183
Red Clover**	4,000	12.0	154	90	78	12	1,668
Lucerne	1,000	14.0	159	130	78	12	2,006
Lupins	6,000	3.0	117	120	95	102	33
Maize	152,700	12.0	92	148	260	37	655
Stubble turnips	18,400	6.9	145	35	190*	22	752
Kale	3,950	7.2	119	60	261*	42	496
Forage rape	3,950	4.9	146	23	174*	20	499
Fodder beet	5,800	13.7	96	130	325*	135	714
Chicory	20,000	15.0	190	25	180	0	1,985
Wheat	2,072,900	8.3	126	49	323	139	532
Barley	421,000	6.6	125	53	284	100	386
Oats	130,200	6.5	104	52	218	104	300
Oilseed rape	599,000	3.3	258	41	306	176	315
Peas	40,000	4.6	125	91	87	121	281
Beans	85,000	4.4	165	60	93	102	464

***** *White clover grass sward 30:70 mix, based on the 3.45% of the UK temporary and permanent grassland area that is sprayed with clover safe herbicides. ** Red clover grass sward 30:70 mix.***

The relative feed value per tonne of dry matter was derived using data from Technical Bulletin 33[6] and the Relative Feed Value Calculator of the Straights Feeders Group[7]. This is based on the replacement cost of the lost feed in terms of barley at £106 per tonne and soya at £277 per tonne. The outputs used for the

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[5] Nix J (2008) The John Nix Farm Management Pocketbook 39th edition (2009)
[6] Energy Allowances and Feeding Systems for Ruminants. Technical Bulletin 33. MAFF/HMSO 1976.
[7] http://www.cowfacts.co.uk/c2/uploads/sfg%20uk%20rfv2.xls

economic assessments were based on the feed value of the grass or forage crop. This, rather than the production costs of the feed, is a reflection of the true loss to the farmer as it is the equivalent value of purchases needed to replace the loss.

3.4. Evaluation of alternative control measures

In previous studies in the arable sector the costs associated with mitigating measures were taken into account in the analysis of the gross margins. However, much of the technical and commercial activity of the livestock sector is downstream of the actual production of the grass and forage.

The wide range of grassland management techniques have justified text books in themselves and a full analysis of their detailed impact on weeds, pests and diseases is beyond the scope of this report. As a consequence a suite of summary points of the most appropriate actions farmers can use for alternative control is provided.

3.5. Summary matrix

All the data from each of the crops in each scenario, was combined to produce tables of the economic and production loss due to each weed, pest or disease group on an industry scale (in executive summary).

4. Assessment of future pesticide availability

4.1. Current pesticides approved for use in grass and forage crops

There are a wide range of active substances currently available for use on grass and forage crops (see Appendix 2 – Currently available active substances).

The market is characterised by a very wide range of active substances, a few of which are used on a large scale. Many products that have been used on cereals, pulses, sugar beet or brassica crops have 'off-label' approval for use on grasses, legumes, fodder beet and fodder brassicas. For many reasons, label recommendations of approved pesticides do not cover the control of every problem which may arise. This is particularly true for crops that are grown on a comparatively small scale in the UK as well as for sporadic pests and diseases. It is for this reason that the extrapolations presented in the Long Term Arrangements for Extension of Use have been developed. If these do not address particular needs growers or their representatives may apply to Chemical Regulation Directorate (CRD) for a specific off-label approval. Many of the products listed here are covered by such off-label approvals.

Grassland crops are characterised by covering a large area (over 6M ha), but having a relatively low pesticide usage per hectare (Figure 1). Wheat covers about 1.9M ha in the UK, but has pesticide use of nearly 5kg of active ingredient per hectare. Both of these crops can be considered to have significant pesticide usage, wheat because of its area and rate of active ingredients applied and grass because of the large area it covers.

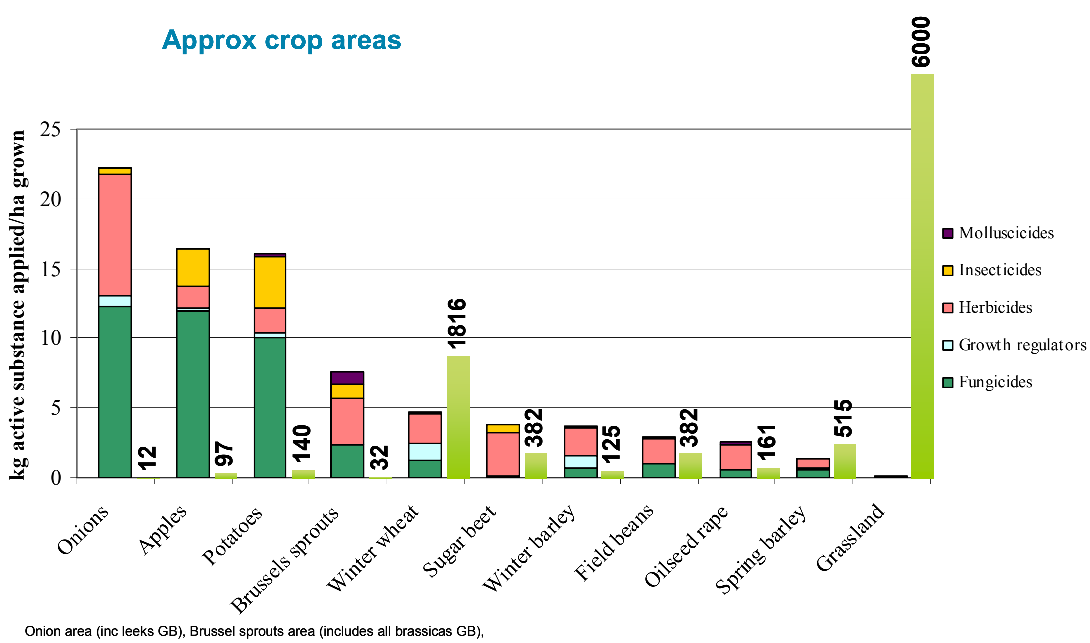

Figure 1. Area of UK crops (light green bars) and weight of active ingredients applied per hectare (multi coloured bars).

4.2. Drivers for change in pesticide availability

There are a number of reasons why the availability of pesticides could change, these are summarised in Table 2.

Table 2. Drivers for change in pesticide availability

Reason for change	Main effects	Pesticides affected
Revision of 91/414/EEC	Change in approval system	Pendimethalin and linuron – weed control Epoxiconazole and some triazoles – foliar disease control
Failure to achieve Annex 1 listing under current regulation	Many products still not on Annex 1 and if not completed before end December 2010 will no longer be approved	Metaldehyde – used to control slugs Asulam – bracken control in rough grazing Older grass-weed herbicides used for volunteer cereal control
Water Framework Directive	Minimising pesticides in water	Mainly affecting herbicides e.g. • propyzamide • carbetamide • clopyralid • glyphosate • MCPA • MCPB • 2,4-DB • 2,4-D
Market acceptability	Residues of particular active substances	Glyphosate – in cereals
Operator safety	None specifically identified	
Cost	None specifically identified	• Grass and forage crops less able to carry high pesticide costs
New product development	Replacing older actives	• Grass and forage products originate from other sectors • Availablility of products for maize is good due to large global market

4.2.1. Revision of 91/414/EEC

At the present time the pesticide approvals system within the European Union is based upon risk. Provided any hazards posed by a pesticide can be mitigated against to reduce the risk to an acceptable level it is possible to gain approval for that substance. The main impact of the new legislation comes from the change to the approval system, moving from a risk based system to a hazard based system with the aim of protecting human health and the environment. This will result in the withdrawal of pesticides that are categorised as carcinogenic, genotoxic, reprotoxic or neurotoxic. In addition some or all active substances that affect hormones, endocrine disruptors, may also be included depending on the adopted cut-off criteria.

Initially (in June 2008) the list of active substances that was potentially at risk from the revision of 91/414/EEC was extensive and covered many of the important pesticides used in the production of combinable crops in the UK, and therefore grass and forage crops. The initial list of what actives were likely to be affected in four different scenarios was released by PSD in May 2008. Initial assessments done on Wheat in the ADAS report for ECPA (Clarke *et al.,* 2008) showed that there would be very significant impacts of these losses on the ability of UK farmers to cost-effectively product wheat. Since then there has been further discussions within the European Parliament and Commission, accompanied by lobbying from interested parties. This has lead to a reduction in the likely impact of the hazard criteria used in the assessment of pesticides for approval for use in the European Union.

The positive vote in the European Parliament on 13 January 2009 on these revised proposals to change the authorisation process for active substances and products, will change the availability of current pesticides.

There are also changes in approval process aimed at simplifying the process and harmonising the availability of plant protection products in different Member States, including the identification of 3 zones where there will be compulsory mutual recognition of product approvals within a zone. This is intended to minimise the duplication of testing, particularly animal testing. This is intended to make product availability other countries easier. It is, however, still unclear how this will apply. It is most likely to help minor uses and we have made no predictions of active substances witch might be available in future because they are approved in another Member State. We believe this impact is likely to be small, but may solve some specific issues.

The legislation is not likely to come into force until late 2011 at the earliest as the draft text had not been tabled prior to the summer recession 2009.. Exact timing depends on how quickly the implementing legislation is agreed. There is still expected to be a degree of negotiation about the details of the implementing legislation, in particular the ‘cut-off criteria’ for actives that are endocrine disruptors.

The exact nature of the changes have not yet been fully agreed, however an assessment made by PSD in December 2008[8] has been used as a guide. The Council Common Position (CCP) means the exclusion of all:

- category 1 or 2 mutagens,
- category 1 or 2 carcinogens or reproductive toxins (unless exposure is negligible),
- endocrine disruptors which may cause adverse effects (unless exposure is negligible),
- persistent organic pollutants (POPs)
- persistent, bioaccumulating, toxic substances (PBTs)
- very persistent, very bioaccumulating substances (vPvBs)

The ENVI Committee of the European Parliament also made some amendments to this position where by there would be further restrictions on substances that have developmental or immunotoxic properties, have transformation products or residues that are PBTs or vPvBs, affect bees, or are on the Water Framework Directive priority hazard list.

PSD (now CRD) assessed 278 actives against 3 scenarios, differentiated by the definition of endocrine disruptor, and 1 scenario based on the ENVI Committee more stringent requirements.

- Annex **2a** - Substances that may not be approved according to the Council Common Position (CCP) with the endocrine disruptor definitions based on the previous UK assessment from May 2008 assuming ‘may cause effect’ is interpreted in a broad way.
- Annex **2b** - Substances that may not be approved according to the Council Common Position (CCP) assuming assessment using the ENVI Committee proposal to define endocrine potential disruptors as substances which are for example R3.
- Annex **2c** - Substances that may not be approved according to the Council Common Position (assuming assessment using the Swedish assessment potential endocrine disruptors which are R2 or R3 and C3, or substances classified as R2 or 3 which have toxic effects on endocrine organs.
- Annex **3** - Additional substances that may not be approved according the ENVI Committee amended criteria.

After the vote of 13th January it has become clear that the most likely scenario to be implemented is Annex 2c. All assessments of the revision of 91/414/EEC in this report are based on the losses of pesticides from annex 2c as assessed in the PSD report of December 2008 (Table 3).

[8] PSD (2008) Revised assessment of the impact on crop protection in the UK of the ‘cut-off criteria’ and substitution provisions in the proposed regulation of the European Parliament and of the Council concerning the placing of plant protection products in the market. http://www.pesticides.gov.uk/environment.asp?id=1980&link=%2Fuploadedfiles%2FWeb%5FAssets%2FPSD%2FRevised%5FImpact%5FReport%5F1%5FDec%5F2008%28final%29%2Epdf

Table 3. Active substances at risk from revisions of 91/414/EEC (scenario 2c – Swedish interpretation of endocrine disruptors) ***Italics – products approved for use in one or more forage or stock feed crops***

Active Substance	Date of expiry of Annex 1 approval	Approved in UK	Function
amitrole	2011	Y	Herbicide
bifenthrin	2018	Y	Insecticide
bitertanol	2020	Y	Fungicide
carbendazim	**2009**	**Y**	**Fungicide**
cyproconazole	**2020**	**Y**	**Fungicide**
dinocap	2009	N	Fungicide
epoxiconazole	**2018**	**Y**	**Fungicide**
esfenvalerate	2011	Y	Insecticide
fenbuconazole	2020	Y	Fungicide
flufenoxuron	2020	N	Insecticide
flumioxazin	2012	Y	Herbicide
flusilazole	**suspended by ECJ**	**Y**	**Fungicide**
glufosinate	**2017**	**Y**	**Herbicide**
ioxynil	2014	Y	Herbicide
linuron	**2013**	**Y**	**Herbicide**
lufenuron	2018	N	Insecticide
mancozeb	**2015**	**Y**	**Fungicide**
maneb	2015	Y	Fungicide
metconazole	**2017**	**Y**	**Fungicide**
pendimethalin	**2013**	**Y**	**Herbicide**
quinoxyfen	2014	Y	Fungicide
tebuconazole	2018	Y	Fungicide
warfarin	2016	Y	Rodent

Timescale

The approval of active substances will remain in place until the approval period under current legislation ends. There is therefore no sudden withdrawal of actives with expected dates of withdrawal between 2011 and 2018 (see Appendix 2 for date of re-evaluation).

4.2.2. Failure to achieve Annex 1 listing

There are some existing approvals which have not yet achieved Annex 1 listing. If active substances fail to get listed before end December 2010 they will cease to be available (see Appendix 4 for list of actives affected).

There are a number of triazole fungicides that have yet to achieve annex 1 listing but there use on grass and forage crops is very limited.

The insecticides that currently have yet make annex 1 listing include bifenthrin, zeta-cypermethrin and tau fluvalinate, general pyrethoids. Their loss just reduces the number of general pyrethroids for control of aphids and beetles. Tefluthrin is used as a seed dressing to protect against pygmy beetle, springtails, symphylids and millipedes in fodder beet. According to the pesticide usage survey of arable crops in 2006 about 5% of sugar beet crops were drilled with treated seed. In 2005, 9% of the field bean area was sprayed with zeta-cypermethrin. In its absence alternative pyrethoids would be required for pea and been weevil control.

The loss of metaldehyde would lead to greater reliance on methiocarb, and the associated increased costs, for the control of slugs or increase levels of crop damage.

4.2.3. Water Framework Directive

The Water Framework Directive (2000/60/EEC) established a framework for the EU on water policy. The UK implementing legislation came into force in January 2004. It requires that all rivers, lakes, ground and coastal waters should reach good ecological and chemical status by 2015. Farming has impacts on water quality through contamination of water from nitrates, phosphates, pesticides, soil and slurries and manures. Pesticides are a concern due to their impact on chemical status, although they can also have an ecological impact through possible impacts on flora and fauna. The Drinking Water Directive sets a maximum allowable concentration of 0.1μg/l for any pesticide and 0.5μg/l for total pesticides in drinking water irrespective of toxicity and these levels have been adopted in the Water Framework Directive (WFD)

The Environment Agency (EA) is the designated Competent Authority for the WFD and is responsible for implementing the legislation, monitoring progress and meeting the requirement. River Basin Districts (RBDs) have been established for England and Wales, and monitoring programmes were started in 2006 to give an overview of the status of each district to identify the significant water management issues. During early 2009 there is a consultation on the River Basin Management Plans, including an overview of status and programme of measures. The consultation on these plans is currently underway, running until June 2009. Details of each RBD consultation can be found at http://www.environment-agency.gov.uk/research/planning/33106.aspx.

Following the consultation the management plans will be implemented between 2009 and 2012. There is a planned review of progress every 6 years, the first of which is in 2013.

Changes in farm management are likely to be needed to meet the WFD objectives and these will be encouraged by incentives and voluntary schemes. Defra has already funded the English Catchment Sensitive Farming Delivery Initiative to encourage changes in behaviour in 40 priority catchments[9]. The Voluntary Initiative aims to reduce environmental impact of pesticides through education and awareness of farmers and spray operators[10].

An EA monitoring programme is in place for the nine pesticides most commonly found in surface water (Figure 2). These are all herbicides that are relatively mobile and persistent – atrazine, chlorotoluron, 2,4-D, dichlorprop, diuron, isoproturon, MCPA, mecoprop and simazine. In 2007, 6.0% of the indicator samples contained pesticides above the 0.1µg/l concentration[11]. In 2007 IPU was the most frequently found pesticide. IPU is due for withdrawal in 2009, and atrazine, diuron and simazine have already been withdrawn at the end of 2007. Of the remaining actives present on the list MCPA and mecoprop are the two most widely used herbicides in the grass and forage sector. Their greatest use is on permanent pasture where together they make up just under 40% of all usage on permanent and temporary grass.

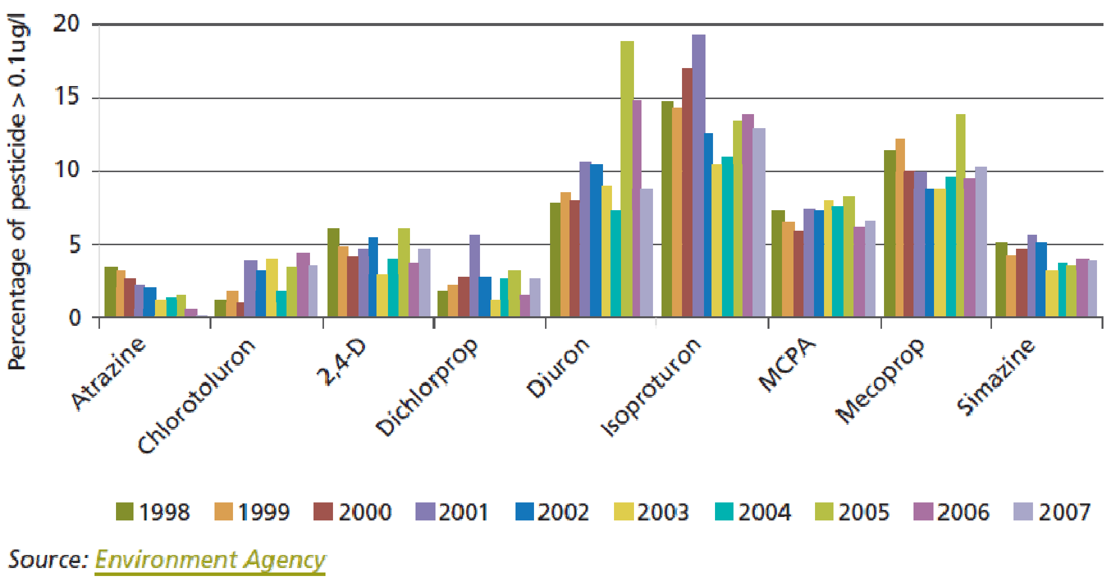

Figure 2. Top 9 active ingredients appearing in water between 1998 and 2007.

The Drinking Water Directive aims to ensure high quality drinking water is supplied to consumers. Water companies must test their water for pesticides (among other things) and report to the Drinking Water Inspectorate who have responsibility for ensuring compliance with the Directive. Testing is undertaken at water intake, output

[9] http://www.defra.gov.uk/farm/environment/water/csf/delivery-initiative.htm
[10] http://www.voluntaryinitiative.org.uk/Content/Water_WP.asp
[11] Defra (2008) Observatory monitoring framework – indicator data sheet DA4 pesticides in water. https://statistics.defra.gov.uk/esg/ace/da4_data.htm

and from the tap. There are 26 water companies supplying 56 million customers. The failure rate for pesticides is low, but certain active substances are more commonly reported – MCPA, mecoprop-P, propyzamide, – and more recently, since a test was developed, metaldehyde.

Based on findings from EA indicator testing and Drinking Water Inspectorate reports from water companies[12] there are a number of actives used in cereals and rape that could be at risk from the Water Framework Directive.

The relatively short list from WFD (Table 4) contains some active substances that will have a very high impact if banned. There are two ways in which active ingredients can be affected under the WFD; chemical status, i.e. active ingredients are being found at high concentrations in water, or ecological status i.e. active ingredients are known to be harmful to aquatic ecosystems. Herbicides are the largest group of pesticides by type used on grass and forage crops. Clopyralid, 2,4-D, MCPA and mecoprop-p are very widely used selective herbicides generally applied in mixed formulated products. These active substances out of a total of 46 single and mixed formulated materials are used on 18% of the total treated area.

Glyphosate is the most widely used herbicide in the world and is used pre-planting and pre crop emergence for total vegetation control. It is also the main herbicide used for destroying grass swards prior to cultivation. Its wide spread useage makes it vulnerable to detection in water, and therefore WFD. Chlorpyriphos is used for the control of leather-jackets and frit fly on grassland.

The WFD tends to be catchment orientated and factors like distance from water courses, terrain, underlying soils and geology, and time of use and prevailing weather will affect how, where and when it is implemented.

Table 4. Substances at risk from restriction due to Water Framework Directive

Chemical status	Ecological Status
carbetamide	2,4-D; 2,4-DB
chlorotoluron	bentazone
clopyralid	carbendazim
glyphosate	chlorothalonil
MCPA	chlorpyriphos
metaldehyde	mecoprop-p
metazachlor	insecticides
propyzamide	

There will be many products remaining after the loss of active substances outlined in the next three sections. However the efficacy, cost and availability may affect the profitability of their use with consequent impacts on the extent of their use.

[12] http://www.dwi.gov.uk/pubs/annrep07/contents.shtm

Timescale

Changes due to the requirements of the Water Framework Directive and the Drinking Water Directive will evolve depending on the impact of voluntary schemes and changes in farming practices. The removal of one active substance may result in the greater use of others which, in turn, may come under the spotlight. Once highlighted as a problem there are a number of solutions possible, including withdrawal. There could be further restrictions placed on its usage such as distances from water courses, certain times of the year, geographical limitations, soil type limitations etc. The full withdrawal of a pesticide could take between 2 and 5 years. The effects of the WFD are likely to be felt sooner than those of the revision of 91/414/EEC.

For the purpose of this study we have taken the worse case scenario, in which all of these substances marked in WFD will be banned from use completely.

In Table 5 we show only the active substances affected by the 2C revision of 91/414/EEC and WFD that will lose approval for use on grass and forage crops.

Table 5. Grassland and forage crops and the principal active substances used that are at risk from revision of 91/414/EEC or WFD

	Reason for withdrawal	Permanent grassland	Temporary grassland	White clover	Red clover	Lucerne	Peas	Beans	Lupins	Maize	Stubble turnips	Kale	Forage rape	Fodder beet	Chicory	
Herbicides																
2,4 – D; 2,4-DB	WFD	x	x													
bentazone	WFD		x*													* as Acumen
carbetamide	WFD			x**	x	x					x*	x*	x*			*seed crops, ** without grasses
clopyralid	WFD	x	x							x	x	x	x	x		
glufosinate	91/414/EEC	x	x	x	x	x	x	x	x	x	x	x	x	x	x	None cropped land and desiccation
glyphosate	WFD	x	x	x	x	x	x	x	x	x	x	x	x	x	x	None cropped land and desiccation
ioxynil	91/414/EEC		x*													SOLA grass seed crops, * on undersown cereals in mixes with bromoxynil
linuron	91/414/EEC		x*													* in Alistell only
MCPA	WFD	x	x	x	x		x									
mecoprop-p	WFD	x	x													and grass seed crops
metazachlor	WFD											xs				Hortic brassicas
pendimethalin	91/414/EEC						x	xs	xs	x						SOLA grass seed crops, hortic brassicas
propyzamide	WFD			x*	x*	x		x**	xs		x*	x*	x*	x~	xs	* seed crops, ** winter, ~ sugar beet seed crops
Insecticides																
chlorpyrifos	WFD	x	x	x*	x*			xs		x				xs		* in grassland
Molluscicide																
metaldehyde	WFD	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Fungicides																
chlorothalonil	WFD	x	x	x*	x*			xs		x				xs		SOLA grass seed crops, hortic brassicas, amenity turf
flusilazole	91/414/EEC									xs	xs					
cyproconazole	91/414/EEC												xs			SOLA grass seed crops
mancozeb	91/414/EEC														xs	SOLA grass seed crops, witloof chicory
metconazole	91/414/EEC						x	x	x							SOLA grass seed crops
quinoxyfen	91/414/EEC	x	x													SOLA grass seed crops
tebuconazole	91/414/EEC								x		x					SOLA grass seed crops, hortic brassicas

4.2.4. *Changes in marketing of actives*

The development of active substances for the grass and forage sector tends to be as a result of 'spin-off' from the arable sector. The ability of livestock farmers to remove many of the problems by grazing or cutting gives them a tool not open to the arable and horticultural growers producing annual crops. Annual forage crops are managed as arable crops but the small areas involved provide little market pull, with many products being developed from their use on horticultural brassicas and legumes

4.2.5. *Market acceptability*

There has been growing interest in issues related to food safety and perceived healthiness of food and food ingredients. There are legislative requirements under the UK Pesticides (Maximum Residue Levels in Crops, Food and Feeding Stuffs) Regulations 1999 that set the upper limit of pesticides on produce, concurrent with good agricultural practice. These are typically well below levels which might have human health implications. There is a testing regime organised and reported on by the Pesticides Residue Committee (PRC)[13]. In the PRC Pesticide Residue Monitoring Report in 2008[14] animal fat, chicken and milk were tested for pesticides residues and no pesticides were detected at or above the reported level.

Residues in cereals have been reported, in particular chlormequat (plant growth regulator) and glyphosate. Although these are not showing in residues in animal products, any changes to their availability could affect production and quality of grains.

Consistently being below MRL is one measure which will help ensure that active substances do not come under greater scrutiny from approvals authorities and market outlets. Pesticides are an emotive substance for many consumers and any concerns about food safety can impact on what is acceptable usage.

There are market outlets that have growing standards that prohibit the use of certain pesticides. Growing to Soil Association organic standards is one example that will affect the livestock feed chain. These standards are a marketing decision by the grower, however if consumer requirements for these products becomes widespread, this may limit the pesticides available.

4.2.6. *Resistance*

There are some weeds, pests and diseases that are able to develop resistance to the herbicides, insecticides and fungicides that are targeted against them. As resistance develops the level of control that is achieved by a certain pesticide can be reduced. One of the main weapons against resistance is the diversity of chemistry available. The more different modes of action that there are for killing a particular weed, pest or disease the more difficult it is for that organism to develop complete resistance.

As the revisions of 91/414/EEC and Water Framework Directive come into force they will gradually reduce the number of active substances and modes of action that are

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[13] Pesticide Residue Committee information http://www.pesticides.gov.uk/prc_home.asp
[14] Pesticide Residue Committee (2009) Pesticide Residue Monitoring Report , Third Quarter 2008

available to prevent and manage resistance. When resistance forms it tends to be to a particular mode of action. Stock feed crops are seldom grown at the scale and intensity that might lead to large scale resistance of weeds, pests or disease, and there are no records of resistance incidence to date. Resistance to pesticides in cereals and oilseeds sectors, in particular black-grass and pollen beetle, may have an impact on the livestock sector if they were to affect the production of these crops which are building blocks of UK ruminant diets.

5. Impact weeds, pests, diseases in growing and utilising the crops – In business as usual (BAU) and as a result of changes to legislation

5.1. Background statistics

Pesticide use on grass and forage crops is dominated by herbicide use. The need to control weeds that affect both the establishment and long term productivity of grassland is vital. The use of fungicides and insecticides is largely confined to the arable crops used for forage and those arable crops undersown with new grass. If seed treatments on maize and fungicide and insecticide use are ignored the amounts of non-herbicide actives applied to grass and forage crops is less than 1% of the total tonnage and less than 2% of the treated area.

5.1.1. Yield and production

The impact of changes in pesticide availability were estimated using the yields in the standard gross margins in Table 1. These yield figures were used to calculate national production and the full national economic impact. Many minor crop areas are very small and not specifically included in official surveys. In these situations, the areas were estimated following industry consultation.

5.1.2. Feed value and prices

The feed value per tonne of dry matter was derived using data from Technical Bulletin 33[15] and the Relative Feed Value Calculator of the Straights Feeders Group[16]. The outputs used for the economic assessments were based on the relative feed value of the grass or forage crop (if it had to be replaced with barley at £105 t). This, rather than the production costs of the feed, is a reflection of the true loss to the farmer as it is the equivalent value of purchases needed to replace the loss.

5.2. Summary of impacts

The yield loss effects, on an area weighted basis, from lack of control due to differing pesticide availability, were entered into the gross margin calculations. This resulted in figures for the total loss of production to the industry, which was translated into a percentage reduction in production, and figures for the cost to the industry based on

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[15] Energy Allowances and Feeding Systems for Ruminants. Technical Bulletin 33. MAFF/HMSO 1976.
[16] http://www.cowfacts.co.uk/c2/uploads/sfg%20uk%20rfv2.xls

reduced feed value per hectare. The percentage losses in production are summarised in Table 6 and Table 7, whilst the economic losses to the industry are summarised in Table 8 and Table 9. The highlighting of the cells in the table indicates how big the potential losses are. The darker the colour the bigger the loss. Five different scenarios are listed. Business as usual is the level of losses that are currently sustained, despite the currently available herbicides, insecticides and fungicides. If improved pesticides could be found, or spraying was (or could be) more widespread, these are the potential increases in yield and gross margin that could occur. The untreated scenario is a scenario in which no pesticides are applied for that particular weed, pest or disease, effectively a worst case scenario.

Revision of 91/141/EEC includes the impact of potential pesticide losses due to the revision of approvals legislation, based on the Swedish definition of endocrine disruption (Table 3). WFD is the potential impact if all of the pesticides listed in Table 4 were to have their approvals revoked (the worst case scenario) as a result of Water Framework Directive legislation. The final scenario is a combination of the losses to the revision of 91/414/EEC and WFD, to indicate whether or not the impacts would be worse in the event that losses occurred under both scenarios. The impacts in each of these scenarios are shown as the additional cost to the industry, therefore if there are already costs occurring in the business as usual scenario, and the situation is no worse under the scenarios there is considered to be no loss to the industry as a result of the revision of 91/1414/EEC or WFD.

Table 6. Percentage loss of production associated with pesticide availability in five scenarios, across grass and forage crops as a result of a range of weeds, pests and diseases. (10-25%, 25-50%, 50%+ loss of production)

Loss of production (%)			Weeds			Pests		Diseases						
Crop	Scenario	UK production (t)	Grass weeds	BLW	Bracken	Leather Jackets	Frit Fly	All diseases	Rusts (inc Crown)	Foliar Diseases	Viruses	Leaf Spots	Soil Borne	Fusarium
Grass Permanent	Revision 91/414/EEC (2c)													
	WFD			0.7										
	91/414/EEC & WFD			0.7										
	Untreated			4.5	3.2	0.0	0.3	5.0						
	Business as usual	60,350,000			2.6	0.0	0.3	5.0						
Grass Temporary	Revision 91/414/EEC (2c)													
	WFD			0.6										
	91/414/EEC & WFD			0.6										
	Untreated			3.0		0.4	0.4		4.5	2.2	1.5			
	Business as usual	17,115,000				0.0	0.4		4.5	2.0	1.5			
White Clover	Revision 91/414/EEC (2c)													
	WFD			30.0										
	91/414/EEC & WFD			30.0										
	Untreated			30.0						5.0	0.4			
	Business as usual	840,000								5.0	0.4			
Red Clover	Revision 91/414/EEC (2c)													
	WFD			30.0										
	91/414/EEC & WFD			30.0										
	Untreated			30.0						10.0				
	Business as usual	48,000								10.0				
Lucerne	Revision 91/414/EEC (2c)													
	WFD			25.0										
	91/414/EEC & WFD			25.0										
	Untreated			25.0						7.0				
	Business as usual	14,000								7.0				
Lupins	Revision 91/414/EEC (2c)													
	WFD													
	91/414/EEC & WFD													
	Untreated										4.5	32.0		
	Business as usual	90,000									4.5	24.0		
Maize	Revision 91/414/EEC (2c)									0.5				0.6
	WFD					0.04	0.04							
	91/414/EEC & WFD					0.04	0.04			0.5				0.6
	Untreated		90.0			0.08	0.08			4.0				3.1
	Business as usual	1,832,400				0.00	0.02			3.5				2.5
Stubble turnips	Revision 91/414/EEC (2c)													
	WFD		1.0	1.6		0.02								
	91/414/EEC & WFD		1.0	1.6		0.02								
	Untreated		6.0	9.6		0.04				7.0	1.5		1.0	
	Business as usual	126,960				0.00				7.0	1.5		1.0	
Kale	Revision 91/414/EEC (2c)									1.0				
	WFD			4.3		0.01								
	91/414/EEC & WFD			6.1		0.01				1.0				
	Untreated			6.1		0.01				7.0	0.6		0.2	
	Business as usual	28,440				0.00				6.0	0.6		0.2	
Forage rape	Revision 91/414/EEC (2c)													
	WFD			6.1										
	91/414/EEC & WFD			6.1										
	Untreated			6.1						5.0	0.7		0.1	
	Business as usual	19,355								5.0	0.7		0.1	
Fodder beet	Revision 91/414/EEC (2c)								0.7	0.8				
	WFD					0.00								
	91/414/EEC & WFD					0.00			0.7	0.8				
	Untreated		85.0			0.01			7.0	4.0	1.8			
	Business as usual	79,170				0.00			6.3	3.2	1.8			
Chicory	Revision 91/414/EEC (2c)													
	WFD													
	91/414/EEC & WFD													
	Untreated			30.0				5.0						
	Business as usual	15						5.0						

Table 7. Percentage loss of production associated with pesticide availability in five scenarios, across pulse and cereal feed crops as a result of a range of weeds, pests and diseases. (10-25%, 25-50%, 50%+ loss of production)

Loss of production (%)

Crop	Scenario	UK production (t)	Weeds: Grass weeds	Weeds: BLW	Weeds: Volunteer OSR	Pests: Pea & bean weevil	Pests: Field thrips	Pests: Pea moth larvae	Pests: Bean seed beetle	Pests: Black bean aphid	Pests: Stem nematode	Diseases: Rust	Diseases: Downy mildew	Diseases: Leaf and pod spots (inc cholate spot)	Diseases: Botrytis	Diseases: Powdery mildew	Diseases: foot & root rots
Peas	Revision 91/414/EEC (2c)			17.0	3.0										0.5	0.3	
	WFD			25.0										4.5	2.0		
	91/414/EEC & WFD			30.0	3.0									4.5	2.0	0.3	
	Untreated		5.4	30.0	4.3	6.0	0.5	3.0		25.0	0.1		9.0	27.0	2.1	0.5	0.3
	Business as usual	185,600			1.3	0.0	0.5				0.1		1.5		0.5	0.3	0.3
Beans	Revision 91/414/EEC (2c)			10.0	2.5												
	WFD		7.8	15.0	3.8												
	91/414/EEC & WFD		7.8	15.0	3.8												
	Untreated		10.8	15.0	3.8	3.6			1.3	6.3	1.0	40.0	1.0	25.0			
	Business as usual	370,600	3.0			0.0				1.3	1.0	10.0	0.1	10.0			

Loss of production (%)

Crop	Scenario	UK production (t)	Weeds: Grass weeds	Weeds: BLW	Pests: WBF	Pests: Slugs	Pests: OWBM	Pests: Aphids	All diseases
Feed Wheat	Revision 91/414/EEC (2c)		8.0						
	WFD		18.8		0.1	1.0	0.3	0.02	
	91/414/EEC & WFD		18.8		0.1	1.0	0.3	0.02	
	Untreated		26.0	15.0	0.1	1.1	0.4	0.02	31.7
	Business as usual	17,101,425	2.0	0.5	0.0	0.1	0.1	0.01	6.1
Feed Barley	Revision 91/414/EEC (2c)		9.0	2.0					1.0
	WFD		19.0			0.3		0.8	0.1
	91/414/EEC & WFD		20.0	2.0		0.3		0.8	2.3
	Untreated		20.8	15.0		0.4		17.0	12.8
	Business as usual	2,778,600	1.6	0.5		0.1		0.8	6.8
Oats	Revision 91/414/EEC (2c)								
	WFD		6.7					0.8	
	91/414/EEC & WFD		6.7					0.8	
	Untreated		6.3	21.0				1.1	4.5
	Business as usual	17,101,425	1.7	1.9				0.3	0.8
Oilseed Rape	Revision 91/414/EEC (2c)								
	WFD		13.9			2.1		1.1	
	91/414/EEC & WFD		13.9			2.1		1.1	
	Untreated		16.0	11.0		2.4		1.4	18.0
	Business as usual	2,778,600	0.6	1.4		0.3		0.2	7.2

The value of these losses is calculated on the basis of the tonnes of dry matter lost with the relative feed values shown in Table 1. The total loss of production and economic losses tend to be greatest in those crops that cover a larger area; grassland and cereals. This is due to the effect being calculated on a national basis rather than per ha. However, in terms of percentage crop area that is lost some of the small area crops are worse affected, e.g. clovers and brassicas.

It is weeds that tend to cause the largest potential for losses, if left untreated. Currently weeds are well controlled or tolerated in most grass and forage crops. The ability for livestock farmers to control weeds through the use of grazing helps reduce the impact of weeds compared to arable situations. Water Framework Directive in particular will reduce the number of herbicides that are available to livestock feed producers, making some weeds more difficult or costly to control. This could result in decreased palatability of grass or forage resulting in lower relative feed value.

In the majority of grass and forage crops the amount of fungicide and insecticide usage is very limited. This means that there is the potential to increased yields, if spray applications were made, although this may not prove to be practicable. As a result of the low insecticide and fungicide usage on grass and forage crops the impacts of fungicide and pesticide losses to the revision of 91/414/EEC and WFD would be small compared to the potential losses already occurring.

From Table 10 it can be seen that although the cost to the industry is greatest for those crops grown on the largest areas it is actually on some of the smaller areas that the potential cost per hectare is greatest. For example loss of herbicide actives (to WFD) for use in lucerne crops could reduce the value of the crop to levels seen in an untreated crop, costing a producer over £250/ha in lost feed value. The lucerne area in the UK is currently small, estimated to be in the region of 1000 ha. It is a drought tolerant crops, so is suited to drier areas of the country. With the potential for hotter drier summers as a result of climate change this crop may grow in popularity, if it is possible to produce weed feed crops economically. The loss of important herbicides to WFD could make this option of a drought tolerant forage crop unavailable due to high costs and poor quality.

The impacts of the losses are potentially largest in the arable sector where rotations and lack of grazing make weed control more difficult. Costs of wheat production could soar if cost of weed control increases (more costly chemicals) and control is poorer (resistance) resulting in reduced yield potentials for a significant proportion of wheat crops.

Table 8. Loss of value (M£) associated with pesticide availability in five scenarios, across grass and forage crops as a result of a range of weeds, pests and diseases.

Key orange >£500M lost, yellow £250-500M lost and pale yellow £100-250M lost

Losses to industry £M		Weeds			Pests		Diseases						
Crop	Scenario	Grass weeds	BLW	Bracken	Leather Jackets	Frit Fly	All diseases	Rusts (inc Crown rust)	Foliar Diseases	Ergot	Viruses	Leaf Spots	Fusarium
Grass Permanent	Revision 91/414/EEC (2c)	-	-	-	-	-	-	-	-	-	-	-	-
	WFD	-	-61.5	-	-	-	-	-	-	-	-	-	-
	91/414/EEC & WFD	-	-61.5	-	-	-	-	-	-	-	-	-	-
	Untreated	-	-382.7	-267.1	-2.5	-25.3	-422.5	-	-	-	-	-	-
	Business as usual	-	-	-220.9	-2.5	-25.3	-422.5	-	-	-	-	-	-
Grass Temporary	Revision 91/414/EEC (2c)	-	-	-	-	-	-	-	-	-	-	-	-
	WFD	-	-17.3	-	-	-	-	-	-	-	-	-	-
	91/414/EEC & WFD	-	-20.0	-	-	-	-	-	-	-	-	-	-
	Untreated	-	-89.3	-	-10.2	-10.2	-	-147.3	-75.2	-4.5	-70.5	-	-
	Business as usual	-	-	-	-10.2	-10.2	-	-147.3	-69.4	-4.5	-70.5	-	-
White Clover	Revision 91/414/EEC (2c)	-	-	-	-	-	-	-	-	-	-	-	-
	WFD	-	-44.6	-	-	-	-	-	-	-	-	-	-
	91/414/EEC & WFD	-	-44.6	-	-	-	-	-	-	-	-	-	-
	Untreated	-	-44.6	-	-	-	-	-	-16.2	-	-1.3	-	-
	Business as usual	-	-	-	-	-	-	-	-16.2	-	-1.3	-	-
Red Clover	Revision 91/414/EEC (2c)	-	-	-	-	-	-	-	-	-	-	-	-
	WFD	-	-2.2	-	-	-	-	-	-	-	-	-	-
	91/414/EEC & WFD	-	-2.2	-	-	-	-	-	-	-	-	-	-
	Untreated	-	-2.2	-	-	-	-	-	-	-	-	-	-
	Business as usual	-	-	-	-	-	-	-	-	-	-	-	-
Lucerne	Revision 91/414/EEC (2c)	-	-	-	-	-	-	-	-	-	-	-	-
	WFD	-	-	-	-	-	-	-	-	-	-	-	-
	91/414/EEC & WFD	-	-	-	-	-	-	-	-	-	-	-	-
	Untreated	-	-	-	-	-	-	-	-	-	-	-	-
	Business as usual	-	-	-	-	-	-	-	-	-	-	-	-
Lupins	Revision 91/414/EEC (2c)	-	-	-	-	-	-	-	-	-	-	-	-
	WFD	-	-	-	-	-	-	-	-	-	-	-	-
	91/414/EEC & WFD	-	-	-	-	-	-	-	-	-	-	-	-
	Untreated	-	-	-	-	-	-	-	-	-	-	-	-
	Business as usual	-	-	-	-	-	-	-	-	-	-	-	-
Maize	Revision 91/414/EEC (2c)	-	-	-	-	-	-	-	-	-	-	-	-8.6
	WFD	-	-	-	-	-	-	-	-	-	-	-	-
	91/414/EEC & WFD	-	-	-	-	-	-	-	-	-	-	-	-8.6
	Untreated	-151.2	-	-	-	-	-	-	-6.7	-	-	-	-12.6
	Business as usual	-	-	-	-	-	-	-	-5.9	-	-	-	-9.4
Stubble turnips	Revision 91/414/EEC (2c)	-	-	-	-	-	-	-	-	-	-	-	-
	WFD	-	-	-	-	-	-	-	-	-	-	-	-
	91/414/EEC & WFD	-	-	-	-	-	-	-	-	-	-	-	-
	Untreated	-1.1	-1.8	-	-	-	-	-	-1.3	-	-	-	-
	Business as usual	-	-	-	-	-	-	-	-1.3	-	-	-	-
Kale	Revision 91/414/EEC (2c)	-	-	-	-	-	-	-	-	-	-	-	-
	WFD	-	-	-	-	-	-	-	-	-	-	-	-
	91/414/EEC & WFD	-	-	-	-	-	-	-	-	-	-	-	-
	Untreated	-	-	-	-	-	-	-	-	-	-	-	-
	Business as usual	-	-	-	-	-	-	-	-	-	-	-	-
Forage rape	Revision 91/414/EEC (2c)	-	-	-	-	-	-	-	-	-	-	-	-
	WFD	-	-	-	-	-	-	-	-	-	-	-	-
	91/414/EEC & WFD	-	-	-	-	-	-	-	-	-	-	-	-
	Untreated	-	-	-	-	-	-	-	-	-	-	-	-
	Business as usual	-	-	-	-	-	-	-	-	-	-	-	-
Fodder beet	Revision 91/414/EEC (2c)	-	-	-	-	-	-	-	-	-	-	-	-
	WFD	-	-	-	-	-	-	-	-	-	-	-	-
	91/414/EEC & WFD	-	-	-	-	-	-	-	-	-	-	-	-
	Untreated	-6.4	-	-	-	-	-	-	-	-	-	-	-
	Business as usual	-	-	-	-	-	-	-	-	-	-	-	-
Chicory	Revision 91/414/EEC (2c)	-	-	-	-	-	-	-	-	-	-	-	-
	WFD	-	-	-	-	-	-	-	-	-	-	-	-
	91/414/EEC & WFD	-	-	-	-	-	-	-	-	-	-	-	-
	Untreated	-	-13.1	-	-	-	-2.2	-	-	-	-	-	-
	Business as usual	-	-	-	-	-	-2.2	-	-	-	-	-	-

Table 9. Loss of value (M£) associated with pesticide availability in five scenarios, across pulse and cereal crops as a result of a range of weeds, pests and diseases.

Key orange >£500M lost, yellow £250-500M lost and pale yellow £100-250M lost

Losses to industry £M		Grass weeds	BLW	Volunteer OSR	Volunteer Potatoes	Pre harvest	Pea & bean weevil	Black bean aphid	Rust	Downy mildew	Leaf & pod spots (inc chololate spot)
Peas	Revision 91/414/EEC (2c)	-	-4	-	-	-	-	-	-	-	-
	WFD	-	-6	-	-	-	-	-	-	-	-1
	91/414/EEC & WFD	-	-9	-	-	-	-	-	-	-	-1
	Untreated	-1	-9	-	-	-2	-1	-6	-	-2	-6
	Business as usual	-	-	-	-	-	-	-	-	-	-
Beans	Revision 91/414/EEC (2c)	-	-6	-2	-	-	-	-	-	-	-
	WFD	-5	-9	-2	-	-	-	-	-	-	-
	91/414/EEC & WFD	-5	-13	-2	-	-	-	-	-	-	-
	Untreated	-7	-13	-2	-	-	-2	-4	-24	-	-15
	Business as usual	-2	-	-	-	-	-	-	-6	-	-6

Losses to industry £M		Grass weeds	BLW	WBF	Slugs	OWBM	All diseases
Feed Wheat	Revision 91/414/EEC (2c)	-173	-	-	-	-	-
	WFD	-406	-	-1	-21	-6	-
	91/414/EEC & WFD	-406	-	-1	-21	-6	-
	Untreated	-562	-324	-2	-24	-8	-685
	Business as usual	-43	-11	-	-2	-2	-132
Feed Barley	Revision 91/414/EEC (2c)	-31	-7	-	-	-	0
	WFD	-66	-	-	-3	-	-
	91/414/EEC & WFD	-69	-7	-	-3	-	-44
	Untreated	-72	-52	-	-59	-	-23
	Business as usual	-6	-2	-	-3	-	0
Oats	Revision 91/414/EEC (2c)	-	-	-	-	-	-
	WFD	-6	-	-	-	-	-
	91/414/EEC & WFD	-6	-	-	-	-	-
	Untreated	-6	-18	-	-	-	0
	Business as usual	-1	-2	-	-	-	-
OSR	Revision 91/414/EEC (2c)	-	-	-	-	-	-
	WFD	-70	-	-	-6	-	-
	91/414/EEC & WFD	-70	-	-	-6	-	-
	Untreated	-80	-55	-	-7	-	-
	Business as usual	-3	-7	-	-1	-	-

Table 10. Loss of value (£/ha) associated with pesticide availability in five scenarios, across forage and feed crops as a result of a range of weeds, pests and diseases. (-£50-£100, -£100-£200, -£200+ / ha)

Losses to £/ha		Weeds		Pests						Diseases						
Crop	Scenario	Grass weeds	BLW	Leather Jackets	Frit Fly	Wire Worm	Slugs	Flea Beetle	Aphids	All diseases	Rusts (inc Crown	Foliar Diseases	Viruses	Leaf Spots	Soil Borne diseases	Fusarium
Grass Permanent*	Revision 91/414/EEC (2c)															
	WFD		-10													
	91/414/EEC & WFD		-10													
	Untreated		-63	0	-4					-70						
	Business as usual			0	-4					-70						
Grass Temporary*	Revision 91/414/EEC (2c)															
	WFD		-15													
	91/414/EEC & WFD		-18													
	Untreated		-78	-9	-9		0				-129	-66	-62			
	Business as usual			-9	-9		0				-129	-61	-62			
White Clover ****	Revision 91/414/EEC (2c)															
	WFD		-180													
	91/414/EEC & WFD		-180													
	Untreated		-180									-66	-5			
	Business as usual											-66	-5			
Red Clover ****	Revision 91/414/EEC (2c)															
	WFD		-554													
	91/414/EEC & WFD		-554													
	Untreated		-554									-228				
	Business as usual											-185				
Lucerne ****	Revision 91/414/EEC (2c)															
	WFD		-250													
	91/414/EEC & WFD		-250													
	Untreated		-250									-156				
	Business as usual											-156				
Lupins***	Revision 91/414/EEC (2c)		-20													
	WFD		-20													
	91/414/EEC & WFD		-34													
	Untreated		-34										-16	-112		
	Business as usual												-16	-84		
Maize*	Revision 91/414/EEC (2c)											-6				-56
	WFD			0	0	0										
	91/414/EEC & WFD			0	0	0						-6				-56
	Untreated	-990		-1	-1	0	0					-44				-82
	Business as usual			0	0		0					-39				-61
Stubble turnips**	Revision 91/414/EEC (2c)															
	WFD	-15	-16	0												
	91/414/EEC & WFD	-15	-16	0												
	Untreated	-60	-96	0		-1		-10				-70	-15		-10	
	Business as usual			0		0		-2				-70	-15		-10	
Kale**	Revision 91/414/EEC (2c)	-21										-75				
	WFD	-43	-37													
	91/414/EEC & WFD	-43	-52									-75				
	Untreated	-43	-52	0			0	-7	-1			-122	-5		-8	
	Business as usual							-2	0			-54	-5		-8	
Forage rape**	Revision 91/414/EEC (2c)															
	WFD		-44													
	91/414/EEC & WFD		-44													
	Untreated		-44									-36	-5		-1	
	Business as usual											-36	-5		-1	
Fodder beet**	Revision 91/414/EEC (2c)										-4	-10				
	WFD		-5													
	91/414/EEC & WFD		-5								-4	-10				
	Untreated	-1108	-5	0				-1	-1		-87	-52	-20			
	Business as usual							-1	-1		-78	-42	-20			
Chicory ****	Revision 91/414/EEC (2c)															
	WFD															
	91/414/EEC & WFD															
	Untreated		-657							-110						
	Business as usual									-110						

5.3. Weeds

5.3.1. Permanent grassland

The economic impact of weeds in regularly defoliated grassland largely results from perennial weeds. Grazing and/or frequent cutting is an effective control mechanism for annual weeds, and unless grazing management results in an open damaged sward, competition from the grass and clover (where present), should keep annual weeds to a minimum. In some situations these 'weeds' can contribute a greater diversity of minerals than grass alone, increasing feed value of sward.

Effects of weed control during establishment are considered in temporary grass and not in this section.

Perennial weeds affect grassland productivity in three ways, shading (competition), interferance with utilisation and low palatability.

Weeds that shade, compete with grass and eventually kill it, resulting in an overall reduction in yield. Clumps of mature Bracken fall into this category. It produces a heavy shade in summer and blankets the ground with dead, slow rotting cover in the autumn, winter and early spring. The 263,000 ha under bracken in the UK[17] will produce little if any useful grass production (For further information about bracken see Appendix for further details on bracken control).

Interference with effective utilisation is caused by unpalatable weeds and their development of harsh low feed value canopies; thistles, nettles and some woody shrubs e.g. gorse are in this category. They also compete with grass when allowed to form dense clumps, although these are rarely as extensive as bracken. At lower levels they result in reduced levels of utilisation, whilst in dense clumps they can completely suppress the underlying grass in the same way as bracken. However, other than with gorse, the terrain rarely limits control efforts so extensive bracken style colonisation is rare.

Low palatability is a graded criterion and is increased by hunger, so less palatable weed grasses, like Yorkshire fog, and Buttercups can be consumed in times of shortage, by which time intake and productivity may already be reduced. The delayed intake of low palatability weeds often results in their lower digestibility. Buttercups are reputedly poisonous although little effect with significant intake has been reported[18]. Ragwort is a more real poisoning concern. This weed is listed under the Weeds Act[19], although unpalatable will be eaten in sufficient amounts to

[17] NERC 2008. Countryside Survey : UK Results from 2007. Bracken cover defined as continuous canopy >95% cover at height of seasonj.
[18] Cooper M.R, and Johnson, A.W. (1984) Poisonous Plants in Britain and their effects on Animal and Man. MAFF Reference Book 161. HMSO London.

[19] This Act applies to the following injurious weeds, spear thistle (*cirsium vulgare (Savi) Ten.*), creeping or field thistle (*cirsium arvense*(L.) Scop.), curled dock (*rumex crispus* L.), broad-leaved dock (*rumex obtusifolius* L.), and ragwort (*sensecio jacobaea* L.);

cause toxicity problems when other more preferable forage is in short supply. The persistence of its toxic principles ensures the hazard remains in stored forages. The economic loss due to low palatability of broadleaved weeds is difficult to determine due to the variability in their distribution, and the impact of the sward conditions at grazing.

Widespread weeds like docks are more complex in their impact. Their numbers can vary as the annual cycle of management varies the frequency of defoliation. They are grazed by stock and while *Rumex obtusifolius* has be shown to have relatively high Mg levels and can help reduce bloat, Courtney[20] (1978) estimated that although they were eaten they had only 65% of the feeding value of the surrounding sward. Thus in a field with a heavy infestation of 25% dock, the economic loss would be 8.75% using feed value as the measure.

The New Atlas of British Flora[21] confirms all the weed species mentioned in this section to be common and widespread. All the species can be found in virtually every 10km square covering the UK. Being widespread and common however does not mean they are causing widespread loss. Table 11 below, derived from PUS 2005, shows the relatively small areas of grassland treated with herbicides, but of this a relatively high proportion treated with at risk products.

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[20] Courtney, A.D. and Johnston, R. (1978). A Consideration of the contribution to production of Rumex obtusifolius in a grazing regime. In *Proceedings 1978 British Crop Protection Conference, Weeds.* 1, 325-339.
[21] Preston C.D., Pearman D.A., Dines T.D. (2002). New Atlas of the British Flora. Oxford.

Table 11. Percentage of grassland area (by category) treated with herbicides and the percentage area treated with 'at risk' products.

Type of grassland	Area treated with all herbicides as % of total area	Area treated with 'at risk' products as % of total area
New sown ley	2.87	2.23
2- 5 year leys	5.45	3.71
All grass < 5 years	8.32	5.94
Permanent pasture	9.06	7.28
Rough grazing	0.74	0.68

Broadleaved weeds could cause over 2.5M tonnes of lost production from forage if left untreated. This figure is based on the 9% of permanent pasture that is sprayed annually[3] all suffering a 50% yield loss if the area remained unsprayed. This is as a result of competition reducing yields and unpalatability of the resultant crop. Using the gross margin figures in Table 1, the total potential yield for permanent pastures is approximately 60M tonnes of grass, giving a total potential yield reduction in a situation with no pesticides of 4.5%. Under the Water Framework Directive and the revision of 91/414/EEC, it is the potential loss of MCPA, 2,4-D and clopyralid from WFD that would have the greatest effect. MCPA and 2,4-D are relatively cheap, clover safe active ingredients, if they were to be lost the cost of herbicide treatment would increase, which may discourage some growers from controlling certain areas of weeds on their land.

The presence of bracken on some rough grazing currently results in the loss of a potential 1.5M t of grass. In the absence of asulam, which has yet to gain annex 1 listing, this figure could increase to close to 2M t.

5.3.2. Temporary grassland

The main weed problems in temporary grass arise from weed competition at establishment. Sward establishment may be via direct reseeds, undersowing in cereals or through various improvement methods to in-situ swards. The impact of the loss of at risk products on leys at establishment could be as high as 50% loss of yield. Although a severe weed infestation of an autumn reseed may be killed off by winter frosts the damage is done by the suppression of the germinating grasses. In practice grazing the weedy reseed is the simplest way to over come this problem, but distant fields being reseeded for silage/hay production may not always be easy to graze as the most appropriate time.

There is little research literature on the effects of weed infestation on undersown leys. After the cereal harvest weeds in leys are still relatively small and the defoliation required to encourage tillering and a thicker sward will also remove many of the weeds. As a consequence early weed infestations have to be severe enough to survive this post-establishment management regime.

The selection of herbicides used on undersown cereals is made to target the main weeds present but if clover has been sown, clover safe herbicides are required. These products tend to be formulations of the clover safe hormone herbicides MCPB and 2,4-DB along with other active substances that are used in other crops at higher rates in products that are not clover safe. It is significant that the more popular product by far[22] on all new direct sown leys was the clover safe combination of 2,4-DB+linuron+MCPA , treating 44% of the total area sprayed. It was also the most popular product on undersown leys treating 35% of the area sown, indicating clover is considered to be of value and worth protecting in between one third and one half of newly sown grass swards.

The amount of clover in newly sown swards varies considerably. The financial value of mixed swards varies with different grass and clover content and with grass of different yield and quality potential (Appendix 5). Very high clover swards in systems with low fertiliser input are environmentally beneficial extensive systems with relatively low DM productivity per hectare. The yield levels of different grass and clover mixes are affected by DM losses of between 5 and 25%, dependant upon pesticide availability. On a per hectare basis the more intensive lower clover systems show greater losses (Figure 3). Extensive systems show lower losses and although by definition they are spread over a wider area to get the same productivity it is unlikely that losses due to weeds would be spread across the whole area. Although the losses at the highest clover content are low it is unlikely that UK livestock grazing requirments could be met if such a production system was universal.

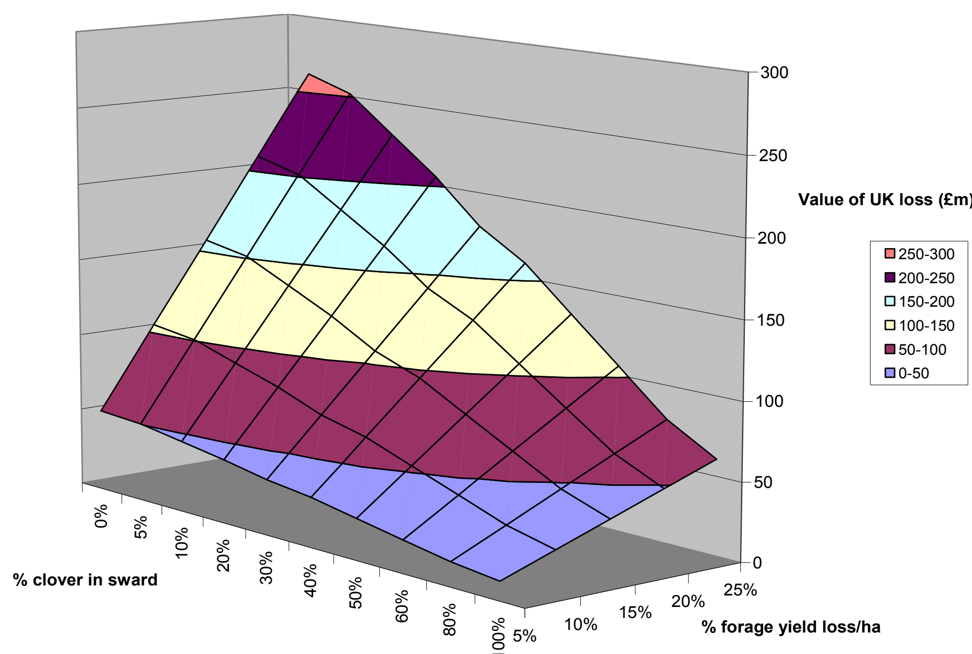

Figure 3. The effect of clover content on the value of production losses from UK temporary grass with varying amounts of clover (£M)

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[22] Pesticide Usage Survey. Grassland and Forage crops in Great Britain. 2005. The areas sprayed mentioned in this report from PUS data are 'spray hectares'. If 1 ha is sprayed twice with a product the area treated is 2 ha.

Reseeding to reduce perennial weed problems is one way of avoiding the economic consequences of high weed populations reducing yield and utilisation efficiency. However the ploughing and rotavation of mature perennial weeds can introduce greater numbers of weed fragments ready to regrow unless the plants are killed beforehand. Seventy percent of all glyphosate used on grassland is used on new direct sown leys prior to sowing. Undersown crops in part arable rotations will have smaller weed sizes following regular cultivation. The high use of glyphosate in direct sown leys can be seen as confirmation of the need to control perennial weeds. The potential losses attributable to untreated docks, thistles, buttercups and other broadleaved weeds are estimated at £89M based on 5.94% of the total short term grass receiving herbicide (Table 11). This is equivalent to 0.5M t DM of lost production.

The possible loss of glyphosate (to WFD) and glufosinate (to 91/414/EEC) means the two principal highly systemic, low residue, non-selective herbicides would be lost. In addition to the indirect affects arising from more docks, thistles and buttercups mentioned above farmers would face higher cultivation costs at reseeding to control perennial weeds and higher subsequent herbicide use. These have been set at a nominal value of £40 per hectare, equally split between agrochemical and cultivation costs. The difficulties in controlling weeds prior to sowing new leys would result in the potential for yield losses equalling approximately 100,000t DM of grass.

5.3.3. White clover : grass swards

White clover is rarely grown as a pure monoculture crop. High clover content increases the risk of bloat in ruminants particularly if there are abrupt changes in clover content of the swards on offer. In technical literature the Dairy Co suggest nitrogen fixed by clover can amount to at least 100kg N/ha[23] and in some cases up to 200 kg N/ha, with organic systems looking to an annual clover contribution of 30+ %. The loss calculations in the tables are associated with this crop are based on a 30:70 clover: temporary grass mix. It is arguable that this scenario may overstate the losses on a national basis because of the higher production levels. To some extent this can be viewed as offsetting future higher potential yields.

If clover saves 150 kg N/ha it is worth about £90 /ha per annum if 34% N costs £200 per tonne. As we have seen recently these savings can rise to £180 /ha when energy prices soar.

Establishment of clover requires pH around 6 – 6.5 with adequate phosphate and potash reserves so rhizobia can function efficiently and colonise newly emerged roots. As clover normally co-exists with grass and its leaf shape and growth habit complement that of grass weed infestations become a problem only when they are particularly heavy or the growth habit is not grass-like and competes with that of the clover. Dense infestations of low growing creeping weeds like chickweed and speedwell can compete with clover particularly on soils with high available nitrogen reserves. If long ungrazed or uncut grass becomes dominant, particularly where small leaved creeping forms of clover are planted, clover is suppressed in the same way as if weeds were involved.

[23] Milk Development Council (2003). Grass + Grassland Management Improvement Programme. 13. Managing Organic Swards - Legume Utilisation.

The main economic value of clover arises from its ability to reduce nitrogen fertiliser inputs. This is accomplished with some reduction in maximum output potential when compared with short term leys. If clover safe herbicides were to become unavailable post planting clover introduction would be required. If separate post planting clover introduction costs £30 – 40 per hectare for the extra machinery pass (depending on the type of machine used), the net saving of fertiliser costs would be reduced by about £7 per hectare if the extra costs were written off over 5 years. Post planting introduction of clover is not without problems as the delay in sowing means the clover can face cooling seedbeds with autumn planting and drier conditions with spring planting.

The active substances approved for white clover are shared with red clover and lucerne, with the exception of MCPB and asulam used as a single product (Table 12).

Table 12. Active substances approved for use on forage legumes

White clover	Red clover	Lucerne	Lupin (all SOLA - S)
2,4-DB	*2,4-DB* and MCPA	*2,4-DB*	*carbetamide*
2,4-DB and MCPA	*2,4-DB*	*carbetamide*	clomazone
asulam (S)	*carbetamide*	diquat (S)	cycloxydim
carbetamide	Diquat	fluazifop-P-butyl (S)	fluazifop-P-butyl
diquat	isoxaben	isoxaben	*glyphosate*
isoxaben	*MCPA and MCPB*	*propyzamide*	isoxaben + terbuthylazine
MCPA and MCPB	*propyzamide*	tri-allate	propaquizafop
MCPB	tri-allate		*pendimethalin*
propyzamide			pyridate (to Dec 2011)
tri-allate			tepraloxydim
			tri-allate

(*At risk substances in italics*)

If the products at risk from the revision of 91/414/EEC and WFD are eventually revoked they will have a significant impact on the way clover and legumes in general are introduced and managed in the UK forage sector. Of the above list only isoxaben will provide selective control of broadleaved weeds; tri-allate targeting grass weeds and diquat providing rapid desiccation of green crop canopy. If MCPA, MCPB, 2,4-DB and propyzamide were to be lost to Water Framework Directive this could result in around 600,000 t less clover available as forage. (The PUS data shows 3.46% of over 6 million hectares of permanent and temporary grass are treated with clover safe material. If clover makes up 30% of swards yielding 8 t DM/ha this level of clover loss would result if post planting introduction was not practiced). However, in most grassland crops the grass would compensate for the lost clover, with no overall loss of production expected (if nitrogen fixation was replaced with artifitial fertiliser).

If clover was not stitched in after non-clover safe herbicide applications were made the loss in value per hectare (including increased fertiliser requirements) would be about £180 /ha (Table 10). This could cost the industry £44.5M in additional nitrogen requirements.

5.3.4. *Red clover*

Like white clover, red clover is usually sown as a mixed sward with grass, the latter adding dry matter yield, and improving dry matter percentage, water soluble carbohydrate, digestibility and metabolisable energy. It tends to be sown in a higher proportion than white clover aiming for a high fresh weight yield. Upright and vigorous in growth it is well suited to cutting and is gaining popularity as a silage crop; grazing can damage the crop by trampling and damage to the plant crowns. It has good drought tolerance, so with the potential for dryer summers could be in increased demand.

The area of the crop is relatively low so the national economic impact of changes in herbicide availability is relatively low compared to the impacts on grass land. However, it is the future potential of the crop to provide high volumes of low cost forage, in the face of rising energy, where the impact could be felt the most. Red clover crops can be extremely vigorous and will co-exist with weeds. The main economic effect of weed infestation is therefore expressed as a reduction in the feed value and palatability of the feed.

As with white clover the main impact of changing legislation comes from the potential loss or restriction of use of MCPA, MCPB, 2,4-DB, propyzamide and carbetamide due to the WFD. Using an estimated red clover area of 4000ha the impacts of the losses of herbicides to the WFD could equate to 14,000 t DM of lost production, based on an average yield of 12t DM / ha this is equivalent to a 30% yield loss (Table 6). At a relative feed value of £154 / tDM, this is equivalent to an industry loss of approximately £2.2M annually in reduced feed value and increased fertiliser costs. The lower proportion of grass in the sward means that unlike white clover mixes it is more difficult of the grass to compensate for the lost clover content of the sward.

5.3.5. *Lucerne*

Deep rooting lucerne is capable of yielding high tonnages of forage in areas of only moderate rainfall. The requirements for its successful establishment and management make it particularly useful on mixed arable and livestock farms. One of the largest concentrations of the crop is in South Essex where the crop is grown for a crop drying operation.

The herbicide options (Table 9) are very limited and with the potential loss of actives lucerne will be very reliant on the effective control of weeds elsewhere in the rotation. As lucerne is perennial and has a dormant period during the winter some green weeds can be removed by the use of diquat (off-label) when the plants are inactive. Other approved herbicides are for use in the establishment phase and offer the control of young weeds. Cutting, grazing and the growing of weed suppressing companion grasses all help control weeds in the established crop. Once perennial weeds or lower crop productivity become a problem the crop is ploughed out and the field returned to the arable rotation.

Due to losses of herbicides as a result of Water Framework Directive the level of control of broad leaved weeds drops to a level similar to that of untreated crops, with a 10% yield loss on average due to build up of perennial weeds. If it is assumed that rotations have to be shortened from 5 years to 3 years there is also an increased cost associated with establishing the crop more regularly increasing the cost per year of drilling, cultivation and seed. Seed cost for 1 ha is £130 (Nix, 2009) and drilling costs based on conventional drilling plus one cultivation are £78. If these occur one in five years the cost per ha per year would be £42, if done every 3 years this woudld increase to £70 per ha per year.

Lucerne is a drought tolerant crop, so is suited to drier areas of the country. With the potential for hotter drier summers as a result of climate change this crop may grow in popularity, if it is possible to produce weed feed crops economically. The loss of important herbicides to WFD could make this option of a drought tolerant forage crop less cost effective.

5.3.6. Field Peas

At present good levels of control for most weed species are achievable in dry harvested peas with two to three applications of herbicide per crop. Typically a pre-emergence residual herbicide is applied, such as pendimethalin (or prior to its loss of approval trifluralin), this is then followed by post emergence herbicides such as bentazone or MCPB, although there is a good range of herbicides available. The main problems with weeds come as a result of competition during the early establishment phase of the crop, which can have yield implications. Where peas are grown in close rotation with oilseed rape, volunteers can become a problem as these are highly competitive with the young plants and cause harvesting difficulties. Once the crop is established its rapid growth means that it is able to compete with weeds. However, surviving weeds can cause problems when it comes to harvesting the crop. Green weeds at harvest can cause blockages and delay harvest, whilst weeds with seeds or seed pods of a similar size to the peas can cause contamination of the feed.

Loss of pendimethalin under the revision of 91/414/EEC and bentazone, glyphosate and MCPB under Water Framework Directive will all impact upon the cost of production of dry harvested peas. In combination the losses from the revision of 91/414/EEC and WFD could result in costs to the industry similar to those seen in untreated situations. Increased use of precision weeding equipment would be required to control weed levels, at £20 per ha per pass this can add considerable costs to the production of pea crops – potentially £9M to the industry. This would drive up the cost of home produced protein crops.

The changes in herbicide availability will cause a reduction in yield of dry harvested peas, despite the use of mechanical weeding (Table 6). The losses are larger for Water Framework Directive (25%) than for the revision of 91/414/EEC (17%), although if the losses from WFD and the revision of 91/414/EEC are combined the total yield losses could be close to those seen in untreated crops (30% of total production).

5.3.7. Field Beans

Beans are often grown in arable rotations with cereal crops. As a result there are a proportion of winter bean crops that are grown on land that has high levels of black-grass present on it. Whitehead and Wright[24] estimated that about 40% of UK arable fields contain black-grass. Other grass weeds that affect arable land include rye-grass, wild oats and annual meadow grass. Grass weeds are currently controlled through the use of propyzamide and carbetamide, as well as some of the older 'fop' and 'dim' herbicides where resistance is not a problem. The loss of herbicides to WFD, including propyzamide and carbetamide, would lead to a reduction in the level of control of grass weeds in bean crops. These plants would compete with the field beans resulting in potential losses of production close to 30% of current levels (Table 6).

Broadleaved weeds are potentially more of a threat to field bean production than grass weeds. Pre-emergence herbicide applications are key to maintaining good levels of control as only bentazone has approval for control of weeds post emergence in beans. This is a relatively expensive chemical and has a limited spectrum of control. The loss of pendimethalin and linuron pre-emergence under the revision of 91/414/EEC would result in a reduced level of control from pre emergence herbicides potentially reducing the total production of beans by 10% (Table 6). The potential loss of bentazone to WFD would remove all post-emergence control options for broadleaved weeds. Combined with the loss of actives to the revision of 91/414/EEC this reduces production by up to 15%. This would reduce the availability of beans as a protein source for livestock feeds.

5.3.8. Lupins

The area of lupins in the UK is small at around 6000 hectares[25] the majority being sown in mixtures with cereals. Over recent years there has been a swing from production in the arable sector as a combinable protein crop, to production in the livestock sector as a high protein forage crop generally in a mix with spring sown cereals. This switch has made the end-user livestock producers less reliant on combine harvesting to secure the crop.

All the active substances available in herbicides for use on lupins are available under Specific off-label approval (SOLA) so are dependent on these products being available under full approval for other crops and for continued approval under SOLA arrangements. The crop provides effective weed suppression when sown in mixes with cereals provided weeds are controlled in the establishment phase. The loss of broad spectrum pre-emergence weed control from pendimethalin (revision of 91/414/EEC) and carbetamide (WFD) will impact both on the yield potential and feed quality of some crops. It is assumed this effect could amount to 10% of the output, on the basis that growers will seek to minimise the impact through stale seedbeds and switching to alternative active ingredients. The feed value and costs are based on the crop being harvested as a whole crop mix with cereal. The loss of actives to

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[24] Whitehead R.& Wright HC.(1989) The Incidence of weeds in winter cereals in Great Britain. *Brighton Crop Protection Conference - Weeds – 1989,* **1**, pp107-118.

[25] D McNaughton, Soya UK Ltd

the revision of 91/414/EEC or WFD, separately, would result in increased numbers of broadleaved weeds in the crop, reducing the feed value of the resulting crop. This loss of feed value could cost the industry £120,000 (Table 8). If the potential losses of actives from WFD and revision of 91/414/EEC are combined this could result in feed values falling further with greater levels of contamination, costing just over £200,000 to the industry. Actual yield losses would be small as the weeds present would bulk up the harvested crop, giving a similar yield of a poorer quality crop.

5.3.9. Forage Maize

In the 2005 PUS 26% of all herbicides used on grass and forage crops were applied to maize yet the crop only made up 1.24% of the total area of grass, forage and rough grazing land. Of the area treated 55% was with products that have since been withdrawn (atrazine) or others likely to be lost from the revision of approval criteria in 91/414/EEC or WFD compliance.

The environmental footprint of the triazine herbicides had been under review for some time and as a consequence a range of new products have appeared. Since the revocation of atrazine in 2005 the area of forage maize has risen by 11% suggesting that the supply of replacement herbicides has been more than sufficient to fill the significant gap in the market. Given this track record, the global nature of the crop and its market pull for new products we forecast there will be little or no economic loss[26] due to compliance with revised approval criteria or WFD compliance.

Uncontrolled grass weeds have the potential to cause large yield losses in the maize crop, however the actives that are currently available provide good levels of control, and it is likely that this level of control can be achieved even with the changes in legislation.

5.3.10. Stubble turnips

Stubble turnips are the most popular stock feed crop in the country and are either spring grown after an early forage crop like rye, or late summer sown after the cereal harvest. Fast growing, they produce a high fresh weight yield in about 3 months. In many cases they are grown with a minimum of inputs. Grass weeds or cereal volunteers can be sufficiently dense to swamp the newly emerging crop if no pre-emergence herbicides have been used. However it can be more cost-effective to see how the crop and weeds germinate and clear up the grass weeds and cereal volunteers with a post-emergence graminicide.

The PUS data for 2005 showed a herbicide treated area of 7,881 hectares out of a national area of about 24,000 hectares. Glyphosate was used on 23% of the treated area, and propaquizafop (graminicide) on 63% of the treated area. If glyphosate is lost as consequence of the WFD the stubbles are likely to carry a higher burden of weeds and as a consequence more selective herbicides may be used on the 1800 hectares involved. This could add around an estimated, £25 /ha depending on the extra product used. This combined with a slight yield loss and reduced feed value

[26] Spray cost in 2004 and 2009 are estimated at £34/ha and £37/ha respectively despite the replacement of atrazine with more modern products. (Nix Farm Management Pocketbook)

would potentially cost the industry £300,000. Catch crops grow rapidly and when sown into stubbles or old grass prior to reseeding weed competition grows along with the crop and adds to the green matter to be grazed, this reduces the impact of weeds on yield losses. The potential loss of production, as a result of herbicide losses to the water framework directive, is 2.6% from broadleaved weeds and grass weeds combined.

5.3.11. Kale and forage rape

The area of kale, forage rape and other leafy forage brassicas is the smallest of the crop types considered. The total area of forage brassicas in 2005 was 10,266 hectares with a sprayed area of 6,222 hectares (61%) recorded by the PUS. The loss of products actually used in this sector is profound and were it not for the small area involved it would have a significant impact on national output.

Table 13. Active substances used on forage brassicas

Active substance	**Area treated**
Glyphosate	*2,044*
Trifluralin	*2,051*
Metazachlor	*1,769*
Other	357
Total	6,222

(*Substances with approvals at risk from revision of 91/414/EEC or WFD in italics*)

Substances at risk from revision of 91/414/EEC or WFD are used on at least 94% of the treated area. It is possible that other at risk substances are included in the 357 hectares treated with ‘other’ active substances.

In addition to the above actives which were shown to be in use in the last PUS propachlor, chlorthal-dimethyl, napropamide, clomazone and pyridate are approved for use on one or all of the brassica crops, along with the graminicides fluazifop-P-butyl, tepraloxydim and cycloxydim. Given the relatively small areas involved and the range of alternative products available the loss of the most popular actives may result in a switch to alternative products and for some, a switch out of the brassicas as stock feed crops. The level of weed control possible with these alternative active ingredients would result in a potential 6.1% reduction in production.

5.3.12. Fodder beet

As a close relation to sugar beet, fodder beet benefits from the large investment in the development of herbicides for the sugar crop. The crops are vulnerable to weed incursion during the early growth stages when repeat low dose herbicides applications are a popular method of providing sustained weed suppression. This repeat spraying is evident from the spray area of 31,914 hectares on a national crop area of just 7,495 hectares; an average of just over 4 separate applications per crop. If herbicides were not available crops losses due to weed competition could amount to over 65,000t DM, or 6.1%. However, despite some losses to the revision of

91/414/EEC and WFD levels of weed control should be sufficient to prevent yield losses.

There are a large number of products (Appendix 2) available for use on fodder beet and relatively few are affected by the change in regulations. The loss of glyphosate and clopyralid will affect pre-drilling weed control and thistle control respectively. The treated area for the two actives in the 2005 PUS was only 2.7% and 3.9% of the total. The economic impact is this likely to be small (Table 8) and should be covered by the use of alternative products.

5.3.13. Chicory

In the UK chicory has been shown to give good lamb growth rates[27] whilst in the US it gave similar or lower live weight gains to pure cocksfoot stands[28]. Autumn sown in mixes with up to 40% of the seed weight or added to existing grass mixes at 1- 2.5 kg/ha establishes palatable swards from spring grazing.

Getting accurate figures for the area of chicory is difficult as its use is randomly spread and its persistence is variable. The available herbicides for use in Chicory are similarly sparse with only three specific off-label approvals for asulam, triflusulfuron-methyl and fluazifop-P-butyl. The last two are targeted at grass weeds as well as general weed control. Asulam provides control of docks and is clover safe on established plants. None of these products are scheduled for revocation under either legislation revision or the WFD although asulam has yet to gain Annex 1 approval under the current 91/414/EEC legislation.

The economic impact of the changes on those growing chicory will be minimal.

5.3.14. Peas and beans

The loss of pendimethalin and linuron to the revison of 91/414/EEC will make the control of broadlevaved weeds, and oilseed rape volunteers more difficult in peas and beans, with potential losses of production ranging from 10-20%. This is exacerbated by the loss of propyzamide and carbetamide to the WFD, with production losses of 30% in peas and 15% in beans possible as a result of increased competition and problems at combining.

5.3.15. Wheat, Barley and Oats

Wheat, barley and oats are important in livestock rations. The impacts of pesticide legislation on the production of these crops have been investigated in HGCA Research Review 70. About 40% of the cereal crops in the UK are grown on land that is infested with black-grass. The revision of 91/414/EEC will result in the loss of pendimethalin. This is an important pre-emergence herbicide used for the control of black-grass and as part of an anti-resistance strategy. This will weaken the level of control that is achievable in cereal crops. An important part of the control of black-

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[27] Newton Rigg research at http://www.cumbria.ac.uk/AboutUs/News/Press%20Releases/2008/April/PR313.aspx

[28] K E. Turner*, D P. Belesky and J M. Fedders (1999) Agron J 91:445-450 . Chicory Effects on Lamb Weight Gain and Rate of In Vitro Organic Matter and Fiber Disappearance

grass in cereals is the herbicides that are applied during the break crop phase. On the majority of arable farms the main break crop is oilseed rape, and the black-grass control is carried out using either propyzamide or carbetamide, both of which are under threat due to detection in water. If these herbicides were lost it would make the production of cereals on black-grass infested land more costly, with reduced yields. Production of wheat could fall by 3M tonnes and barley by 0.5M tonnes if areas remained the same. Grain is a world commodity and prices are driven by world supply and demand, however there may be a local UK effect on feed grain prices if availability was limited. With lower yield per hectare there is the potential that greater areas of land will be required to produce the same amount of wheat and barley.

5.3.16. Oilseed rape

Oilseed rape meal is a useful cheep source of protein in livestock feed rations it is produced as a bi-product of oil production. The impacts of pesticide legislation on the production of these crops have been investigated in HGCA Research Review 70, Oilseed rape is grown in roation with cereals and as a result is affected by similar weed species and distributionis as cereals. However, a different range of herbicides are available on oilseed rapecompared to cereals. For the control of black-grass there are three main herbicides that are used propyzamide, carbetamide, and metazachlor. These herbicides are typically very effective at controlling black-grass as there is little known resistance to these active ingredients. This means that oilseed rape can serve as a good cleaning crop in cereal rotations to reduce the level of black-grass seed return, prior to drilling cereals. Under the revision of 91/414/EEC there is little effect on the herbicides available for use on oilseed rape, however WFD could potentially have far more serious consiquences.

All three of the main herbicides targeted at black-grass control in oilseed rape are already being detected in water. This means that there is a risk that resistrictions, or ultimately loss of approveal could occur in order to protect water. If approval for all three herbicides was lost this would make black-grass control in oilseed rape almost impossible, with potential yield losses of 30-40%, in affected fields. The redction in yield could potentially make the production of oilseedrape, on black-grass infected sites, unviable, resulting in a restructuring of the current arable rotations. There will also be an impact on the cereal crops as the loss of good herbicides in oilseed rape would reduce the ability to control black-grass in the following cereal crops, with resultant yield impacts.

The reduced availability of oilseed rape as a result of reduced area would result in a decrease in the availability of UK grown protein for inclucsion in livestock rations. This could lead to an increased dependence on imported soya protein.

5.4. Pests

5.4.1. Pests of grass and forage crops

There is limited documentary evidence of the impact of pest species on grass and forage crops. “Control of pests and diseases of grass and forage crops” (Anon,

1985) MAFF booklet[29] provides some detail, and much of the information in this section is taken from that source.

In general, the ability of established grass to produce new tillers means that it rarely suffers obvious losses from pests. For grass leys and stock feed crops the effect can be much more serious with a crop potentially being wiped out. The impact of pests, as with other crops, is usually during establishment. However, even taking into account the considerable damage that could occur at this stage the average annual effect of pests on grass and forage crops is unlikely to result in significant use of pesticides.

5.4.2. Permanent grassland

Due to large plant populations and the lower standards by which farmers judge this crop, pest attacks can often be overlooked. Damage to established swards can be obvious (e.g. that caused by leatherjackets) but is often insidious (e.g. that caused by frit fly) and usually results in the decline of the proportion of ryegrasses in a sward[30].

Many species of aphids can be found on established grass but only one species is usually responsible for damage. This is the fescue or grass aphid. Populations often increase after mild, open winters and the resulting migration to grasses and sometimes cereals can be serious. Aphids are unlikely ever to be controlled in permanent grassland.

The grubs of five species of chafer beetle are pests of local importance in Britain. The species which is most widespread and the most troublesome in grassland is the garden chafer[31]. Damage appears in September and October but, generally, more than 50/m^2 chafer grubs must be present in the soil before damage becomes evident. Control measures are rarely if ever applied.

Although frit fly is usually considered to be a pest of re-seeded grass it can cause damage, particularly to ryegrass in established pastures. This either results in the decline of the proportion of ryegrass in a sward or reduces the persistency of some medium-term leys. Only a very limited area of crop is treated against this pest.

Damage by leatherjackets to established grass may result in clearly defined patches. However, in other cases the first signs are either dry-looking areas of grass debris or ‘clod pulling’ by livestock and birds. Often attacks remain undetected until the flush of spring growth reveals patches of greatly reduced vigour. Only 0.01% of the crop is treated. Cultivation and any aid to establishment will limit damage.

It is estimated that leather jackets and frit fly could cost the industry £2.5M and £25M respectively in lost feed value (at £140/t). This is based on leather jackets causing a 5% yield reduction on 1% of the permanent grass land area and frit fly causing a 5% yield reduction on 6% of the permanent grassland area.

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[29] Anon (1985) Control of pests and diseases of grass and forage crops. MAFF (Publications), Alnwick, Northumberland. Booklet 2045 84pp.
[30] Clements R O (1980) Grassland pests – an unseen enemy. *Outlook on Agriculture* **10**: 219-223.
[31] Raw F (1952) The ecology of the garden chafer Phyllopertha horticola with preliminary observations on control measures. *Bulletin of Entomological Research* **42**: 605-646

5.4.3. Temporary grassland

There are four main pests which may be important during establishment: frit fly, leatherjackets, wireworms and slugs, but occasionally minor pests may become significant.

There are, normally, three generation of frit fly per year but, on grass, egg laying may be almost continuous due to an overlap of generations. Damage to re-seeded grass usually occurs in autumn, but spring-sown leys may also suffer[32]. Attacked plants are stunted with the usual yellow 'deadheart' tiller symptoms. The most severe attacks have occurred on direct-drilled crops, but many crops following traditional cultivations have also suffered, except where a six-week interval had been left between ploughing and sowing. Crops emerging before the end of September may be susceptible to direct egg laying. All ryegrasses (especially Italian varieties) and meadow fescues are the main cultivated grass hosts. Only a limited area of crop is treated against frit fly.

Leatherjackets feed through the autumn and winter during mild weather, causing damage to re-seeded grass, especially later-sown crops[33]. Usually they attack young plants, biting off the stems at or just below ground level. Only 0.6% of the crop area is treated against this pest.

Grassland is the natural habitat of wireworms and the largest infestations occur in old pasture. When permanent grass (at least five years old) is broken up or desiccated the re-seeded grass is liable to be damaged. At first the wireworms may feed on the dying turf, but then they will attack the young plants. Damage often becomes more serious in the second or third years of the new sward. Good cultivations will reduce the population.

Slugs are particularly active in wet seasons and most damage occurs in the autumn and mild periods during the winter. They are more or less confined as serious pests to the heavier soils, being most numerous where drainage is poor and the soil rich in organic matter. Only 0.3% of the crop is treated against slugs.

A range of other pests can damage temporary grassland. These include wheat flea beetle, wheat shoot beetle, grass and cereal flies, grass and crambid moths and common rustic moth. In general, there is little if any pesticide applied against these pests.

5.4.4. Forage legumes

As the national crops of lucerne, sainfoin and vetches are relatively small, this section deals primarily with red and white clover. In general, pests are not considered a major problem.

Several species of aphid occur on clover. Of these the pelargonium aphid, the pea aphid the leaf-curling plum aphid and the vetch aphid are most commonly found in large numbers. The injury caused by aphids is twofold: plant vigour is lowered by the

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[32] Clements R O (1979) Factors affecting the incidence of stem-boring Diptera in agricultural grassland and their effect on yield. PhD Thesis University of Reading

[33] Jones F G W, Jones M G (1974) Pests of field crops. Edward Arnold, London, 406pp.

removal of plant sap, while the wound in the leaf tissue may allow fungal diseases to cause secondary damage. Aphids rarely if ever warrant control.

As with grass seedlings, leatherjackets and wireworms may damage clover seedlings at establishment. The most serious damage is caused during spring and early summer.

The pea and bean weevil and other *Sitona* species are common in clover crops, where both adults and larvae may be important[34]. Adults of the narrower pear-shaped clover seed weevils may also be encountered. Although they make small holes in the young leaves and flowers they are of little direct significance. Damage by adult *Sitona* weevils consists of notching on the margins of the leaves. Seedlings are particularly susceptible to this type of defoliation. The larvae can eat a considerable proportion of the root nodules of legume crops. There are no chemical control options for forage legumes.

Clover cyst nematode is widely distributed and has been associated with the loss of white clover from swards. Damage can remain symptomless but, plants may become chlorotic or even stunted, particularly when under stress from other factors. Chemical control is not used against this pest.

Stem nematode (*Ditylenchus dipsaci*) can be responsible for serious losses in red clover crops where it is known as 'clover sickness'[35]. 'Races' or 'strains' of the nematode exist. These may be specific to a plant species. The red clover race damages red clover and kidney vetch, the white clover race damages white clover but not red clover, and the lucerne race severely damages lucerne and alsike clover but not red or white clovers. The symptoms differ with the species of forage legume affected. The effects of infestation are usually seen at the seedling stage when a characteristic swelling appears on the stem below the seed leaves. Young seedlings may be killed and patches produced within the crop. Control of stem nematode usually involves resistant varieties. Chemicals are rarely if ever used.

On heavy soils in wet seasons, slugs can severely thin newly germinated crops. Young seedlings are attacked underground and at soil level in the spring and autumn. The leaves of established plants may be grazed, particularly in the autumn, but damage is not usually economically important. There is no evidence of significant levels of use of slug pellets against slugs in forage legumes.

5.4.5. Maize

Frit fly is potentially a serious pest of maize. However, its importance varies greatly from year to year depending not only on the abundance of the adult flies but also on the growing conditions of the crop after the period of egg laying in late May and early June. In practice only 2% of the crop is treated.

Slugs are potentially damaging to maize during the establishment phase but only about 1.6% of crops are treated.

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[34] Gratwick M (1992) Pea, bean and clover weevils and Pests of grass and clover seed crops. In *Crop Pests in the UK. Collected edition of MAFF leaflets.* Chapman & Hall London pp190-199.
[35] Southey J F (1982) Plant Nematology. HMSO London. 440pp

Leatherjackets and wireworms will damage virtually any young plant. Maize is no exception and, owing to the small plant populations, serious damage may result even where small numbers of the pests are present. These insects tend to be a problem only where maize is grown after grass. Leatherjackets are most likely to be damaging in the spring where grass was present during the previous autumn. However, wireworm damage may occur up to four years after the previous grass crop. Despite the potential for damage only about 2% of the crop is treated against both of these pests.

5.4.6. Forage brassicas

In this section brassicas include appin, cabbage, fodder beet, fodder radish, fodder rape, kale, mangels, swede and turnip. Many pests can attack brassicas grown for fodder. In normal circumstances most of these pests will be of little significance except where the crops are precision grown in a maximum yield plan.

Two aphid species commonly occur on forage brassicas: the cabbage aphid and the peach-potato aphid. In some years the cabbage aphid causes serious losses to brassicas including forage crops but not turnips.

The peach-potato aphid is most important as a vector of viruses (e.g. cauliflower mosaic virus in brassicas and a range of viruses in other crops) but may also become numerous on brassica crops, particularly in hot years. In years when peach-potato aphids are numerous on fodder crops, treatment can increase yield by up to 10 tonnes/ha. In practice, about 4.5% of the area of kale and about 8.2% of the area of fodder beet are treated. Despite the losses of insecticides to 91/414/EEC and WFD there will be little impact on the control of aphids as plenty of alternative insecticides are available and losses without pesticides are, on average, relatively small (1-2% yield loss on affected crops).

The cabbage root fly is most important on horticultural crops[36] but cabbage grown for fodder is also liable to be seriously attacked. Where farmers grow swedes or turnips primarily for fodder, but with the option of selling some for culinary use, control measures will be necessary. Plants can be attacked at all stages of growth but the most serious damage is usually done to young plants, which can be killed if severely attacked in the seedbed. The heaviest attacks occur during May and June. Damage is caused by the larvae which feed on the roots of the plants. The best form of cultural control is to plant crops out of phase with the main egg-laying period of the flies. Very little if any insecticide is used against cabbage root fly.

Several species of butterflies and moths can be pests of forage brassicas. Those found most commonly are the caterpillars of cabbage white butterflies, cabbage moth and the diamond-back moth. Treatments are rarely applied against caterpillars.

Flea beetles (also known as turnip ‘fly’) are perhaps the best known of the forage brassica pests. There are many species of flea beetle and a wide range of crops may be attacked, but the small striped flea beetle is the most common. Beet and mangels are seldom damaged as seriously as brassicas.

[36] McKinlay R G (1992) Vegetable crop pests. Macmillan Press, London. 406pp.

Most species of flea beetle overwinter as adults and emerge in the spring to feed on any suitable plants. The adults survive until July or August when beetles of the next generation replace them. On warm days the beetles fly considerable distances, collecting on newly sown host crops as soon as these appear above ground. The main damage is done by the adult beetles eating holes in the leaves and stems of seedling plants, starting just before the seed leaves appear above ground. Hence the damage is often confused with germination problems. Plants are still attacked after the first true (rough) leaf has been produced but, unless growth is checked by drought or frost, or the beetles are very numerous, attacks become progressively less damaging. Damage to seedling leaves at an early stage can often lead to gross distortion. Losses are usually greatest in dry springs when seedlings are checked. Seedlings may be destroyed over a large area of the crop unless preventive control measures are taken. About 11.5% of the area of stubble turnips, 14.3% of the area of kale and 1.4% of the area of fodder beet are treated. Despite treatments there is still a slight loss of yield on affected crops, which costs the industry an estimated £57,000 in lost feed value. The reduction in pesticide availability due to changes in legislation will not have an effect on the level of control achieved on flea beetle.

Slugs can cause damage to seedling brassicas by eating leaves, stems or even the seeds. Control can be achieved by using molluscicide pellets. About 1.4% of the area of kale is treated against slugs. Leatherjackets may also occasionally damage seedling brassicas, cutting them off at soil level. Leatherjackets are easily controlled using a high-volume spray of an appropriate insecticide. A total of 0.9% of the area of kale and 1.4% of the area of fodder beet is treated against leatherjackets.

Wireworms can be a problem after grass and 4% of the stubble turnip area is treated to prevent damage to seedlings. Nematodes can be damaging in light, sandy soils and 3.3% of the area of fodder beet is treated.

With currently available pesticides, and the current level of usage it is estimated that the potential lost feed value, due to pest attack on forage brassicas, could be costing the industry £76,000. However, if no pesticides were used or available the cost in lost feed value could rise as high as £244,000. Under the current proposed revisions of 91/414/EEC and WFD there would be sufficient insecticides left to maintain the level of control that is obtained at present.

5.4.7. Peas and beans

The level of pest control acheiveable in peas and beans will not be affected by the changes in legislation unless significant numbers of insecticides are lost to WFD.

5.4.8. Wheat, barley, oats and oilseeds

The revision of 91/414/EEC will result in a reduction in the number of pyrethoid insecticides available, however, there remain plenty of alternatives so pest control in cereals and oilseeds will remain possible at levels similar to those currently acheiveable.

Under the WFD all insecticides could come under pressure as due to their very nature they tend to harmful to aquatic organisms. If resistrictions to the use of insecticides were put in place, or if approvals were revoked it could significantly reduce the ability to control pests in cereals and oilseeds. However, as the pest attacks tend to be patchy yield losses would be limited except in particularly bad pest years.

The more significant pest problem could come about as a result of the loss of metaldehyde to the WFD. Metaldehyde is already under scrutiny due to its recent detection in water at levels exceeding those set out in the Drinking Water Directive. If the approval for metaldehyde was revoked it would result in growers having to use the more expensive methiocarb to control slugs. If a similar area was treated with methiocarb as metaldehyde it is likely that methiocarb would start to be detected in water. Despite the ability to substitute with methiocarb there is the likelihood that the level of control acheiveable will be less, with increased grazing damage expected during establishment.

5.5. Diseases

5.5.1. Permanent grassland

The impact of diseases on permanent pasture is poorly documented. Swards are more diverse in species than in short-term leys but diseases affecting the foliage and roots are still likely to cause some loss of yield and palatability. The range of diseases found is similar to that reported for short-term grass crops (in the next section) but may be more heterogeneous, with small losses from a wider range of pathogens. *Drechslera* spp. and crown rust have been reported late in the season[37]. Fungicides are expected to improve productivity, but some of the limited work to date did not achieve good control [20] and only 2 out of 16 sites gave significant yield responses. Some of the newer azole and strobilurin fungicides may well provide larger responses, though there has been negligible fungicide use historically. It is estimated that disease could be reducing yields by 5%, causing losses on permanent pasture of up to 3M tDM, this is potentially worth £422M to the industry if this disease was controlled. However, these losses arise from a range of diseases with effects which vary in time of infection, severity and appropriate treatment; some of which are fungal and some viral in origin, all interacting differently with the grass and with its management system. The losses thus are due to a disease complex rather than one single cause, and while the losses may be very significant further research is needed before effective treatments can be consider routinely worthwhile.

5.5.2. Temporary grassland

Grassland less than 5 years old extended to 1.06 million hectares in 2005 when the last pesticide usage survey on grass and forage crops was under taken. The young grass leys produced are the most disease prone of grassland types as crops are grown in pure stands with high fertility to produce high yields. They are affected by several common foliar diseases and fungicide treatments are sometimes required to control them. Fungicides were applied to 10,000ha of new sown leys and to 9,300 ha of grassland that was 2-5 years old. A further 42,000ha of undersown leys would

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[37] Clements RO, Murray PJ, Bentlley BR, Lewis GC, French N, 1990. The impact of pests and diseases on the herbage yield of permanent grassland at eight sites in England and Wales. *Annals of applied Biology* **117**: 349-357.

have received some fungicide that was applied primarily for the benefit of the covering cereal crop, mainly spring barley[38]. Thiram was the main fungicide seed treatment, though the area treated was modest at less than 30,000ha. No fungicides were used on permanent pasture and overall 92% of grassland remained untreated. The most widely used fungicides used included azoxystrobin alone and in mixtures, epoxiconazole and prothioconazole. On direct sown leys azoxystrobin and epoxiconazole were the most frequently used fungicides in 2005.

Epoxiconazole is due to be lost to the revision of 91/414/EEC, however there are alternative triazole fungicides that could be used, such as prothioconazole.

Where crown rust is a severe problem in late summer and early autumn, grass forage is unpalatable to stock and replacement feed stocks may need to be purchased. Crown rust was previously considered a problem of the south and west but is has been northwards in recent years. Brown rust is also a widespread disease particularly on Italian ryegrass in spring and early summer. It is more damaging where crops are cut for conservation. Stem rust is sometimes severe on perennial ryegrass in hot summers. The reduced palatability and therefore loss of feed value, plus loss of yield could equate to £147M in lost feed values as a result of untreated rust on temporary grass (Table 8).

Severe powdery mildew affecting 30% leaf area reduced the D value by 1.4 units at first conservation cut, whilst 20% crown rust reduced water soluble carbohydrate level by 3.4 units[39]. Dry matter yield reductions range from 5-20% for mildew, Drechslera leaf spot and Rhynchosporium. Drechslera leaf spots affect ryegrass, meadow fescue, cocksfoot and timothy reducing yield and quality. They can be controlled with azole fungicides such as propiconazole. Rhynchosporium can also be controlled by azole fungicides and resistant varieties of Italian ryegrass are available. Rhynchosporium also affects cocksfoot. Although some foliar diseases on temporary grassland are treated with fungicides they still cost the industry an estimated £69M in lost feed value. In the absence of control it is estimated that this figure would rise to £75M in lost feed value.

Viruses such as barley yellow dwarf virus (BYDV) and ryegrass mosaic virus (RgMV). Some Italian ryegrass cultivars have resistance to RgMV. Where resistant cultivars are not used the potential yield losses as a result of viral attack could result in lost feed value worth £71M (Table 8).

Seedling diseases caused by *Fusarium* spp. and *Pythium* spp. can seriously affect establishment. Seed treatment with thiram and careful seed-bed preparation are key factors in their control. Thiram is currently expected to remain available after legislative changes so the level of seedling disease control should remain unaffected.

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[38] Garthwaite DG, Thomas MR, Anderson HM, Battersby A, 2006. Pesticide usage Survey Report 210 Grassland and Fodder Crops in Great Britain 2005 (including Aerial Applications 203-2005). Defra Publications, London.

[39] Thomas JE 1997. The Significance of Disease as a Limiting factor to Variety Performance Potential, In: Seeds Of Progress, BGS Occassional Symposium no. 31. Ed JR Weddell pp114-123

Ergot is a common fungal disease of grasses that infects the flowers and produces black resting bodies known as sclerotia in place of normal seeds. The sclerotia contain alkaloids that are toxic to livestock, impairing growth and sometimes causing lameness or abortion. Ergot is common in ryegrasses and control can be achieved by regularly topping swards to prevent flowering. Pastures should be grazed hard to reduce flowering and avoid infested grass ears. There are no effective fungicides to control ergot. Deep ploughing to bury ergots is advisable where problems have occurred to prevent ergots producing air-borne spores in the following crop. Fortunately ergots are relatively short-lived compared with other sclerotial fungi and most decay within one year. Seed stocks should be free from ergot contamination.

Undersown grasses

Most of the fungicides applied to grass are used on cereals, principally spring barley, undersown with grass. They may help establish healthy grass seedlings, but the main targets are cereal diseases rather than grass diseases. If the use of fungicide products is restricted in future, undersowing may be replaced by direct sowing.

Powdery mildew control in cereals and grass might be rather less effective if quinoxyfen and the new active ingredients cyflufenamid and proquinazid were lost. The situation on these new products is not yet defined but either or both could be used as alternatives to quinoxyfen. Established products based on morpholoine products, cyprodinil and metrafenone could also be used more often to control powdery mildew.

For under-sown crops epoxiconazole is an important product that would be lost along with cyproconazole, metconazole and tebuconazole. Difenoconazole, fenbuconazole, fluquinconazole, flusilazole, prochloraz and propiconazole are other azoles that might be affected if approvals legislation were to include more strict definitions of endocrine disruptors, leaving only weaker products such as bromuconazole and triadimenol still available. The availability of prothioconazole is uncertain, if it remains available then it could replace epoxiconazole and other changes would have no impact. New recommendations would need to be developed for these fungicides on non-cereal crops. In practice, under-sowing of cereals is likely to be less popular and more grass will be direct sown.

Fungicide scenarios to control foliar diseases on grasses would be similar to those on cereals as strobilurin recommendations would remain, whilst azole products would be lost or reduced in number.

Chlorothalonil would remain available under the revision of 91/414/EEC, but could be lost under the Water Framework Directive. It is valuable for septoria control in wheat, and leaf spots on grasses. Strobilurin and remaining azole products would be required as substitutes.

Overall the impacts of the revision of 91/414/EEC and WFD would have little impact on the level of control of disease achieved in temporary grassland. Where products are lost there are alternatives, and the area typically treated is relatively small. If further information were available about the impacts of disease on grassland yields it may be possible to increase yields from those currently obtained through better use of modern fungicides as current losses to the industry due to disease are estimated to be in the region of £290M in lost feed value.

5.5.3. *White clover*

Although affected by several foliar and virus diseases and sometimes by clover rot[40], there are some differences in prevalence of foliar diseases compared with red clover. Powdery mildew, scorch and stemphylium are less important and black blotch more important. The damage from clover rot is likely to be less in white clover than in red clover crops. Clover phyllody caused by phytoplasma is quite common and may also affect productivity. Reproductive activity of grazing animals may be adversely affected by the presence of pseudopeziza leaf spot and pepper spot that both increase oestrogenic activity in white clover [41,40]. In practice fungicides are not used and small losses are likely to continue to be acceptable.

5.5.4. *Red clover*

Red clover is commonly affected by a number of foliar diseases and is also affected clover rot and viruses notably *Red clover necrotic mosaic virus*. Foliar diseases include black botch, downy mildew, pseudopeziza leaf spot, pepper spot, powdery mildew, rust, scorch and stemphylium leaf spot[40,41]. The disease-induced yield losses may be significant in some crops judged by the severity of leaf loss. There are no specific foliar fungicide recommendations and control of diseases by harvesting the crop remains the main option. The loss of fungicides will therefore have little impact on the crop. Further work is required to demonstrate that fungicides produce any significant benefits. Where clover rot is a problem, the biological control fungus *Coniothyrium minitans* could be used to kill sclerotia and reduce inoculum in infested fields.

5.5.5. *Lucerne*

There are several common diseases on lucerne including black stem, downy mildew, pepper spot, powdery mildew, Pseudopeziza leaf spot, rust and verticillium wilt, clover rot may kill young plants and crown wart is associated with poorly drained areas[41]. As with other legumes a complex of soil-borne root pathogens are capable of causing problems where there are short rotations or adverse soil conditions. Virus diseases may well be causing some loss of yield, but there is no published data on their importance. Overall production losses from disease are estimated to be 7% (Table 6), an estimated loss of feed value equal to £155,000.

Regular cutting of the crop for forage contributes to disease management by removing inoculum. Other significant problems, notably verticillium wilt and clover rot are difficult to control with pesticides. Biological control of clover rot may be possible with the fungal parasite *Coniothyrium minitans* (as Contans) and resistant cultivars are required for verticillium wilt. There are no specific fungicide recommendations for

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[40] O'Rourke C.J, 1976. Diseases of grasses and forage legumes in Ireland. Dublin: An Foras Talúntais, 115pp.

[41] Lewis GC, Clements RO, 2000. Pests and diseases of forage, amenity grass and fodder crops. In: Pest and Disease Management Handbook, Ed. DV Alford. Blackwell Sciences Ltd., Oxford, pp. 84-122.

lucerne, though broad-spectrum treatments could well produce yield responses. Changes to fungicide availability are not expected to impact on lucerne.

5.5.6. Lupins

There have been some damaging disease outbreaks on lupins in recent years. Anthracnose, brown spot and rust can be severe. At Rothamsted, control of rust on white lupins with tebuconazole gave yield responses of 86% and 30% in 1997 and 1998 (respectively)[42]. The gross national value of these yield responses depends on the area of the crop grown and the incidence of the disease, it is currently estimated that 80% of crops might be affected by disease. If this area all had a yield response of 30% this could increase the overall yield (on a 6000 ha crop) by 4,320 tonnes. This could be worth an additional £500,000 in increased relative feed value. Widely spread occasional crops like lupins can avoid the epidemic diseases seen in the commodity crop.

There are other foliar diseases (e.g. grey mould), soil-borne diseases (e.g. sclerotinia rot) and virus diseases that threaten lupins so losses from disease are likely to be moderate and variable (£0.5-0.6M in lost feed value). Losses from disease are an important factor affecting the scale of lupin production. Seed treatment to control anthracnose and foliar fungicides are important to maintain crop performance[43].

There are some label recommendations for foliar sprays of metconazole and various off-label approvals for seed treatments and foliar fungicide sprays. The level of losses is unlikely to be affected by the revision of 91/414/EEC or WFD, although the loss of azole fungicides may impact on disease control in lupins where rust and leaf spots are important. At least in the short term strobilurin products may perform adequately against these diseases.

5.5.7. Maize

Maize crops are often grown intensively on specific fields. The crop is still expanding from the 129,000 ha recorded in 2005 to 153,000ha in 2008. This leads to build up of soil and trash-borne diseases. Damping off diseases can be controlled using a thiram seed treatment. Eyespot was first recorded on forage maize in the UK in 1998 and has recurred each year since. Crops develop symptoms towards the end of August and can suffer severe loss of green leaf. In recent years, eyespot has been severe in some crops in the west and Wales, but it can be found in other regions of England. There is an Off-label approval for the use of flusilazole to control eyespot and other foliar diseases. This was not available in 2005 when the last pesticide usage survey was conducted and it is expected to be lost to the revision of 91/414/EEC. The use of fungicides on maize is limited as livestock farmers may have to use contractors to apply treatments when crops are tall. There have been suspected cases of northern leaf blight in England in 2008, which might also reduce

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[42] Etheridge JV, Bateman GL, 1999. Fungicidal control of foliar diseases of white lupins (*Lupinus albus*). *Crop Protection* **18**: 349-354.

[43] Anon. 2009. Agronomy of lupins. www.lupins.iger.bbsrc.ac.uk/knowledge.htm.

yield. *Fusarium* spp. continue to cause concern within maize crops as both stem and cob rots. The latter may produce mycotoxins which subsequently affect growth of livestock fed maize rations. The extent of such problems is not known but expert opinion suggests that it could be costing the industry £9.4M in lost feed value (Table 8). Fungicides are not used specifically against *Fusarium* spp. though this is an area that would benefit from further research. Metconazole used in general programs does have some control of Fusarium and its loss to the revision of 91/414/EEC could increase losses from Fusarium by £8.6M. Maize smut is an occasional problem that can reduce plant growth and hence yield.

Disease losses are estimated to be 8% from eyespot, 5% from fusarium seedling, stalk and cob diseases and 0.1% from smut on affected crops if left untreated. There is considerable seasonal variation in their severity. Fungicides have limited impact (1%) on these diseases because few crops are currently treated with foliar sprays. The loss of fungicide seed treatments that are used on 62% of the crop and flusilazole would have an impact on productivity. However, it may be possible to develop recommendations for other fungicides.

The loss of flusilazole for eyespot control on maize is important as this is the only available product. New recommendations for other fungicides would be required to help control this disease.

5.5.8. Stubble turnips

Stubble turnips are grown as a relatively short-term crop on about 24,000ha but nevertheless can be severely affected by foliar diseases particularly dark leaf spot. Severe disease attacks can defoliate the crop in autumn. Foliar fungicide can be of significant benefit in maintaining green leaf. No foliar sprays were recorded in 2005 surveys though seed treatments were used on 14,000ha. Azoxystrobin alone or in mixture with difenoconazole has a label recommendation for fodder brassicas. Clubroot is a significant problem in some crops though the benefits of using resistant varieties may diminish in future as the resistance is overcome by new races of clubroot. On some farms, stubble turnips are grown in close rotations with oilseed rape and this is increasing disease problems in both crops.

Swedes and turnips

A range of diseases affect root brassicas, and problems are similar to those discussed for kale and stubble turnips. Powdery mildew can very damaging in some crops of swedes and predispose plants to bacterial rots. Clubroot and dry rot are also of concern. No fungicide use was recorded in the 2005 PUS apart from 1% of the area (13,000ha) receiving sulphur. There are various off-label recommendations available and sulphur can be used for powdery mildew control. Seed treatments for disease control have been mainly with thiram and iprodione.

5.5.9. Kale

In common with other brassica crops a range of foliar diseases affect kale crops and these can cause early loss of leaves and reduce overall productivity. Leaf spotting is commonly caused by dark leaf spot, downy mildew, light leaf spot, phoma leaf spot, powdery mildew, ringspot and white blister. There are some problems with damping off diseases (*Pythium* spp., *Rhizoctonia solani*) soon after sowing. Ringspot is often the most important disease and azoxystrobin or difenoconazole (off-label) may be used on fodder brassicas. Chlorothalonil has a general brassica recommendation for ringspot control. Damage from clubroot can be very severe in some crops where brassica rotations are too short and soil is acid. Liming to increase the soil pH to >7.0 prior to kale cropping is still the main control measure. Kale crops are also affected by aphid-borne viruses such as *Turnip mosaic virus, Cauliflower mosaic virus* and *Turnip yellows virus*. Early virus infection will reduce the productivity of affected plants.

There are limited recommendations for foliar fungicides available for kale and other fodder brassicas and treated areas have been small. Only 96 ha of kale, cabbage and fodder rape were sprayed in 2005 whilst seed treatments were used on 4700 ha. There are likely to be some effects of disease on productivity in many crops, but only the more severely affected crops are likely to treated.

Chlorothalonil would remain available under the revision of 91/414/EEC, but could be lost under the Water Framework Directive. It is valuable for foliar disease control on brassica crops. Strobilurin and remaining azole products would be required as substitutes.

5.5.10. Fodder rape

The range of diseases affecting fodder rape is similar to that reviewed for kale. Small losses are likely to occur in many crops but few of these justify specific fungicide treatment.

5.5.11. Fodder beet

The diseases affecting fodder beet and mangolds are the same as those that affect sugar beet. Powdery mildew, rust and Ramularia leaf spot are the most important diseases but cercospora leaf spot is also a threat. There is good evidence that fungicides increase the yields of sugar through disease control and leaf greening effects[44]. Yield responses from single sprays have averaged 5% [45], but can exceed 10%[44]. Two spray programmes can produce much larger yield responses. These principles also apply to fodder beet. There is some use of fungicides on fodder beet (8.8% crop treated in 2005) and potential to increase this in future as awareness of the benefits of fungicides and new products are promoted[46].

In addition to foliar diseases, there is a complex of soil-borne seedling pathogens, and rhizomania caused by *Beet necrotic yellow vein virus* to consider. Seed

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[44] Self MM, Orson J, 2009. Monitoring ‘in season’ and long term changes in yields of sugar beet (*Beta vulgaris* L.). *Aspects of Applied Biology* **91**, *Crop Protection in Southern Britain*: 57-61.

[45] May M, Stevens M, 2008. Fungicides for 2008. *British Sugar Beet Review* **76**: 14-19.

[46] Bardsley E, Bush M, 2009. A new fungicide for broad spectrum disease control and to maximise yield potential in sugar beet. .*Aspects of Applied Biology* **91**, *Crop Protection in Southern Britain*: 51-56.

treatments help seedling establishment, but resistant varieties or the avoidance of affected fields are required to control rhizomania.

Disease losses are likely to come mainly from rust and other foliar diseases, but in some years aphid-borne virus yellows (*Beet mild yellows virus, Beet yellows virus*) may be important. Rhizomania may be damaging on a few farms and soil-borne diseases cause low levels of damage more widely.

5.5.12. Chicory

There is little production of chicory in pure stands in the UK. Some chicory is used in forage mixtures. Mildew and rust have been reported from the USA (Hannaway and Myers, 2004)[47] and Phytophthora root rot is important on forced roots[48]. Other unnamed *Phytophthora* species have been found on roots in the UK[49] The absence of specific disease information for the forage crop in the UK, foliar and root diseases are estimated to cause a 5% loss in yield. It is unlikely that changes in pesticide use will impact on this crop. In the USA sulphur has been used and might have some beneficial effects on chicory foliar diseases if used on grassland mixtures.

5.5.13. Peas and beans

The revision of 91/414/EEC will make the control of botrytis and powdery mildew in peas more difficult as a result of the loss of metconazole, although there are still some alternatives available. However, if chlorthalanil is lost to WFD there will be greater impacts on disease control in peas. The level of disease control in beans is unlikely to be affected by the changes in legislation.

5.5.14. Wheat, Barley and Oats

The loss of epoxiconazole to the revision of 91/414/EEC would have slight impacts on the ability to control key wheat diseases such as septoria. There would be increased pressure on the remaining triazoles, such as prothioconazole, which could result in increased resistance occurring. In 2006 epoxiconazole was one of the most widely used fungicides in wheat, showing how important it is in the control of disease. It is also widely used in barley and oat crops but there are plenty of alternatives fo controlling the main diseases of these crops.

5.5.15. Oilseed rape

Ther revision of 91/414/EEC and WFD will have little impact on the ability to control disease in oilseed rape.

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[47] Hannaway DB, Myers D, 2004. Forage Fact Sheet: Chicory (*Cichorium intybus* L.). http:forages.oregonstate.edu/fi/topics/fact_sheet_print_forb.cfm?specid+14&use=Soil

[48] Benigni M, Bompeix G, 2004. Control of *Phytophthora cryptogea* (Pethyb and Laff) of witloof chicory (*Cichorium intybus* L.) with azoxystrobin applied before the forcing period. *Crop Protection* **23**: 1011-1014.

[49] K Green, ADAS Boxworth, pers. comm.

Assessment of future status of pesticide availability

Pesticide impacts

As fungicide use is low on grass and forage crops, any changes are likely to have a limited impact.

One of the most widely used groups of fungicides is the strobilurins (e.g., azoxystrobin, kresoxim methyl and pyraclostrobin) and these continue to be available under all scenarios. They have broad spectrum activity and could replace fungicides from other groups. However, if their use is increased, their performance may be affected by the selection of fungicide resistant strains.

Water Framework Directive

There would be some impact with the loss of chlorothalonil, which is a valuable product for use on undersown cereals, grasses and forage brassicas. It could be replaced by strobilurin products such as azoxystrobin on grasses and brassicas unless fungicide resistance reduces its efficacy. Carbendazim is also affected by WFD but current use is small, so impacts will be negligible.

6. *Impact of climate change*

6.1. Weeds

The greatest magnitude of change at temperature extremes is predicted by the IPCC[50] with very cold winter and very hot summer conditions showing the most warming. What is uncertain in the UK, particularly the western areas with the majority of grass and forage crops, is how much rain may accompany the higher temperatures. Initial analyses suggest conditions would become drier over much of the lowland areas of the country see Figure 4 for a comparison of average rainfall in the period 1971-2000 with the predicted rainfall in the 2020's.

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50 Alcamo, J., J.M. Moreno, B. Nováky, M. Bindi, R. Corobov, R.J.N. Devoy, C. Giannakopoulos, E. Martin, J.E. Olesen, A. Shvidenko, 2007: Europe. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,* M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 541-580.

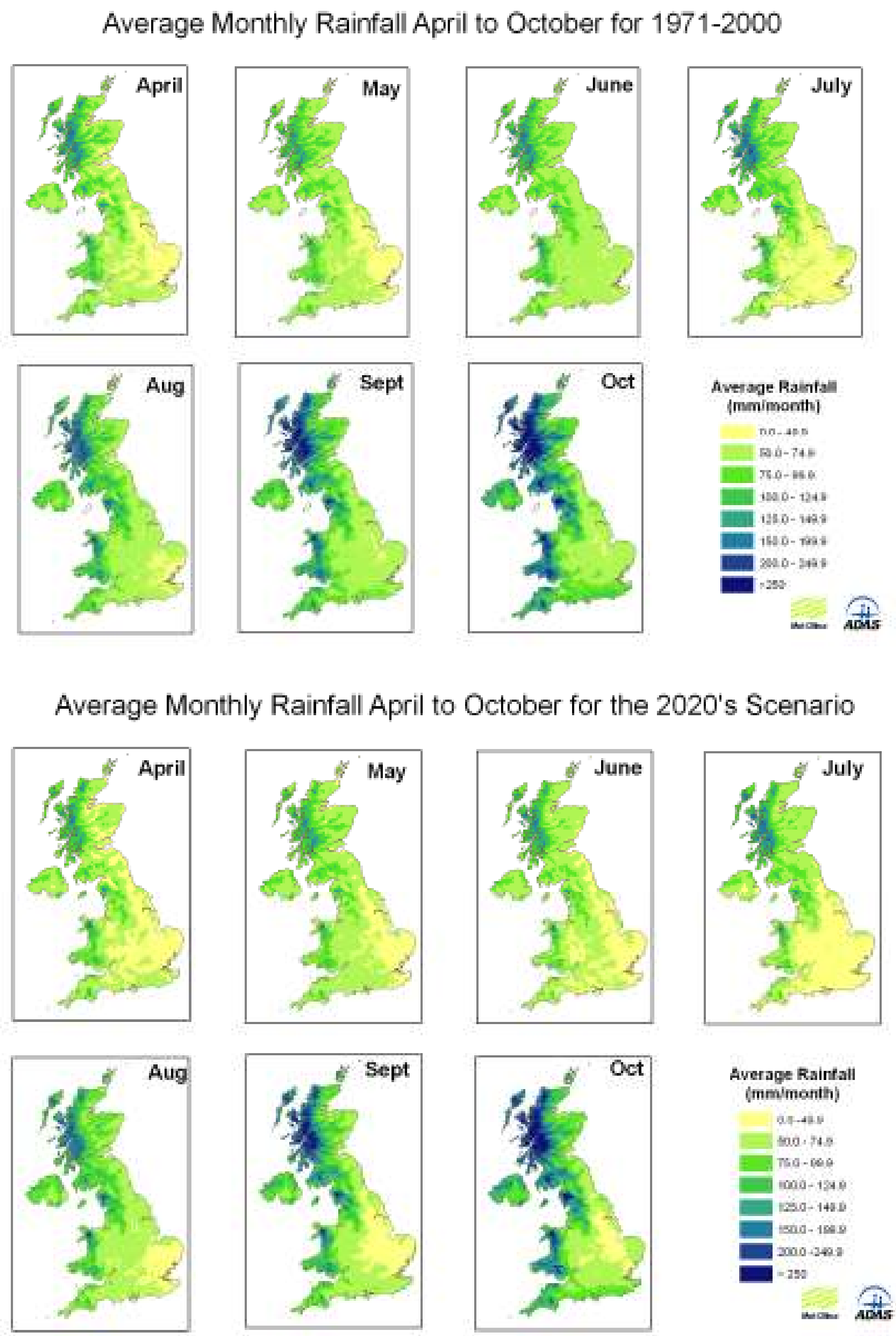

Figure 4. Average Monthly mean rainfall April – October for 1971-2000 and the predicted rainfall for the 2020's.

6.1.1. Permanent grassland

Rising temperatures will lengthen the growing season in the autumn and spring, as we have seen in some recent winters. This will increased the risk of sward deterioration if grass is either grazed in wet weather or left as the land is too wet for access. In summer hotter drier conditions will result in the death of shallow rooted material and the uprooting of dead or droughted plants. Both scenarios, wet or dry may lead to increased weed numbers due to the appearance of bare soil. Shorter winters should lead to reduced feed costs, so some savings may be available for herbicidal weed control. Dry summer weather can lead to increases in *Poa annua* as a short term colonist of bear soil. Although various treatments have been evaluated for the control of this grass (e.g. low rate Dalapon), efficient grassland management and over sowing of new grass is probably the most reliable.

Where feasible the long or short term alternation of grazing and mowing can provide effective weed suppression without the need to reseed permanent grass. If reseeding becomes necessary there will be longer autumn and spring windows to do so.

6.1.2. Temporary grassland

Many of the above comments about the impact on climate change on permanent grass also apply to temporary grass; grazing damage could occur as a result of longer grazing periods or drought. The main risk is that the lower durability of temporary grass swards could reduce their longevity. The degree to which species in the mixes could be changed (a swing to more Cocksfoot and Fescues) would need careful analysis. More tolerance of close grazing or drought may be bought at the cost of lower productivity in the rest of the year.

The clean entry of reseeds from arable rotations will be important in keeping initial weed levels low.

6.1.3. White clover

Legumes, and white clover in particular, are likely to increase in importance as the effects of climate change become more apparent. Rising energy use in the manufacture of fertiliser is also likely to add to this as life cycle carbon balances are scrutinised more closely. As we have shown in the report the proposed losses from the available portfolio of clover and legume safe herbicides are significant. However longer autumn and spring reseeding windows will give better opportunities for slot-seeding /overcasting of clover seed before cold or drought reduce establishment and effective nodule formation. The post-emergence sowing of clover allows both tight grazing and non clover-safe herbicides to be used to reduce weeds before clover is established.

In established swards the balance of wet and warmth during the summer will govern not only how the grass:clover balance is maintained, but also the level of nitrogen fixation. Overall climate change is likely to increase both the productivity of clover and its importance in grassland farming.

6.1.4. Red clover, Lucerne

The forage legumes red clover and lucerne will be affected by the balance of hot dry weather and warm wet weather across the UK. It seems likely that more red clover may be used in the west while eastern counties with high pH soils and drier summers will see a resurgence in lucerne plantings, with its increased drought tolerance.

The longer spring and autumn windows will benefit both crops, but with a depleted portfolio of suitable herbicides weed control may be a limiting problem as neither crop is amenable to early defoliation as a means of controlling weeds.

At present one of the largest concentrations of lucerne is on the Dengie peninsular in Essex, one of the driest areas of the country. The increase in dry summers could see an expansion elsewhere particularly on the drier calcareous soils south of a line between the Severn and the Tees. Lucerne and manures from associated livestock units may be one of the ways arable farmers seek to cope with rising energy and nitrogen costs.

As with all the comments about the increasing value of legumes, as crops become more important a wider portfolio of agrochemcials is likely to develop.

6.1.5. Maize

Climate change will bring a significant challenge to maize growers as the scope for higher usage of the crop for grain increases in southern areas, whilst the area suitable for growing the forage crop expands northwards. The crop will have a longer growing period and warmer winters mean seedbeds will have higher weed populations prior to drilling the crop in the spring.

6.2. Pests

Climate change, and in particular global warming, is likely to have pronounced effects on the status and distribution of plant pests. The close link with the climate is due largely to the fact that key pests, which include species of insect, mollusc, and nematode are cold-blooded (poikilothermic) and as such are profoundly affected by temperature changes[51]. These changes are likely to be seen through the distribution of species, with new geographical regions becoming suitable, while other areas may become unsuitable. In addition, the relative performance, in terms of reproduction or number of generations is likely to be altered for species already present in a given location. This may be particularly apparent for species with short generation times and low developmental threshold temperatures such as aphids.

However, climate change is not simply a matter of global warming and plant pests are also sensitive to factors such rainfall, which in turn may influence the moisture content of soils. Soil moisture content is of particular relevance to soil dwelling organisms such as the larval stages of a number of insect pests as well as slugs.

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[51] Oakley, J. N. (2008) Control needs for changing pest distributions. *HGCA R & D Conference 2008 - Arable cropping in a changing climate*. pp. 87-92.

Climatic changes not only impact pests, but also the natural enemies of pests, which may have important roles in regulating crop damage. In particular, milder winters are likely to result in increased survival of both pests and natural enemies, however, the implications of these changes are difficult to predict. Similarly, climate change is likely to alter the synchronicity between pests and crop plants. This is due to the fact that for many crop plants germination is triggered by day-length while development of insects for example, is typically determined by temperature. As a result pests are likely to be present earlier in the year, due to milder conditions in winter and spring, while plant germination will remain unaffected. Therefore, crop plants may be subject to attack at earlier more susceptible stages.

In addition as alternative grass and forage crops may become more popular due to climate change (e.g. sorghum, grain maize) higher temperatures increase the likelihood that exotic pests inadvertently imported as a result of international trade will become established. Many exotic pests of current concern are either able to feed on a wide range of crop and non-crop plants or their preferred food plant is already grown, thereby reducing barriers to establishment. Coupled with these risks are potential changes to land use as a result climate change with different crops grown resulting in new pest pressures. These changes should be considered against a background of likely changes in crop management practices in response to legislative changes such pesticide approval and usage.

Predicting the impact of climate change on plant health is difficult; however, changes are likely to lead to both opportunities and threats. Recognising and responding to these challenges will require careful monitoring of the status and distribution of both native and non-native pests. Furthermore, the effective dissemination of information to farmers and growers will be central to the implementation of pest control measures appropriate for a changing pest pressures. Table 14 shows the predicted impacts of climate change on pests of grass and forage crops.

Table 14. Summary of likely impacts of climate change on pests of grass and forage crops

	Native Pests		Non-Native Pests
	Increased risk/severity	**Decreased risk/severity**	
Grassland	Stem nematode (*Ditylenchus dipsaci*) Marsh crane fly (*Tipula oleracea*)	September crane fly (*Tipula paludosa*)	
Maize		Slugs e.g. grey field slug (*Deroceras reticulatum*)	Corn rootworm (*Diabrotica* spp.) European cornborer (*Ostrinia nubilalis*)
Brassica	Peach-potato aphid (*Myzus persicae*) Cabbage stem flea beetle (*Psylliodes chrysocephala*) Diamondback moth (*Plutella xylostella*)		

6.2.1. Grassland pests

Although the area of grassland treated with insecticides is relatively low grassland pests (including leather jackets, root knot nematodes and cyst nematodes) can cause significant losses at sites where infestation is severe[52]. In parts of the UK where grassland is important the impact of climate change on the distribution and status of pests may alter in frequency, spread and intensity.

Around 40% of white clover / perennial ryegrass swards are infested with stem nematode[53]. Damage, which includes stunting, is most marked on the establishment of clover seedlings and is typically more severe in spring after mild winters. Increased severity of this pest following mild winters is thought to be due to the nematode remaining active at temperatures at which clover is not. Indeed, studies of the stem nematode have revealed that the rate of egg laying and subsequent development increases linearly with increased temperature, up to 20°C[54]. This linear

[52] Clements, R. O., Murray, P. J., Bentley, B. R., Lewis, G. C. & French F. (1990) Impact of pests and diseases on the herbage yield of permanent grassland at eight sites in England and Wales. *Annals of Applied Biology*. **117**: 349-357.

[53] Cook, R., Mizen, K. A., Plowright, R. A. & York (1992) Observations on the incidence of plant parasitic nematodes in grassland in England and Wales. *Grass and Forage Science*. **47**: 274-279.

[54] Griffith, G. S., Cook, R. & Mizen, K. A. (1996) Effects of temperature on the white clover (*Trifolium repens*) / stem nematode (*Ditylenchus dipsaci*) host pest system. *Aspects of Applied Biology*. **45**: 239-246.

relationship between temperature and development allows predictions of the number of generations completed within a year to be calculated i.e. a mean annual temperature of 10°C would allow up to seven generations to be completed. However, a mean annual increase of 2°C, within the range predicted by the IPCC by 2050, would allow two additional generations to be completed. As such increased annual temperatures are likely to increase the incidence and severity of this pest.

Despite the apparent importance of temperature in determining the pest status of the stem nematode, other climatic variables should not be ignored. For example, rainfall, and its effect on soil moisture levels, is of particular importance to grassland pests and is crucial even for stem nematodes in allowing movement over external surfaces of the plant. For another group of grassland pests, commonly known as leather jackets, soil moisture rather than temperature is likely to have the greatest influence on the pest status of these insects. The September crane fly or 'daddy long legs' is the most serious agricultural pest within this group. However, populations of the soil dwelling larvae are thought to be particularly influenced by soil moisture levels and density-dependent regulation, possibly through cannibalism (Blackshaw pers. comm.). Therefore, warmer soils in spring and early summer may actually have the effect of reducing populations by increasing the activity of larvae, which in turn may lead to greater levels of mortality (Blackshaw pers. comm.). Furthermore, emergence of adults is thought to be synchronised by daylength rather than temperature (Blackshaw pers. comm.). By contrast, the marsh crane fly (*Tipula oleracea*), a closely related species that is currently of less agricultural significance, has several generations throughout the year and development is thought to be controlled by thermal triggers (Blackshaw pers. comm.). Clearly more research is required for this group of insects in order to fully understand the impact that climate change is likely to have on these pests. It is also perhaps worth noting that a potentially more important impact of significant changes in populations of these insects would be environmental, with many species of birds reliant on crane flies as a food source in the rearing of chicks.

6.2.2. Maize

An increase in annual temperature and in particular milder winters is likely to increase the likelihood of non-native pests establishing. Several serious agricultural pests are predicted to shift their geographic range northwards as a result of climate change, such as the western corn rootworm. Western corn rootworm was first recorded in the UK near Heathrow airport in 2003. Current opinion is that the pest may initially become established in southern England, but is unlikely to cause severe economic damage. Attempts to eradicate this initial infestation appear to have been successful, with no beetles recorded in 2008. However, this is likely to only be a temporary reprieve as climate change is predicted to result in large parts of the southeast of England becoming suitable for the pest by 2050[55].

European corn borer is a major pest of maize in both America and Europe, where larvae bore through the stem of the plant causing it to lodge. However, from being a

[55] Baker, R. H. A., Cannon, R. J. C. & MacLeod, A. (2003). Predicting the potential distribution of alien pests in the UK under global climate change: *Diabrotica virgifera virgifera*. *The BCPC Conference – Pests & Diseases 2003.* Volume 2, pp. 1201-1208.

rare migrant to the UK before the 1930s, the European corn borer has established in the southeast of England, although it is typically found feeding on mugwort rather than maize. Currently at the limit of its climatic range, temperature increases are likely to result in the spread of this pest across much of the rest of the UK. Indeed, model simulations predict that climate change may lead to northwards shift in the potential distribution of this pest of up to 1200 km, or between 165 and 500 km for each 1°C rise in temperature, with an additional generation found in all regions where the insect currently occurs[56].

Slugs are serious agricultural pests affecting a wide range of crops including cereals and maize. As molluscs, slugs are particularly sensitive to both ambient temperature and soil moisture and as such may be strongly influenced by climate change. Deterministic models have assessed how different climate change scenarios may impact on the abundance and pest status of the grey field slug. Currently southwest England has the best conditions for this pest, while the northeast has the most adverse conditions. However, by 2080 it is predicted that the north and west of Scotland will provide the most favourable conditions for the pest, while the east of England and Scotland will have the harshest conditions. The currently favourable conditions in southwest England and west Wales are projected to decrease, with changes becoming evident by 2020[57].

6.2.3. Brassica crops

Oilseed rape provides a large area of *Brassica* crops from which pests can switch to forage brassicas as alternative hosts. The range of pests affecting brassicas with oilseed rape as a main host includes; the pollen beetle, cabbage stem flea beetle, cabbage seed weevil, rape winter stem weevil as well as slugs. With the exceptions of pollen beetles and slugs, climate change is likely to increase to some degree the severity of damage caused by each of these pests. In addition, the peach-potato aphid and the cabbage aphid, both important pests, are likely to become more damaging in *Brassica* crops, and in the case of the peach-potato aphid several other crops.

An additional result of climate change, through milder winters with fewer frosts, is likely to be an increase in aphid survival, particularly for species or particular clones of species that reproduce asexually throughout the year. This is important because aphid clones of species, such as the peach-potato aphid, that have developed insecticide resistance are more likely to pass from one year to the next. This trend is likely to place greater pressure and emphasis on insecticide resistance management.

Brassica crops are also likely to be at increased risk from the diamondback moth. This pest is a regular migrant to the UK where it completes two generations, but is not thought to overwinter in large numbers. Milder winters are, therefore, likely to

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[56] Porter, J.H., Parry, M.L. & Carter, T.R. (1991) The potential effects of climatic change on agricultural insect pests. *Agricultural and Forest Meteorology*. **57**: 221–240.

[57] Willis, J. C., Bohan, D. A., Choi, Y. H. Conrad, K. F. & Semenov, M. A. (2006) Use of a individual-based model to forecast the effect of climate change on the dynamics, abundance and geographical range of the pest slug *Deroceros reticulatum* in the UK. *Global Change Biology*. **12**: 1643-1657.

lead to successful overwintering of this pest leading both to higher populations and increased risk of insecticide resistant strains developing, as has occurred in many other parts of the world.

6.3. Disease

6.3.1. Effects of climate change on disease

General effects on crops have been reviewed up to 2080[58], balancing some disease factors in relation to warmer or even hot drier summers with milder, wetter winters. Rainfall events are likely to be more variable so storm damage and flooding will also contribute to disease problems. The scale of changes in the next 10 years is likely to be small, but establish trends that could continue up to 2050 and beyond. Published reviews point out the difficulties of making generalised predictions about the future status of diseases, given the complexities of the interactions involved with the growth of the host plant also being affected. Elevated levels of CO_2 are thought to have limited direct effects on many pathogens, but improved productivity by the host plant could favour both biotrophic and necrotrophic pathogens[59]. Ozone depletion in the stratosphere will increase UV-B radiation, but it appears that some fungal species may be able to adapt to higher levels of UV-B[60]. Direct effects of ozone are likely to be small where pathogen activity requires wet, humid or cloudy weather as ozone levels are low under these conditions[61]. Furthermore, ozone does not generally have much effect on the gaseous atmosphere within the soil.

6.3.2. Grassland diseases

Diseases of grassland and forage legumes have received limited attention and disease reports often relate to experiments evaluating new cultivars. Several of the diseases affecting grass are distinct strains of the species affecting cereal crops. There are likely to be similarities in the impacts of climate change on individual pathogens in grass and cereal crops, though impacts may be less pronounced in grass because of the perennial nature of the crop. Crown rust is a major problem in ryegrass, reducing yield by up to 30% and palatability[5]. It is most obvious in mild wet autumns and could remain active for longer periods with higher temperatures during the winter. This must be balanced against the effects of hotter (>25ºC) and drier summers that will decrease inoculum where grass is drought-stressed. For other rusts and powdery mildew, higher temperatures could provide more favourable conditions for their development.

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58 http://www.nfuonline.com/documents/Policy%20Services/Environment/Climate%20Change/NFU%20Climate%20Change.pdf

59 Manning, W.J. & Tiedemann, A. von. (1995) Climate change: potential effects of increased atmospheric carbon dioxide (CO_2), ozone (O_3,and ultraviolet-B (UV-B) radiation on plant diseases. *Environmental Pollution* **88**: 219-245.

60 Rasanayagam, M.S., Paul, N.D., Royle, D.J. & Ayres P.G. (1995). Variation in responses of spores of *Septoria tritici* and *S. nodorum* to UV-B irradiation *in vitro*. *Mycological Research* **99**:1371-1377.

61 Jahn, M., Kluge, E. & Enzian, S. (1996). Influence of climate diversity on fungal diseases of field crops – evaluation of long-term monitoring data. *Aspects of Applied Biology* **45**, *Implications of "Global Environmental Change" f or crops in Europe*:247-252.

Many grasses are affected by leaf spot pathogens that develop under cool humid conditions (e.g. *Rhynchosporium* spp. and *Dreschlera* spp. on ryegrass, *Mastigosporium rubricosum* on cocksfoot). These are expected to become more prevalent in period autumn to early spring, but become less prevalent during the summer when rainfall has decreased.

6.3.3. Maize

The distribution of mycotoxin producing *Fusarium* species, especially *Fusarium graminearum*, is changing in the UK and is a potential hazard to the cereal supply chain and livestock feedstuffs. The number of crops with grain exceeding mycotoxin thresholds was higher in 2008 than in previous surveys. This followed a combination of wet weather whilst crops were flowering and again at crop maturity. Under climate change scenarios, fusarium ear blight is expected to be favoured by short periods of wet weather with higher temperatures during the summer[62]. This situation could further aggravated by expansion of maize production, particularly grain maize, as maize is often affected by *Fusarium graminearum* that will affect other cereal crops[63].

In addition to the increased risk of fusarium problems on maize, recent reports of Northern leaf blight in the UK (J Thomas, pers, comm.) suggest that there are significant new disease threats to the crop. These would be favoured by higher summer temperatures. As they are often trash-borne, it will be difficult to eradicate them once established at a few locations. Eyespot a foliar disease of maize, has caused some problems already in western parts of the UK, though problems may become less frequent with a decrease in summer and early autumn rainfall.

6.3.4. Brassica crops

On livestock farms, with mixed rotations including oilseed rape, wider rotations may be required, in the longer term, to sustain brassica crop production if brassicas are also included as forage crops in the livestock feed supply. Clubroot is a major disease of brassica crops generally. Its future activity is dependent on rainfall distribution as wet soils are required for germination and infection of its resting spores. Higher soil temperatures are likely to extend the period when crops are affected by several weeks in autumn and possibly in spring as well[64].

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[62] O'Rourke, C.J. (1976). Diseases of grasses and forage legumes in Ireland. Dublin: An Foras Talúntais, 115pp.

[63] Edwards, S. (2007) HGCA Project report No. 413 Investigation of Fusarium mycotoxins in UK wheat production.

[64] Smith JA, Gladders P 2009.Effects of climate change on soil-borne diseases of oilseed rape. Aspects of Applied Biology 91, Crop Protection in Southern Britain: 159-162

Table 15. Summary of example diseases and possible changing status due to climate change

Crop	Disease	Status / Distribution	Nature of Change
Grassland	Crown rust (*Puccinia coronata*)	Increased	Performance
	Leaf spots (*Dreschlera* spp., *Rhynchosporium* spp. Mastigosporium spp.)	Decreased (summer) Increased (winter)	Performance Performance
Maize	Fusarium stalk and cob rots (*Fusarium graminearum*)	Increased	Performance
	Eyespot (*Kabatiella zeae*)	Increased	Performance
	Northern leaf blight (*Setosphaeria turica*)	Increased	Range
Brassica	Clubroot (*Plasmodiophora brassicae)*	Increased	Performance
Including OSR	Light leaf spot (*Pyrenopeziza brassicae*)	Unchanged	Performance
	Powdery mildew (*Erysiphe cruciferarum*)	Increased	Performance
	Stem canker (*Leptosphaeria maculans* and *Leptosphaeria biglobosa*)	Increased	Performance
	Stem rot (*Sclerotinia sclerotiorum*)	Increased	
Other: **Lucerne, legumes.**	Wilt diseases (*Verticillium* spp., *Fusarium oxysporum). Sclerotinia sclerotiorum*	Increased Increased	Range Performance
	Phytoplasmas	Increased	Range

7. Summary – Prioritised impacts and mitigation strategies

Table 16. Summary of EBLEX/DairyCo Research and Development and Knowledge Transfer priorities for grass and forage crops as a result of changing pesticide availability

Table ES3 - crop protection priorities: summary matrix						
Crop	Importance to industry	Weeds	Pests	Diseases	R&D priorities	KT priorities
Permanent grass	Large area	1		2	Improve weed management in long-term grass	Improve long-term grassland management
	a high proportion on land that can not be ploughed				Develop tools to ensure total herbicide use in a catchment meets both efficacy and water quality requirements	Promote existing knowledge on herbicide use and water risk to farmers. Link messages on production efficacy with water quality.
					Develop and test opportunities to improve disease control in long-term grass	
Temporary grass	Large area	1	2	2	Improve weed management in temporary grass	Improve temporary grassland management
					Develop tools to ensure total herbicide use in a catchment meets both efficacy and water quality requirements	Promote existing knowledge on herbicide use and water risk to farmers. Link messages on production efficacy with water quality.
					Develop and test opportunities to improve pest and disease control in temporary grassland	
White clover	Reduces N use	1		2	Improve weed management in white clover	Improve white clover management
	Increases growth rates in cattle and sheep				Develop tools to ensure total herbicide use in a catchment meets both efficacy and water quality requirements	Promote existing knowledge on herbicide use and water risk to farmers. Link messages on production efficacy with water quality.
					Develop and test opportunities to improve disease control in white clover	
Red clover	Reduces N use	1		2	Improve weed management in red clover	Improve red clover management
	High protein content silage Good animal performance				Develop tools to ensure total herbicide use in a catchment meets both efficacy and water quality requirements	Promote existing knowledge on herbicide use and water risk to farmers. Link messages on production efficacy with water quality.
	Drought resitant				Develop and test opportunities to improve disease control in red clover	
Lucerne	Drought tolerant	1		2	Improve weed management in lucerne	Promote best practice in weed control in lucerne
					Develop and test opportunities to improve disease control in lucerne	
Lupins	Good protein source	2		2	Improve weed management in lupins	Promote best practice in weed control in lupins
	(replacement for soya meal)				Develop and test opportunities to improve disease control in lupins	
Maize				3	Develop and test opportunities to improve disease control in maize	
Stubble turnips	Fills gap in autumn / winter when grass not growing	3		3	Improve weed management in stubble turnips and share information from other brassica crops	Promote best practice in weed control in stubble turnips
					Develop and test opportunities to improve disease control in stubble turnips and share information from disease control on other brassica crops	
Kale	Winter forage Good growth rates	2		3	Improve weed management in kale and share information from other brassica crops	Promote best practice in weed control in kale. Integrate messages with weed control in oilseed rape activities
					Develop and test opportunities to improve disease control in kale and share information from disease control on other brassica crops	
Forage rape	Winter forage Good growth rates	2		3	Improve weed management in stubble turnips and share information from other brassica crops	Promote best practice in weed control in forage rape. Integrate messages with weed control in oilseed rape activities
					Develop and test opportunities to improve disease control in forage rape and share information from disease control on other brassica crops	
Fodder beet	High yielding High energy			3	Develop and test opportunities to in fodder beet and share information from sugar beet	

KEY
based on economic impact and likelihood of achievement

1 **First priority** 2 **Second priority** 3 **Third priority**

* **Existing work** ? **Needs discussion**

Table 17. Summary of implications for EBLEX/DairyCo in relation to pulses, cereals and oilseeds resulting from wider studies carried out for HGCA and PGRO

Crop	Importance to industry	Weeds	Pests	Diseases	Main issue	Action priorities
Peas	Protein source	High	Low	Low	Increasingly chalenging to grow, although grass weed control my be less affected there will be fewer broadleaved weed control options.	Monitor rotational/cropping changes and be prepared to switch to alternative protein sources, maintain liaison with PGRO
Beans	Protein source	High	Low	Low	Increasingly chalenging to grow, although grass weed control my be less affected there will be fewer broadleaved weed control options.	Monitor rotational/cropping changes and be prepared to switch to alternative protein sources, maintain liaison with PGRO
Wheat		Medium	Low	Medium	Risk of herbicide resitrictions reducing overall production. Impact of disease control unclear until endocrine disruption impacts clearer	Monitor implications and retain close contact with HGCA
Barley		Medium	Low	Low	Herbicide restrictions or unavailability will lead to lower production due to higher weed pressures	Monitor implications and retain close contact with HGCA
Oats		Low	Low	Low	Unlikely to have significant impacts as oats tend to be grown in areas were there are few, or no, grass weeds	
Oilseed rape	Protein source	High	Medium	Medium	Future of UK OSR at risk from herbicides and molluscicides appearing in water	Monitor rotational/cropping changes and be prepared to switch to alternative protein sources. Maintain close contact with HGCA

KEY
High = risk of impact on feed availability could be immediate and requires action or monitoring
Low = likelihood of implications on feed availability are small based on current knowledge of impacts

7.1. Permanent grassland

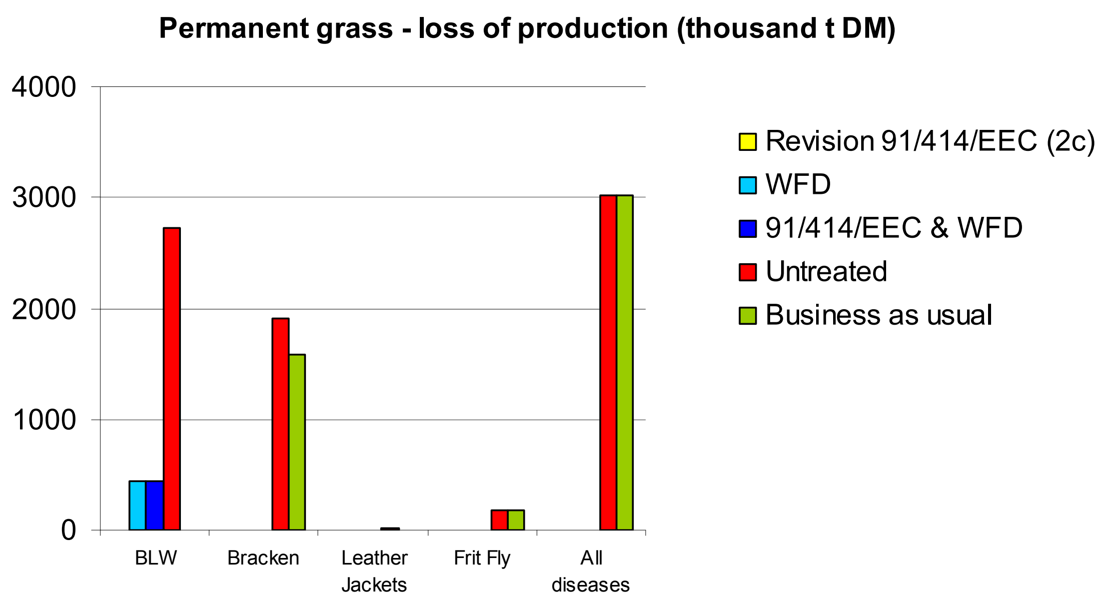

Figure 5. Permanent pasture loss of production (thousand t DM) as a result of changes in pesticide availability

Broad leaved weeds are the main problem in permanent pasture with the potential to cause big yield losses if left uncontrolled of more than 2.75M tDM (Figure 5) this is equivalent to £383M in reduced feed value (Table 8). Currently about 9% of the area (PUS, 2005) is currently sprayed with herbicides. The major herbicides used on grass MCPA, 2,4-D, MCPB and clopyralid are all being detected in water as a result of widespread usage. This makes them at risk of restrictions as a result of the water framework directive. If these actives were to be lost it would increase the cost of weed control in permanent pasture and potentially reduce yields, costing an average of £10/ha (Table 10). There is the risk that some weed infested pastures would remain untreated, resulting in the loss of production in the region of 0.5M tDM.

Little or no insecticide is applied to permanent pasture. Leather jackets and Frit flies cause damage to some pastures but the losses are small compared to those from uncontrolled disease and weeds. The impacts of legislation would be minimal on pest control in permanent grass.

Little or no disease control is currently carried out on permanent grassland. There is very little supporting evidence for the effects of disease in permanent grassland. If it is assumed that all grassland loses, on average, 5% of its potential yield to disease this could be costing the industry £400M a year in lost relative feed value or £70 a hectare. If disease control was carried out there is the potential that an additional 3M tonnes of permanent grass could be made available for stock feeding. The changes in pesticide legislation will have little impact on disease in permanent as so little fungicide is actually sprayed.

7.2. Temporary grassland

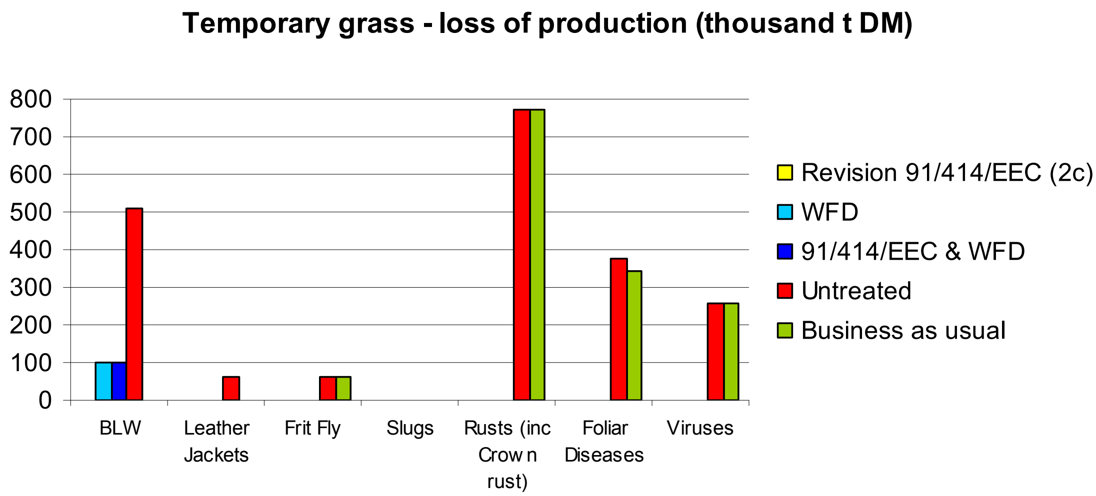

Figure 6. Temporary pasture loss of production (thousand t DM) as a result of changes in pesticide availability

As with permanent grassland weeds have the potential to cause large losses in temporary grassland. The most vulnerable stage is during the establishment of the new crop. If weed populations are high they will out compete the grass species. Herbicide usage on temporary grassland tends to occur during this establishment phase. Glyphosate is important in the control of perennial weeds prior to the establishment of the new crop, whilst MCPA, 2,4-DB and clopyralid are all widely used in temporary grassland (predominantly in the first two years of establishment), and are all being detected in water. The loss of these active ingredients could increase difficulties in establishing leys, especially were perennial weeds are concerned. The loss of linuron to the revision of 91/414/EEC on it own would cause little impact, but when combined with the potential losses from WFD its loss could reduce the level of control achieved still further.

Only very small areas of temporary grassland are sprayed with insecticides, predominantly aimed at controlling frit flies and leather jackets. Chlorpyrifos was the main insecticide used, and this is not affected by the changes in legislation, so pest control should be unaffected by either the revision of 91/414/EEC or WFD.

Small amounts of fungicides are currently applied to limited areas of temporary grassland, predominantly aimed at controlling foliar diseases. These have some impact on the level of disease present, but yield losses as a result of disease are still common. Many diseases go untreated with estimated losses to the industry of £290M in relative feed value (table 8), or £250 / ha (table 9).

7.3. White clover, red clover, lucerne

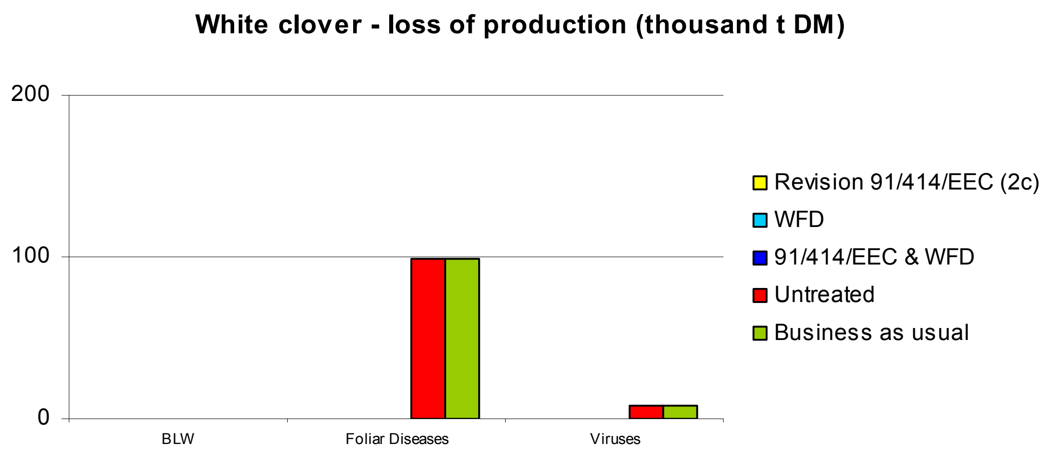

Figure 7. White clover loss of production (thousand t DM) as a result of changes in pesticide availability

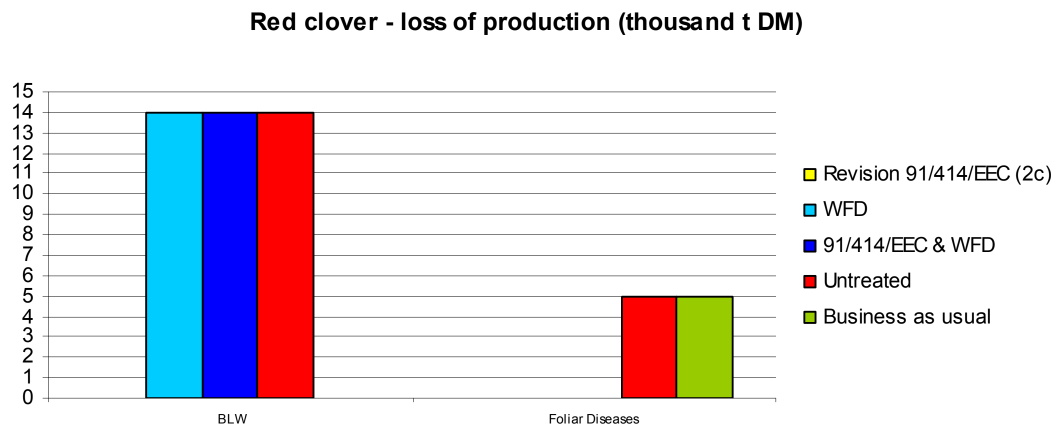

Figure 8. Red clover loss of production (thousand t DM) as a result of changes in pesticide availability

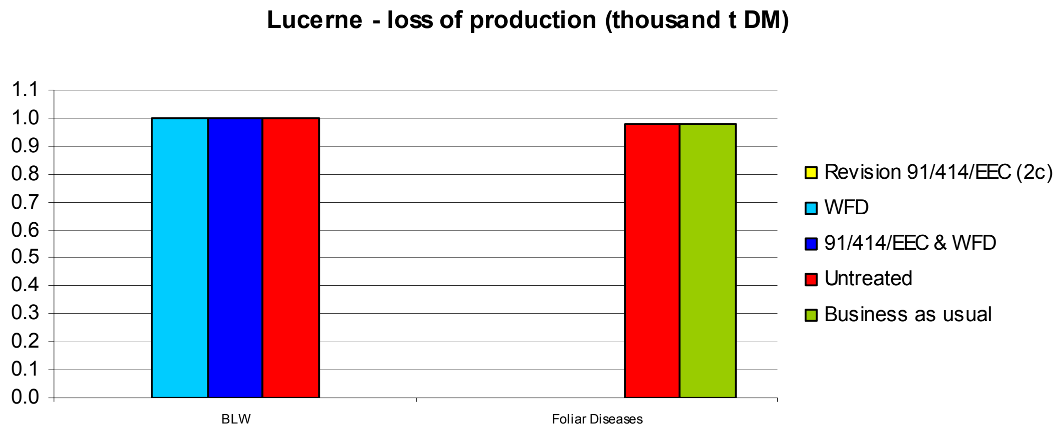

Figure 9. Lucerne loss of production (thousand t DM) as a result of changes in pesticide availability

Clover forms a useful addition to grass swards, providing a cost effective nitrogen source, resulting in reduced requirements for artificial fertilisers. Swards containing clover are at risk from the same weeds that affect temporary and permanent pasture. However, the range of herbicides available for treating swards containing clover is much reduced compared to pure grass swards. The main clover safe herbicides available are MCPA and 2,4-DB, both of which are at risk from WFD. Loss of these herbicides could reduce yields to levels similar to those seen in untreated situations (Figure 7, Figure 8, Figure 9). In the absence of clover safe herbicides growers will have to choose between;

- spraying with a non-clover safe herbicide to remove weeds but also loose the clover,
- to not spray and risk perennial weeds getting established and causing yield losses,
- to stitch clover into existing swards after herbicides have been applied

Similar herbicides are approved for use in lucerne. If these herbicides are lost some control of weeds can be achieved through the use of diquat during the dormant winter period. Alternative weed control would involve cultivating the crop out, and replanting, if weeds became too competitive.

Disease in clover causes some losses but relatively small areas are sprayed with fungicides. Where the clover is affected by disease grass species are likely to fill the gaps, yield losses will be reduced as a result.

7.4. Lupins

Changes in legislation would result in the loss of pendimethalin to the revision of 91/414/EEC and carbetamide to water framework directive. This would drastically reduce the herbicide options in lupins. The weedy silages produced as a result would have a lower feed value than a lupin grass silage, resulting in potential losses of about £20-34 per ha as a result of poorer feed value (Table 10). Losses of production to disease are already considerable (4,000 tDM Figure 10) with current treatments, this is unlikely to be affected by the loss of active ingredients to 91/414/EEC or WFD.

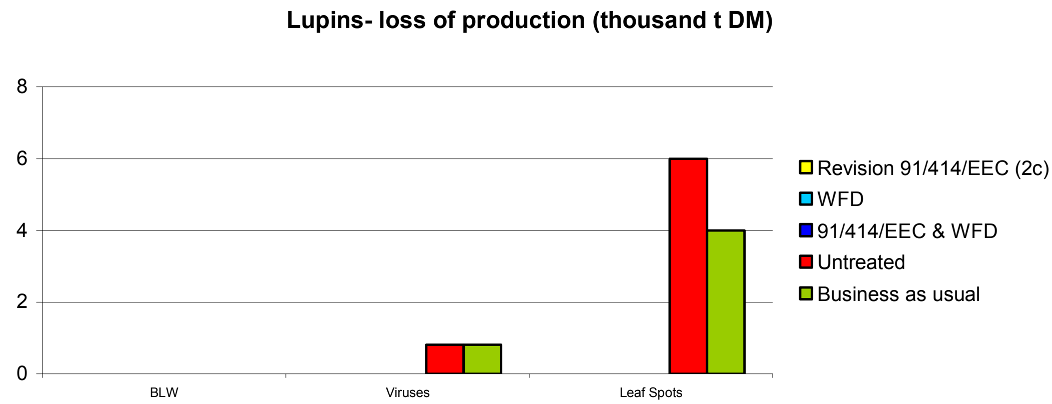

Figure 10 Lupins loss of production (thousand t DM) as a result of changes in pesticide availability

7.5. Maize

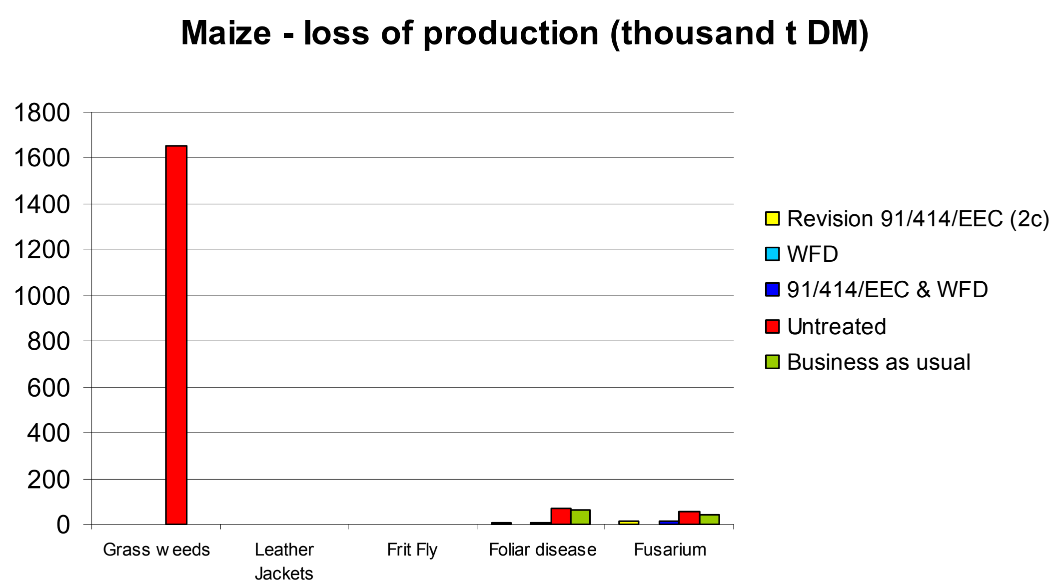

Figure 11. Maize loss of production (thousand t DM) as a result of changes in pesticide availability

Maize is an important international crop, with a wide range of pesticides available for use. Weed control in maize has already been affected by the loss of atrazine to Water Framework Directive, but this has not affected the area grown. In fact the area has increased since the loss of atrazine. It is expected that the large global market for maize will ensure that there are sufficient herbicides present to control weeds. Where weeds are difficult to control with herbicides the row spacing of maize crops lends itself to mechanical weeding.

In 2005 no fungicides were applied to maize except in the form of seed treatments. These actives currently remain unaffected by the changes in legislation. Flusilazole is approved (off label) for the treatment of eyespot and foliar diseases. Its loss to the revision of 91/414/EEC would effectively leave the seed treatment thiram as the only approved fungicide for use on maize. This would make the control of foliar diseases and eyespot difficult, potentially resulting in yield losses that could amount to £8.6M in lost feed value.

7.6. Forage brassicas and fodder beet

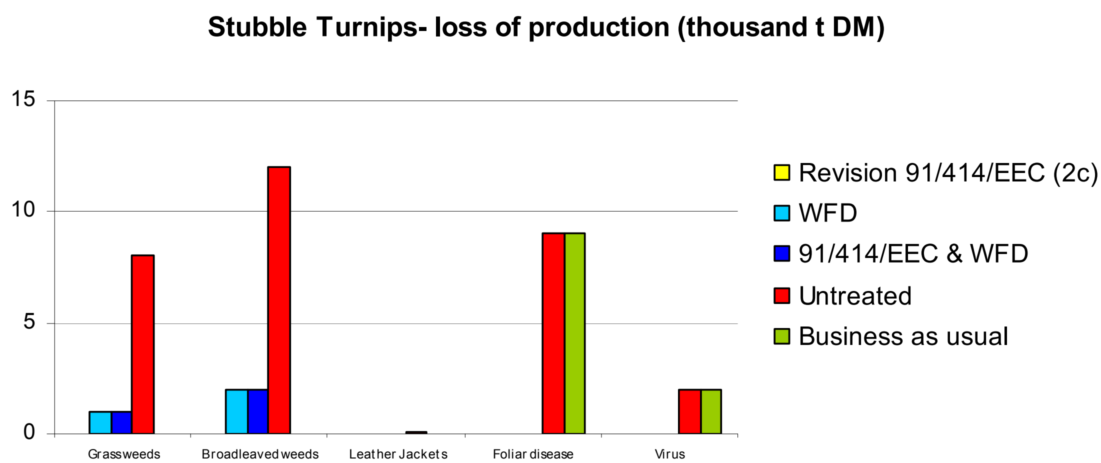

Figure 12. Stubble turnips loss of production (thousand t DM) as a result of changes in pesticide availability

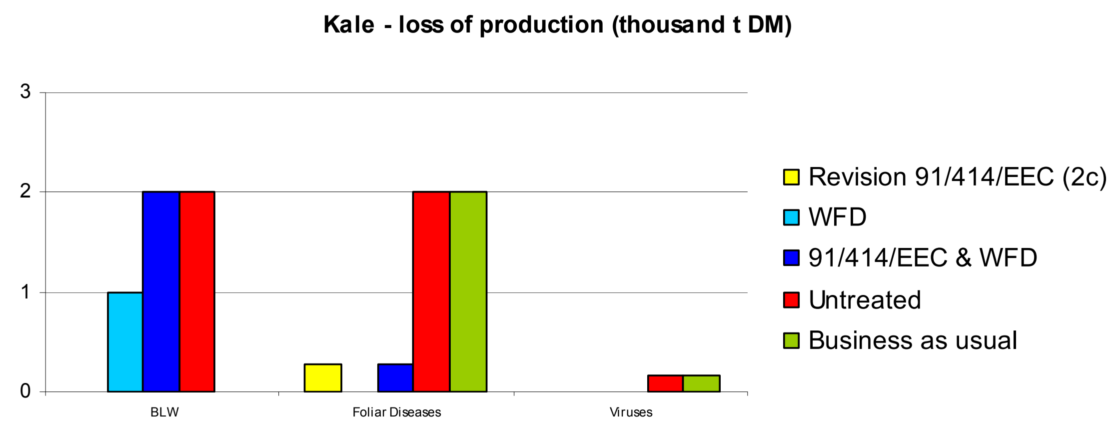

Figure 13. Kale loss of production (thousand t DM) as a result of changes in pesticide availability

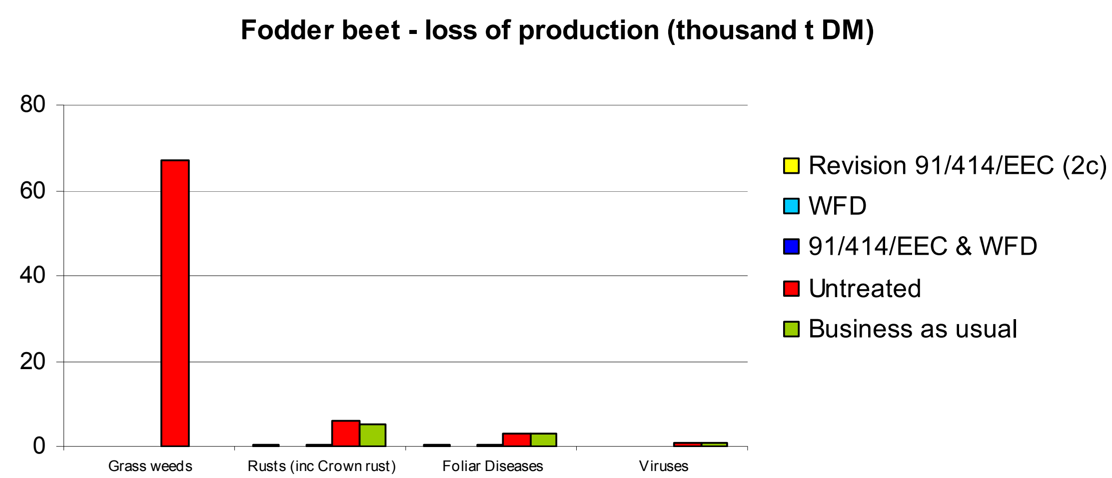

Figure 14. Fodder beet loss of production (thousand t DM) as a result of changes in pesticide availability

Under the Water Framework Directive key actives for the control of weeds in forage brassicas would be lost. This could result in reduced yields (Figure 12 & Figure 13) and lost feed values as a result of weed contamination in the crop. The wide range of herbicides available in fodder beet, as a result of the large world market for sugar beet, mean that the losses of herbicdes are likely to have little impact on this crop (Figure 14).

Loss of fungicides could cause yield losses due to foliar disease.

7.7. Combining peas

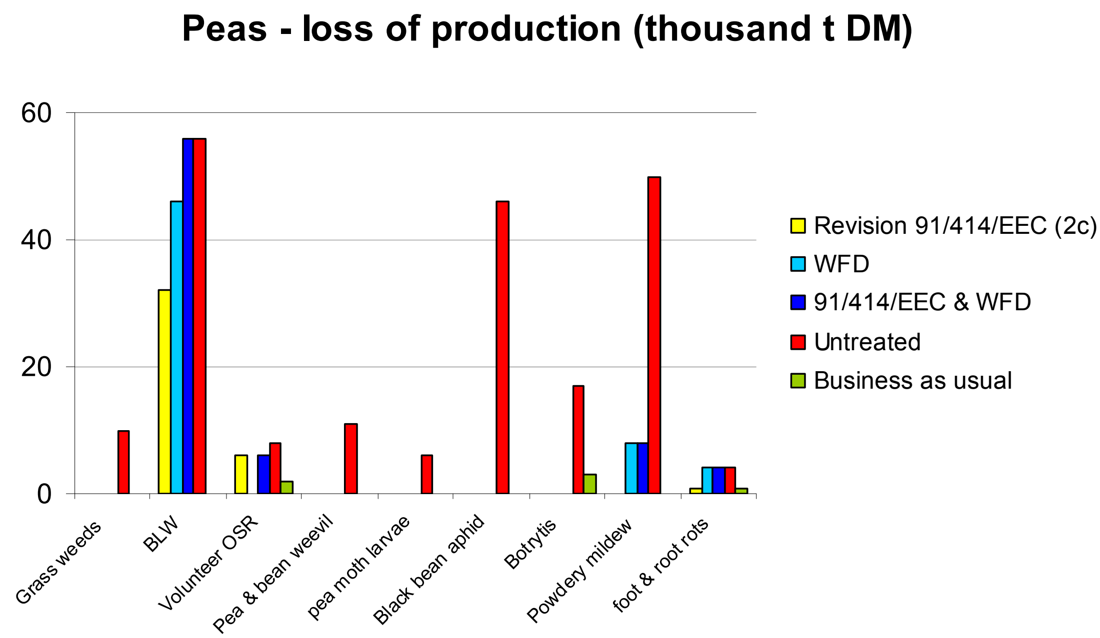

Figure 15. Peas loss of production (thousand t DM) as a result of changes in pesticide availability

Broadleaved weeds can cause large losses in pea crops, competing with young plants during establishment and then causing contamination problems during harvest. Competition from weeds could reduce pea yields by 30% on average, with some crops completely lost if left untreated. A number of key herbicides (cyanazine, simazine and trifluralin) have already been lost to pea growers as a result of problems in water. The loss of pendimethalin to the revision of 91/414/EEC and bentazone to WFD will drastically reduce the options for broadleaved weed control in peas, with the risk that yields could fall to levels close to those seen in untreated situations (Figure 15). Some control could be achieved through the use of mechanical weeders. These would increase costs and could cause damage to young plants, but would increase the potential yields of crops.

The potential loss of chlorothalonil to the WFD could cause powdery mildew and foot rots to become harder to control. In the 2006 PUS of arable crops, chlorothalonil was applied 39,000 spray ha of crop, with an average of 1.4 applications made per crop, this equates to about 60% of the crop.

7.8. Beans

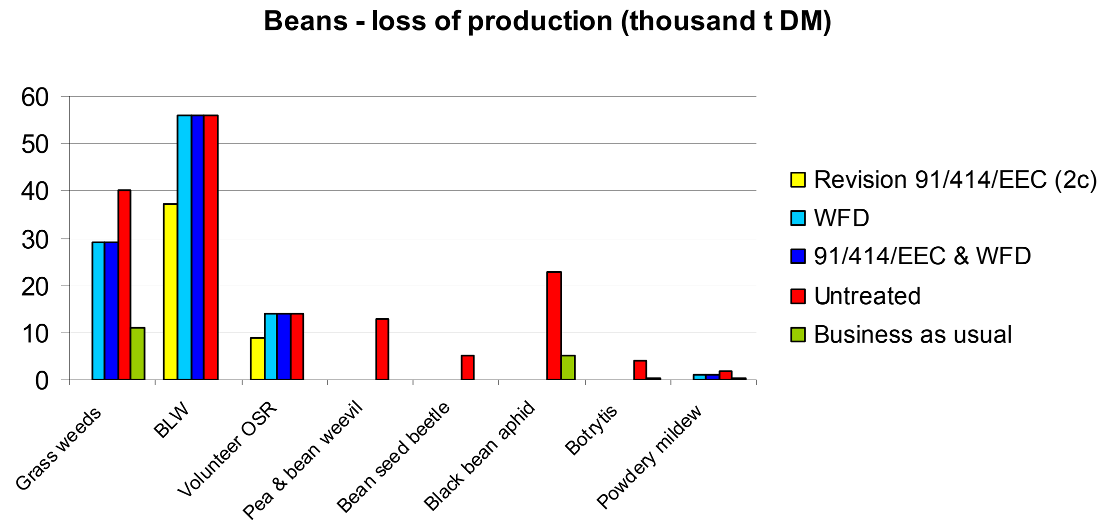

Figure 16. Beans loss of production (thousand t DM) as a result of changes in pesticide availability

In winter beans grass and broadleaved weeds are the main threat to production with potential yield losses from untreated crops reaching 100,000t as a result of their combined effects (Figure 16). The majority of weed control in beans has to occur pre-emergence as only bentazone has approval for post-emergence applications. The loss of bentazone, propyzamide and carbetamide to the WFD could effectively mean that weed control in winter beans would be dependant upon solely mechanical means.

The impact of insecticide loses would be minimal.

Chlorothalonil was applied to 70% of the bean area in 2005, applied mainly to treat chocolate spot. Due to its usage on large areas across a wide range of crops there is the risk that it might be lost or restricted in its use due to WFD. Boscalid and pyraclostrobin would be potential alternatives for the control of chocolate spot in beans, boscalid is a relatively new active that was not available during the last pesticide usage survey.

7.9. Wheat, Barley and Oilseeds

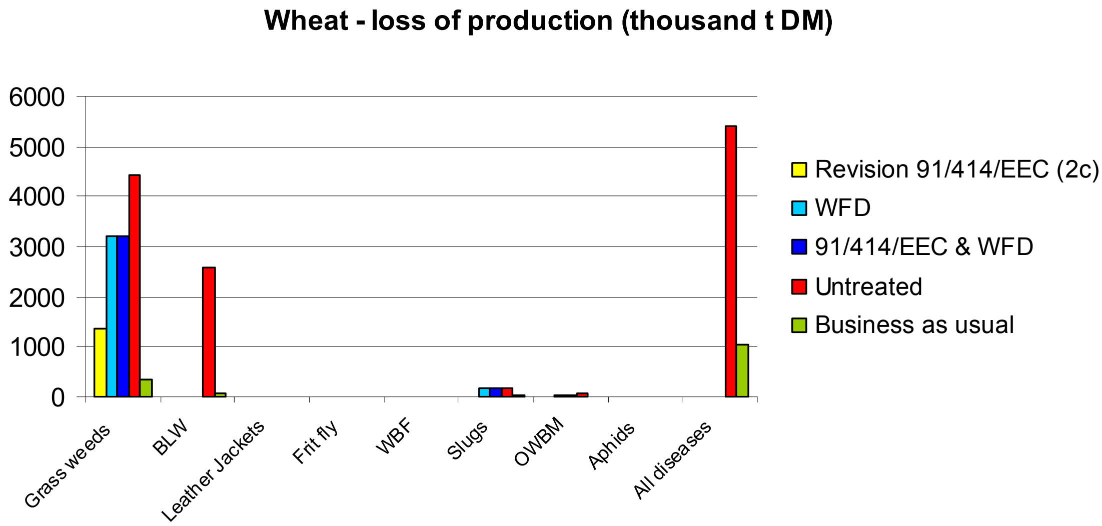

Figure 17. Wheat loss of production (thousand t DM) as a result of changes in pesticide availability

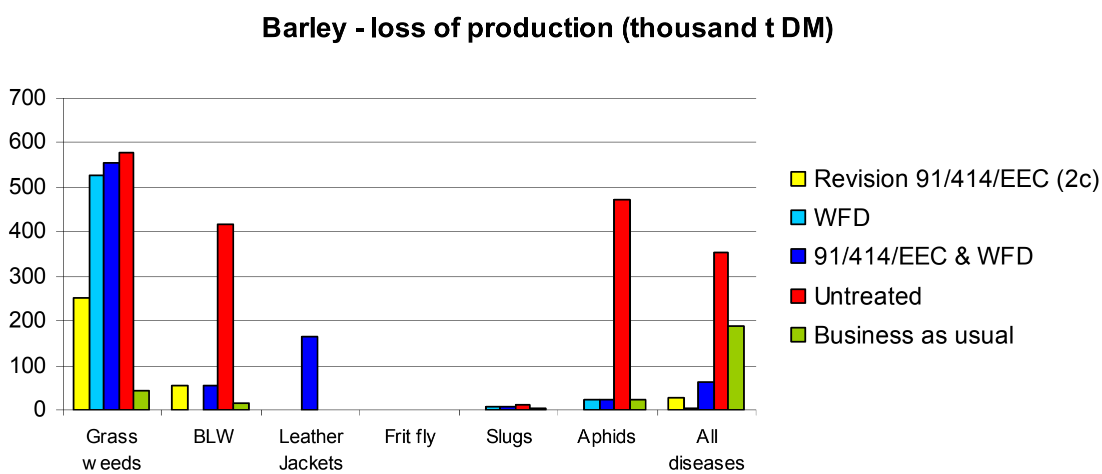

Figure 18. Barley loss of production (thousand t DM) as a result of changes in pesticide availability

Wheat and barley are important elements in livestock rations providing supplementary carbohydrates and energy. In the October 2008 UK supply and demand balance sheet 6.9M t of wheat were used for animal feed, of which 3.3M t went to compounders and 1.5M t was fed on farm, the remainder was fed on integrated poultry units. The potential loss in wheat production due to the effects of changing pesticide availability ranges from 1.4M t to 3.2M t (8% - 18.8% loss of production Table 6). This loss is based on the wheat area remaining the same or similar to levels seen in 2008/09. If the area of wheat remained the same the reduced availability from within the UK is likely to increase our dependence upon imports to meet with requirements for milling, bio-ethanol production and animal feeds.

Barley is not fed in quite such a large volume as wheat. In the October 2008 UK supply and demand balance sheet, 3M t of barley went for animal feed with 0.7M going to compounders and 2.2M t being fed on farm, the remainder went into integrated units. Under the changing pesticide availability winter barley production could reduce by between 9% and 20.8% (250,000t – 580,000t), with similar effects expected upon spring barley. With almost 50% of the UK barley crop grown for feed, and the majority of that grown on farm for fed on farm, there is the likelihood that there will be reduced availability of UK barley for animal feed. Lower yields on farm would result in producers needing to buy in additional feed, increasing costs to livestock producers.

Oilseed rape is grown predominantly for its oil. However the meal produced as a co-product is an important source of protein in livestock rations. The animal protein feed market is dominated by soya meal (43%) and rape meal (28%) The majority of the soya meal is included in pig and poultry rations due to requirements for specific amino acids, whilst rape meal is the predominant supplementary protein source used for ruminants. Rape meal costs on average £4.77 per 1% protein compared with soya meal costing £6.24 per 1% protein, making it the cheaper source of protein.

If oilseed rape could no longer be grown in the UK due to changes in pesticide availability, the rape meal currently used would need to be replaced by other home grown sources of protein such as field beans and peas, or imported soya or maize products. The 750,000 tonnes of rape meal currently used provides approximately 250,000 tonnes of protein. To replace this with protein from field beans would need over 1 million tonnes, or over 260,000ha (at average 3.75t/ha yield), requiring a trebling of the current field bean area. This is, however, still less than half the current area of oilseed rape. More realistically, imports of soya, maize and rape meal, will replace some of the lost rape meal. In the medium term there may also be an increase in co-products from bioethanol plants using wheat as a feedstock, which under current estimates would produce over 1 M tonnes of distilled wheat feed at around 34% protein, which could replace the rape meal feed.

Appendix 1

Glossary of Latin names and abbreviations

Table 18. Table of common and Latin names

Common Name	*Scientific Name*
Weeds	
Annual meadow grass	*Poa Annua*
Barley	*Hordeum vulgare*
Barren brome	*Anisantha sterilis*
Black-grass	*Alopecurus myosuroides*
Bracken	*Pteridium aquilinum*
Buttercups	*Ranunculus spp*
Charlock	*Sinapis arvensis*
Chickweed	*Stellaria media*
Cleavers	*Galium aparine*
Couch	*Elytrigia repens*
Creeping thistle	*Cirsium arvense*
Docks	*Rumex Spp.*
Gorse	*Ulex europaeus*
Rye-grass (Italian)	*Lolium multiflorum*
Nettles	*Urtica dioica*
Oat	*Avena sativa*
Oilseed rape	*Brassica napus ssp oleifera*
Parsley-piert	*Aphanes arvensis*
Pea	*Pisum sativum*
Rye-grass (perrenial)	*Lolium perenne*
Pineapple weed	*Matricaria disciodes*
Poppy	*Papaver rhoeas*
Potatoes	*Solanum tuberosum*
Ragwort	*Senecio jacobaea*
Red dead-nettle	*Lamium purpurium*
Rough-stalked meadow-grass	*Poa trivialis*
Scented mayweed	*Matricaria recutita*
Scentless mayweed	*Tripleurospermum inodorum*
Shepherd's-purse	*Capsella bursa-pastoris*

Common Name	*Scientific Name*
Small-flowered crane's-bill	*Geranium pusillum*
Spear thistle	*Cirsium vulgare*
Spring barley	*Hordeum vulgare*
Spring beans	*Vicia faba (spring)*
Spring oats	*Avena sativa (spring)*
Spring oilseed rape	*Brassica napus ssp oleifera (spring)*
Spring peas	*Peas (spring)*
Spring wheat	*Triticum aestivum (spring)*
Thistles	*Cirsium spp.*
Wheat	*Triticum aestivum*
White clover	*Trifolium repens*
Wild-oat	*Avena fatua*
Winter barley	*Hordeum vulgare*
Winter beans	*Vicia faba (winter)*
Winter oats	*Avena sativa (winter)*
Winter oilseed rape	*Brassica napus ssp oleifers (winter)*
Winter wheat	*Triticum aestivum (winter)*
Winter wild-oat	*Avena sterilis*
Yorkshire fog	*Holcus lanatus*

Pests	
Bird-cherry aphid (autumn BYDV)	*Rhopalosiphum padi*
Brassica pod midge	*Dasineura brassicae Winn.*
Cabbage aphid	*Brevicoryne brassicae L.*
Cabbage leaf miner	*Phytomyza rufipes Meig.*
Cabbage moth	*Mamestra brassicae*
Cabbage root fly	*Delia radicum*
Cabbage seed weevil	*Ceutorhynchus assimilis Payk.*
Cabbage stem flea beetle	*Psylliodes chrysocephala L.*
Cabbage stem weevil	*Ceutorhynchus quadridens Panz. ,*
Cabbage white butterflies	*Pieris* spp.
Cereal cyst eelworms	*Heterodera major*
Clover cyst nematode	*Heterodera trifolii*
Clover seed weevil	*Apion* spp
Common rustic moth	*Mesapamea secalis*
Diamond-back moth	*Plutella xylostella*
European corn borer	*Ostrinia nubilalis*

Common Name	*Scientific Name*
Field slug	*Deroceras reticulatum*
Frit fly	*Oscinella frit*
Garden chafer	*Phyllopertha horticola*
Gout fly	*Chlorops pumilionis*
Grain aphid (autumn BYDV & summer feeding)	*Sitobion avenae*
Grass aphid	*Metopolophium festucae*
Grass and cereal flies	*Opomyza* spp.
Grey field slug	*Deroceras reticulatum*
Keeled slug	*Tandonia budapestensis*
Leaf-curling plum aphid	*Brachycaudus helichrysi*
Leatherjackets	*Tipula paludosa*
Marsh crane fly	*Tipula oleracea*)
Nematodes - stem	*Ditylenchus dipsaci*
Orange wheat blossom midge	*Sitodiplosis mosellana*
Pea and bean weevil	*Sitona lineatus*
Pea aphid	*Acyrthosiphon pisum*
Peach potato aphid	*Myzus persicae*
Pelargorium aphid	*Acyrthosiophon malvae*
Pollen beetle	*Meligethes spp.*
Rape winter stem weevil	*Ceutorhynchus picitarsis Gyll.*
September crane fly	*Tipula paludosa*
Small striped flea beetle	*Phyllotreta undulate*
Stem nematode	*Ditylenchus dipsaci*
Vetch Aphid	*Megoura viciae*
Western corn rootworm	*Diabrotica virgifera virgifera*
Wheat bulb fly	*Delia coarctata*
Wheat flea beetle	*Crepidodera ferruginea*
Wheat shoot beetle	*Helophorus nubilus*
White and yellow-soled slugs	*Arion spp*
Wireworm	*Agriotes* spp.

Common Name Diseases	*Scientific Name*
Anthracnose	*Colletotrichum acutatum*
Barley yellow dwarf virus	*Barley yellow dwarf virus (BYDV)*
Black blotch	*Cymadothea trifolii*
Black stem	*Ascochyta imperfecta*
Brown rust	*Puccinia graminis f. sp. lolii*
Brown spot	*Pleiochaeta setosa*
Cercospora leaf spot	*Cercospora beticola*
Clover rot	*Sclerotinia trifoliorum*
Clubroot	*Plasmodiophora brassicae*
Crown rust	*Puccinia coronata*
Crown wart	*Physoderma alfalfae*
Dark leaf and pod spot	*Alternaria brassicae and Alternaria brassicIcola*
Downy Mildew	*Peronospora trifoliorum*
Downy mildew (Kale)	*Hylaperonospora brassicae*
Drechslera leaf spot	*Drechslera spp.*
Dry rot	*Leptosphaeria maculans*

Common Name	*Scientific Name*
Diseases	
Ergot	*Claviceps purpurea*
Eyespot	*Kabatiella zeae*
Fusarium diseases	*Fusarium spp*
Fusarium foot rot	*Fusarium spp*
Grey mould	*Botryotinia fuckeliana (asexual stage Botrytis cinerea)*
Halo spot	*Selenophoma donacis*
Light leaf spot	*Pyrenopeziza brassicae (asexual stage Cylindrosporium concentricum)*
Maize smut	*Ustilago zeae*
Northern leaf blight	*Setosphaeria turcica*
Phoma B	*Leptosphaeria biglobosa (asexual stage Phoma B - Phoma lingam)*
Phoma Leaf Spot and Stem Canker	*Leptosphaeria maculans (asexual stage Phoma A - Phoma lingam)*
Phytophthora root rot	*Phytophthora cryptogea*
Pepper spot	*Leptosphaerulina trifolii*
Powdery mildew	*Blumeria graminis*
Powdery mildew (clover)	*Erysiphe trifolii*
Powdery mildew (fodder beet)	*Erysiphe betae*
Powdery mildew (lucerne)	*Erysiphe pisi*
Powdery mildew (kale)	*Erysiphe cruciferarum*
Pseudopeziza leaf spot	*Pseudopeziza trifoliorum & P. medicaginis*
Ramularia leaf spot (fodder beet)	*Ramularia beticola*
Rhynchosporium	*Rhynchosporium secalis / R. orthosporum*
Ringspot	*Mycosphaerella brassicicola*
Rust (clover, lucerne, lupins, fodder beet)	*Uromyces fallens, U. pisi, U. viciae-fabae, U. betae*
Sclerotinia stem rot	*Sclerotinia sclerotiorum*
Scorch (clover)	*Kabatiella caulivora*
Septoria nodorum	*Septoria nodorum (Stagonospora nodorum)*
Septoria tritici	*Septoria tritici (Mycosphaerella graminicola)*
Sharp eyespot	*Rhizoctonia cerealis*
Snow rot	*Typhula incarnata*
Stem rust	*Puccinia graminis*
Stemphylium leaf spot	*Stemphylium sarcinaeforme*
Take-all	*Gaeumannomyces graminis*
Turnip yellows	*Turnip yellows virus (TuYV)*
Verticillium wilt (Lucerne)	*Verticillium. albo-atrum)*
White blister	*Albugo candida*
Yellow rust	*Puccinia striiformis*

Abbreviation	Full name
a.i.	Active ingredient
AHDB	Agriculture and Horticulture Development Board
AMG	Annual meadow-grass
BYDV	Barley Yellow Dwarf Virus
CCP	Common Council Position
CRD	Chemicals Regulation Directorate
CSFB	Cabbage Stem Flea Beetle
EA	Environment Agency
EEC	European Economic Community
ENVI	Environment Committee of the European Parliement
EU	European Union
Ha	Hectare
HGCA	Home Grown Cereals Authority
MDC	Meat Development Council
MRL	Maximum Residue Level
N	Nitrogen (fertiliser)
OSR	Oilseed rape
OWBM	Orange Wheat Blossom Midge
PBT	Persistent, bioaccumulating, toxic substances
PGRO	Processors and Growers Research Organisation (peas and beans)
POP	Persistent Organic Polutant
PPPs	Plant Protection Products
PRC	Pesticides Residue Committee
PSD	Pesticides Safety Directorate
PUS	Pesticide Usage Survey
vPvB	Very Persistent, Very Bioaccumulating substances
WFD	Water Framework Directive

Appendix 2

Currently available active substances

Table 19 - Agricultural herbage - Grass

Target	Active ingredient	Other Information
Diseases		
Crown rust	propiconazole	
Drechslera leaf spot	propiconazole	
Rhynchosporium	Propiconazole	
Foliar disease	Carbendazim	Grass seed crops (SOLA)
Pests		
Aphids	pirimicarb	
Birds/mammals	aluminium ammonium sulphate	
	aluminiium phosphide	
	strychnine hydrochloride	(restricted public access areas)
Flies	chlorpyrifos	
	cypermethrin	
Leatherjackets	chlorpyrifos	
Slugs/snails	methiocarb	(seed admixture)
Plant growth regulation		
Quality/yield control	sulphur	
Weeds		
Aquatic weeds	MCPA	
Broad-leaved weeds	2,4-D	
	2,4-D+dicamba	
	2,4-D+dicamba+triclopyr	
	2,4-D+MCPA	
	2,4-DB+linuron+MCPA	
	2,4-DB+MCPA	
	amidosulfuron	
	asulam	
	bentazone+MCPA+MCPB	
	bromoxynil+ioxynil+mecoprop-P	
	citronella oil	
	clopyralid	
	clopyralid	(off-label - spot treatment)
	clopyralid+fluroxypyr+triclopyr	

Target	Active ingredient	Other Information
	clopyralid+triclopyr	
	clopyralid+triclopyr	(off-label via weed wiper)
	dicamba+MCPA+mecoprop-P	
	dicamba+mecoprop-P	
	dichlorprop-P	
	fluroxypyr	
	fluroxypyr+triclopyr	
	glyphosate	
	glyphosate	(wiper application)
	MCPA	
	MCPA+MCPB	
	MCPB	
	mecoprop-P	
	thifensulfuron-methyl	
Crops as weeds	fluroxypyr	Volunteer potatoes
Grass weeds	glyphosate	
Weeds, miscellaneous	fluroxypyr	
	glufosinate-ammonium	
	glyphosate	
Woody weeds/scrub	asulam	

Table 20. Maize

Diseases		
Damping off	thiram	(off-label - seed treatment)
Eyespot	flusilazole	(off-label)
Foliar disease	flusilazole	(off-label)

Pests		
Aphids	nicotine	
	pirimicarb	
	pirimicarb	(off-label)
	pymetrozine	(off-label)
Caterpillars	Bacillius thuringiensis	(off-label)
	indoxacarb	(off-label)
	nicotine	
Flies	chlorpyrifos	
	clothianidin	
	lambda-cyhalothrin	(off-label)
Leaf miners	nicotine	
Pests/miscellaneous	lambda-cyhalothrin	(off-label)
Slugs/snails	methiocarb	
Symphylids	clothianidin	(reduction)
Wireworms	Clothianidin	

Weeds		
Broad-leaved weeds	bromoxynil	
	bromoxynil + prosulfuron	
	bromoxynil + terbuthylazine	
	bromoxynil + terbuthylazine	(off-label)
	clopyralid	
	flufenacet+ isoxaflutole	
	fluroxypyr	
	isoxaben	(off-label grown for game cover)

	mesotrione	
	mesotrione + terbuthylazine	
	mesotrione + terbuthylazine	(off-label)
	nicosulfuron	
	pendimethalin	
	pendimethalin	(off-label)
	rimsulfuron	
Crops as weeds	fluroxypyr	
	fluroxypyr	(off-label)
	mesotrione	
	nicosulfuron	
	pendimethalin	
	rimsulfuron	
Grass weeds	bromoxynil + terbuthylazine	(off-label)
	flufenacet+ isoxaflutole	
	mesotrione	
	mesotrione + terbuthylazine	(off-label)
	nicosulfuron	
	pendimethalin	
Weeds misc	bromoxynil + terbuthylazine	(off-label)
	fluroxypyr	

Table 21. Fodder brassicas

Target	Active ingredient	Other Information
Diseases		
Alternaria	azoxystrobin	
Bacterial blight	copper oxychloride	(off-label)
Black rot	copper oxychloride	(off-label)
Bottom rot	copper oxychloride	(off-label)
Downy mildew	fosetyl-aluminium	(off-label)
Phytophthora	copper oxychloride	(off-label)
Powdery mildew	azoxystrobin+difenoconozole	
Ring rot	azoxystrobin, difenoconozole	(off-label)
Spear rot	copper oxychloride	(off-label)
Stem canker	copper oxychloride	(off-label)
White blister	azoxystrobin	

Target	Active ingredient	Other Information
	azoxystrobin+difenoconozole	
	mancozeb+metalaxyl-M	(off-label)
Pests		
Aphids	cypermethrin	
	nicotine	
	pirimicarb	
	pymetrozine	(off-label)
	thiacloprid	(off-label)
Beetles	alpha-cypermethrin	
	deltamethrin	
Caterpillars	alpha-cypermethrin	
	Bacillus thuringiensis	(off-label)
	cypermethrin	
	deltamethrin	
	nicotine	
Miscellaneous	dimethoate	(off-label)
Weeds		
Broad-leaved weeds	chlorthal-dimethyl	
	chlorthal-dimethyl+propachlor	
	clomazone	(off-label)
	clopyralid	
	metazachlor	(off-label)
	napropamide	
	propachlor	
	trifluralin	
Crops as weeds	fluazifop-P-butyl	(stockfeed only)
Grass weeds	chlorthal-dimethyl+propachlor	
	fluazifop-P-butyl	(stockfeed only)
	metazachlor	(off-label)
	napropamide	
	propachlor	
	trifluralin	

Table 22. Lucerne

Target	Active ingredient	Other Information
Pests		
herbage (seed crop)	dimethoate	
Weeds		
lucerne	2,4-DB	
lucerne	carbetamide	Voluntary withdrawn 2010
lucerne (seed crop)	isoxaben	Voluntary withdrawn 2010
lucerne	propyzamide	
lucerne	tri-allate	pending

Table 23. Root brassicas

Target	Active ingredient	Other Information
Diseases		
Alternaria	azoxystrobin	(off-label)
	azoxystrobin+difenoconozole	(off-label)
	fenpropimorph	(off-label)
	iprodione+thiophanate-methyl	(off-label)
	tebuconazole	
Botrytis	propamocarb hydrochloride	(off-label)
Crown rot	fenpropimorph	(off-label)
	iprodione+thiophanate-methyl	(off-label)
Damping off	propamocarb hydrochloride	(off-label)
	thiram	(off-label seed treatment)
	thiram	(seed treatment)
Disease control/foliar feed	tebuconazole	(off-label)
Downy mildew	metalaxyl-M	(off-label)
	propamocarb hydrochloride	(off-label)
Foliar diseases	azoxystrobin	(off-label)
	flusilazole	(off-label)
	tebuconazole	(off-label)
	tebuconazole+trifloxystrobin	(off-label)
Fungus diseases	tebuconazole	(off-label)
Phytophthora	propamocarb hydrochloride	(off-label)
Powdery mildew	azoxystrobin	(off-label)
	azoxystrobin+difenoconozole	(off-label)
	fenpropimorph	(off-label)
	sulphur	
	sulphur	(off-label)
	tebuconazole	(off-label)
Rhizoctonia	azoxystrobin	(off-label)
	tolclofos-methyl	(with fleece or mesh covers)
	tolclofos-methyl	(without covers)
Ring spot	tebuconazole	(off-label)
Sclerotinia	boscalid+pyraclostrobin	(off-label)
	tebuconazole	
Stem canker	flusilazole	(off-label)
White blister	mancozeb+metalaxyl-M	(off-label)
	metalaxyl-M	(off-label)
	propamocarb hydrochloride	(off-label)

Target	Active ingredient	Other Information
Pests		
Aphids	deltamethrin	(off-label)
	lambda-cyhalothrin+pirimicarb	(off-label)
	nicotine	
	pirimicarb	
	pirimicarb	(off-label)
	thiacloprid	(off-label)
Beetles	deltamethrin	
Caterpillars	deltamethrin	
	nicotine	
Cutworms	Bacillus thuringiensis	(off-label)
	cypermethrin	(off-label)
	lambda-cyhalothrin	(off-label)
	lambda-cyhalothrin+pirimicarb	(off-label)
Flies	chlorpyrifos	(off-label)
	lambda-cyhalothrin	(off-label)
Leaf miners	nicotine	
Pests, miscellaneous	deltamethrin	(off-label)
	dimethoate	(off-label)
	lambda-cyhalothrin	(off-label)
Weevils	lambda-cyhalothrin	(off-label)
Weeds		
Broad-leaved weeds	chlorpropham	(off-label)
	chlorthal-dimethyl	
	chlorthal-dimethyl+propachlor	
	clomazone	(off-label)
	clopyralid	
	glyphosate	
	metamitron	(off-label)
	metazachlor	
	propachlor	
	propachlor	(off-label)
	prosulfocarb	(off-label)
	trifluralin	
Crops as weeds	cycloxydim	
	fluazifop-P-butyl	(stockfeed only)
	glyphosate	
Grass weeds	chlorpropham	(off-label)

Target	Active ingredient	Other Information
	chlorthal-dimethyl+propachlor	
	cycloxydim	
	fluazifop-P-butyl	(stockfeed only)
	glyphosate	
	metamitron	(off-label)
	metazachlor	
	propachlor	
	propachlor	(off-label)
	propaquizafop	
	propaquizafop	(off-label)
	prosulfocarb	(off-label)
	trifluralin	
Weeds, miscellaneous	glyphosate	
	metamitron	(off-label)

Table 24. Fodder beet

Target	Active ingredient	Other Information
Diseases		
Aphanomyces	hymexazol	(off-label - seed treatment)
Black leg	hymexazol	(seed treatment)
Botrytis	iprodione	(off-label)
Cercospora leaf spot	azoxystrobin+cyproconazole	
	cyproconazole+trifloxystrobin	
	epoxiconazole+pyraclostrobin	
Damping off	cymoxanil+fludioxonil+metalaxyl-M	(off-label - seed treatment)
Downy mildew	copper oxychloride	(off-label)
	fosetyl aluminium	(off-label)
	fosetyl aluminium+propamocarb hydrochloride	
	mancozeb	(off-label)
	metalaxyl-M	(off-label)
Foliar diseases	cyproconazole	(off-label)
	epoxiconazole+pyraclostrobin	(off-label)
	fosetyl aluminium	(off-label)
Powdery mildew	azoxystrobin+cyproconazole	
	carbendazim+flusilazole	
	carbendazim+flusilazole	(off-label)
	cyproconazole+trifloxystrobin	
	difenoconazole+fenpropidin	
	epoxiconazole+pyraclostrobin	
	flusilazole	
	quinoxyfen	
	sulphur	
	sulphur	(off-label)
Ramularia leaf spots	azoxystrobin+cyproconazole	
	cyproconazole	
	cyproconazole+trifloxystrobin	
	difenoconazole+fenpropidin	
	epoxiconazole+pyraclostrobin	
	propiconazole	(reduction)
Root malformation disorder	azoxystrobin	(off-label)
	mancozeb	(off-label)
	metalaxyl-M	(off-label)
Rust	azoxystrobin+cyproconazole	
	carbendazim+flusilazole	
	cyproconazole+trifloxystrobin	

Target	Active ingredient	Other Information
	difenoconazole+fenpropidin	
	epoxiconazole+pyraclostrobin	
	fenpropimorph	
	flusilazole	
	propiconazole	
Seed-borne disease	thiram	(seed soak)
Pests		
Aphids	beta-cyfluthrin+clothianidin	(seed treatment)
	chlorpyrifos	(off-label)
	cypermethrin	
	cypermethrin	(off-label)
	cypermethrin	(off-label - outdoor and protected crops)
	deltamethrin	(off-label)
	dimethoate	
	dimethoate	(excluding Myzus
	imadacloprid	
	lambda-cyhalothrin	
	lambda-cyhalothrin+pirimicarb	
	lambda-cyhalothrin+pirimicarb	(off-label)
	nicotine	
	oxamyl	
	oxamyl	(off-label)
	pirimicarb	
	pirimicarb	(off-label)
Beetles	chlorpyrifos	
	chlorpyrifos	(off-label)
	deltamethrin	
	deltamethrin	(off-label)
	imidacloprid	
	lambda-cyhalothrin	
	lambda-cyhalothrin	(off-label)
	lambda-cyhalothrin+pirimicarb	
	lambda-cyhalothrin+pirimicarb	(off-label)
	oxamyl	
	oxamyl	(off-label)
	tefluthrin	(seed treatment)
	thiamethoxam	(seed treatment)
Birds/mammals	aluminium ammonium sulphate	

Target	Active ingredient	Other Information
Catterpillars	cypermethrin	
	cypermethrin	(off-label - outdoor and protected crops)
	lambda-cyhalothrin	
	lambda-cyhalothrin	(off-label)
	nicotine	
Cutworms	Bacillus thuringiensis	(off-label)
	cypermethrin	
	lambda-cyhalothrin	
	lambda-cyhalothrin	(off-label)
	lambda-cyhalothrin+pirimicarb	
	lambda-cyhalothrin+pirimicarb	(off-label)
	methiocarb	(reduction)
	zeta-cypermethrin	
Flies	oxamyl	
	oxamyl	(off-label)
Free-living nematodes	oxamyl	
	oxamyl	(off-label)
Leaf miners	dimethoate	
	imidacloprid	
	lambda-cyhalothrin	
	lambda-cyhalothrin	(off-label)
	lambda-cyhalothrin+pirimicarb	
	lambda-cyhalothrin+pirimicarb	(off-label)
	nicotine	
	thiamethoxam	(seed treatment)
Leatherjackets	chlorpyrifos	
	chlorpyrifos	(off-label)
	methiocarb	(reduction)
Millipedes	imidacloprid	
	methiocarb	(reduction)
	oxamyl	
	oxamyl	(off-label)
	tefluthrin	(seed treatment)
	thiamethoxam	(seed treatment)
Pests, miscellaneous	chlorpyrifos	(off-label)
	deltamethrin	(off-label)
	lambda-cyhalothrin	(off-label)
Slugs/snails	methiocarb	
Springtails	imidacloprid	

Target	Active ingredient	Other Information
	tefluthrin	(seed treatment)
	thiamethoxam	(seed treatment)
Symphylids	imidacloprid	
	tefluthrin	(seed treatment)
	thiamethoxam	(seed treatment)
Weevils	lambda-cyhalothrin	
Wireworms	thiamethoxam	(seed treatment)
Weeds		
Broad-leaved weeds	carbetamide	
	chloridazon+ethofumesate	
	chloridazon+metamitron	
	chloridazon+metamitron	(off-label)
	chloridazon+quinmerac	
	chloridazon+quinmerac	(off-label)
	chlorpropham	(off-label)
	chlorpropham+metamitron	
	clopyralid	
	desmedipham+ethofumesate+ phenmedipham	
	desmedipham+phenmedipham	
	diquat	
	ethofumesate	
	ethofumesate+metamitron	
	ethofumesate+phenmedipham	
	glufosinate-ammonium	
	glyphosate	
	lenacil	
	lenacil+triflusulfuron-methyl	
	metamitron	
	phenmedipham	
	propyzamide	
	sodium chloride	(commodity substance)
	trifluralin	
	triflusulfuron-methyl	
	triflusulfuron-methyl	(off-label)
Crops as weeds	carbetamide	
	cycloxydim	
	fluazifop-P-butyl	
	glyphosate	

Target	Active ingredient	Other Information
	glyphosate	(wiper application)
	lenacil+triflusulfuron-methyl	
	propaquizafop	(off-label)
	propyzamide	
	quizalofop-P-ethyl	
	quizalofop-P-tefuryl	
	sodium chloride	(commodity substance)
	tepraloxydim	
Grass weeds	carbetamide	
	chloridazon	
	chloridazon+ethofumesate	
	chloridazon+metamitron	
	chloridazon+metamitron	(off-label)
	chloridazon+quinmerac	
	chloridazon+quinmerac	(off-label)
	chlorpropham	(off-label)
	chlorpropham+metamitron	
	cycloxydim	
	desmedipham+ethofumesate+ phenmedipham	
	diquat	
	ethofumesate	
	ethofumesate+metamitron	
	ethofumesate+phenmedipham	
	fluazifop-P-butyl	
	fluazifop-P-butyl	(off-label)
	glufosinate-ammonium	
	glyphosate	
	lenacil	
	metamitron	
	propaquizafop	
	propaquizafop	(off-label)
	propyzamide	
	quizalofop-P-ethyl	
	quizalofop-P-tefuryl	
	tepraloxydim	
	tepraloxydim	(off-label)
	tri-allate	
	trifluralin	
Weeds, miscellaneous	diquat	

Target	Active ingredient	Other Information
	glufosinate-ammonium	
	glyphosate	

Table 25. Lupins

Target	Active ingredient	Other Information
Crop control		
Desiccation	diquat	(off-label)
	glyphosate	(off-label)
Diseases		
Ascochyta	azoxystrobin	(off-label)
	metconazole	(qualified minor use)
Botrytis	chlorothalonil	(off-label)
	cyprodinil+fludioxonil	(off-label)
	metconazole	(qualified minor use)
Damping off	cymoxanil+fludioxonil+metalaxyl-M	(off-label)
	thiram	(off-label - seed treatment)
Downy mildew	cymoxanil+fludioxonil+metalaxyl-M	(off-label)
	fosetyl-aluminium	(off-label)
Foliar diseases	chlorothalonil	(off-label)
Pythium	cymoxanil+fludioxonil+metalaxyl-M	(off-label)
Rust	azoxystrobin	(off-label)
	metconazole	(qualified minor use)
Seed borne diseases	fosetyl-aluminium	(off-label)
Pests		
Aphids	deltamethrin	(off-label)
	lambda-cyhalothrin	(off-label)
	lambda-cyhalothrin+pirimicarb	(off-label)
Pests, miscellaneous	deltamethrin	(off-label)
Weeds		
Broad-leaved weeds	carbetamide	(off-label)
	clomazone	(off-label)
	isoxaben+terbuthylazine	(off-label)
	linuron+trifluralin	(off-label)
	pendimethalin	(off-label)
	propyzamide	(off-label)

Target	Active ingredient	Other Information
Grass weeds	carbetamide	(off-label)
	linuron+trifluralin	(off-label)
	pendimethalin	(off-label)
	propaquizafop	(off-label)
	propyzamide	(off-label)
	tepraloxydim	(off-label)
	tri-allate	(off-label)

Table 26. Chicory

Target	Active ingredient	Other Information
Diseases		
Alternaria	iprodione	(off-label)
Botrytis	azoxystrobin	(off-label)
	cyprodinil+fludioxinil	(off-label)
	iprodione	(off-label)
Damping off	thiram	(off-label seed treatment)
Downy mildew	copper oxychloride	(off-label)
	dimethomorph+mancozeb	(off-label)
	mancozeb	(off-label)
Foliar diseases	fosetyl aluminium	(off-label)
	mancozeb	(off-label)
	thiram	(off-label)
Phytophthora	fosetyl aluminium	(off-label for forcing)
Rhizoctonia	azoxystrobin	(off-label)
Rust	mancozeb	(off-label)
Sclerotinia	azoxystrobin	(off-label)
Seed-borne diseases	thiram	(seed soak)
Septoria	Bordeaux mixture	
	chlorothalonil	(qualified minor use)
	copper ammonium carbonate	
	copper oxychloride	
	mancozeb	(off-label)
Pests		
Aphids	acetamiprid	(off-label)
	cypermethrin	(off-label)
	deltamethrin	(off-label)
	nicotine	
	pirimicarb	
	pirimicarb	(off-label)
	pirimicarb	(off-label - for forcing)
	pymetrozine	(off-label)
Beetles	deltamethrin	(off-label)
Caterpillars	Bacillus thuringiensis	(off-label)
	deltamethrin	(off-label)
	diflubenzuron	(off-label)
	lambda-cyhalothrin	(off-label)
	nicotine	

Target	Active ingredient	Other Information
Cutworms	lambda-cyhalothrin	(off-label - for forcing)
Flies	lambda-cyhalothrin	(off-label)
Leaf miners	nicotine	
Leaf hoppers	deltamethrin	(off-label)
Pests, miscellaneous	deltamethrin	(off-label)
	lambda-cyhalothrin	(off-label)
	spinosad	
Plant growth regulation		
Quality/yield control	gibberellins	
Weeds		
Broad-leaved weeds	metamitron	(off-label)
	pendimethalin	(off-label)
	propachlor	(off-label)
	propachlor	(off-label under crop covers)
	prosulfocarb	(off-label)
	triflusulfuron-methyl	(off-label)
Crops as weeds	propaquizafop	(off-label)
Grass weeds	fluazifop-P-butyl	(off-label)
	metamitron	(off-label)
	propachlor	(off-label)
	propachlor	(off-label under crop covers)
	propaquizafop	(off-label)
	prosulfocarb	(off-label)

Appendix 3

Active substances at risk from revision of 91/414/EEC

Table 27. Active substances that have been reviewed with a view to possible withdrawal from EU markets. Council reasons for review. 2C used for this analysis.

2A	2B	2C	3
Council Common position: Endocrine disrupter: initial UK assessment	Council Common position: Endocrine disrupter ENVI* proposal	Council Common position: Swedish criteria	**Additional** None currently hazardous: ENVI* neurotoxicological criteria (EU Parliament Enviro't, Public Health and Food Safety Committee)
Herbicides	**Herbicides**	**Herbicides**	**Herbicides**
flumioxazine	flumioxazine	flumioxazine	2,4-D
glufosinate	glufosinate	glufosinate	2,4-DB
linuron	linuron	linuron	dichlorprop p
pendimethalin	pendimethalin	pendimethalin	MCPA
2,4-D	amitrole	ioxynil	MCPB
amitrole	ioxynil		mecoprop
ioxynil	metribuzin		mecoprop-p
metribuzin			
picloram			
triflusulfuron			
Insecticides	**Insecticides**	**Insecticides**	**Insecticides**
bifenthrin	bifenthrin	bifenthrin	acrinathrin
esfenvalerate	esfenvalerate	esfenvalerate	alpha cypermethrin
flufenoxuron	flufenoxuron	flufenoxuron	beta-cyfluthrin
lufenuron	lufenuron	lufenuron	chlorpyrifos
deltamethrin	deltamethrin		chlorpyrifos methyl
dimethoate			cyfluthrin
			cypermethrin
			dimethoate
			ethprophos
			etofenprox
			fenamiphos
			formetanate
			fosthiazate
			lambda cyhalothrin

2A	2B	2C	3
Council Common position: Endocrine disrupter: initial UK assessment	Council Common position: Endocrine disrupter ENVI* proposal	Council Common position: Swedish criteria	**Additional** None currently hazardous: ENVI* neurotoxicological criteria (EU Parliament Enviro't, Public Health and Food Safety Committee)
			methamidophos
			methiocarb
			oxamyl
			phosmet
			pirimicarb
			pirimiphos-methyl
			tau fluvalinate
			tefluthrin
			zeta-cypermethrin
Fungicides	**Fungicides**	**Fungicides**	**Fungicides**
bitertanol	bitertanol	bitertanol	metiram
carbendazim	carbendazim	carbendazim	thiram
dinocap	dinocap	dinocap	ziram
flusilazole	flusilazole	flusilazole	
quinoxyfen	quinoxyfen	quinoxyfen	
cyproconazole	cyproconazole	cyproconazole	
difenoconazole	epoxiconazole	epoxiconazole	
epoxiconazole	fenbuconazole	fenbuconazole	
fenbuconazole	mancozeb	mancozeb	
fluquinconazole	maneb	maneb	
iprodione	metconazole	metconazole	
mancozeb	myclobutanil	tebuconazole	
maneb	tebuconazole		
metconazole			
metiram			
myclobutanil			
penconazole			
prochloraz			
propiconazole			
tebuconazole			
tetraconazole			
thiram			

2A	2B	2C	3
Council Common position: Endocrine disrupter: initial UK assessment	Council Common position: Endocrine disrupter ENVI* proposal	Council Common position: Swedish criteria	**Additional** None currently hazardous: ENVI* neurotoxicological criteria (EU Parliament Enviro't, Public Health and Food Safety Committee)
triticonazole			**Other**
triademenol			metam

Appendix 4

Active substances that have yet to achieve annex 1 listing

Table 28. Active substances that have yet to achieve annex 1 listing

Substance	Status	Date of expiry of Annex 1	Approved in UK	Function	Approve for use in grass or forage crops
bromuconazole	list 3		Y	F	No
cyproconazole	list 3	2020	Y	F	Field beans, SOLA for grass seed crops and fodder beet
fluquinconazole	list 3	2020	Y	F	No
guazatine	list 3		Y	F	No
prochloraz	list 3	2020	Y	F	SOLA for grass seed crops
tetraconazole	list 3	2008	Y	F	Approval expired
carbetamide	list 3		Y	H	Fodder rape seed crops, kale seed crops, lucerne, red clover, swede seed crops, turnip seed crops, white clover, winter field beans, SOLA for lupins
carboxin	list 3 VW		Y	H	No
cycloxydim	list 3 VW		Y	H	Combining peas, fodder beet, field beans, Swedes
fluazifop-p	list 3 VW		Y	H	Field beans, combining peas, fodder beet, swedes, turnips, kale, SOLA for lucerne
napropamide	list 3		Y	H	Kale
propachlor	list 3		Y	H	Fodder rape, kale, Swedes, turnips
propaquizafop	list 3		Y	H	Combining peas, fodder beet, Swedes, turnips, field beans, SOLA for lupins
quinmerac	list 3 VW		Y	H	Fodder beet,
quizalofop-p-ethyl	list 3		Y	H	Combining peas, fodder beet, field beans
quizalofop-p-tefuryl	list 3		Y	H	Combining peas, fodder beet, field beans
terbuthylazine	list 3		Y	H	Combining peas, spring field beans, SOLA for forage maize and lupins
triallate	list 3		Y	H	Combining peas, fodder beet, red clover, white clover field beans, lucerne, SOLA for lupins

Substance	Status	Date of expiry of Annex 1	Approved in UK	Function	Approve for use in grass or forage crops
triflusulfuron	list 3	2018	Y	H	Fodder beet
bifenthrin	list 3	2018	Y	I	Combining peas
tau fluvalinate	list 3	2020	Y	I	SOLA for grass seed crops
tefluthrin	list 3	2020	Y	I	Fodder beet
zeta-cypermethrin	list 3	2018	Y	I	Combining peas, field beans
metaldehyde	list 3 VW		Y	Mollusc	All crops
chlormequat	list 3		Y	PGR	No

Appendix 5

Value of clover incorporation

National economic impact of loss of legumes at different percentage contribution in grass:legume mixes £M/UK. Figure in bold relates to table 1

Temporary grass + white clover

Total area 1,057,913 % area affected 40% Hectares affected 423165

	% Grass in sward	100%	95%	90%	80%	70%	60%	50%	40%	20%	0%
	% Clover in sward	0%	5%	10%	20%	30%	40%	50%	60%	80%	100%
	Value: £/ha	2555	2720	2545	2028	1684	1342	1169	998	826	573
% loss	5%	54.05	57.54	**53.84**	42.91	35.62	28.39	24.74	21.12	17.47	12.13
	10%	108.10	115.08	107.68	85.82	71.24	56.77	49.48	42.25	34.93	24.26
	15%	162.15	172.63	161.53	128.73	106.86	85.16	74.22	63.37	52.40	36.39
	20%	216.20	230.17	215.37	171.64	142.48	113.54	98.97	84.50	69.86	48.52
	25%	270.24	287.71	269.21	214.54	178.10	141.93	123.71	105.62	87.33	60.65

Permanent grass + white clover

Total area 5,035,443 % area affected 20% Hectares affected 1,007,089

	% Grass in sward	100%	95%	90%	80%	70%	60%	50%	40%	20%	0%
	% Clover in sward	0%	5%	10%	20%	30%	40%	50%	60%	80%	100%
	Value /ha	1399	1693	1423	1302	1177	1046	911	771	636	573
% loss	5%	70.45	85.26	71.65	65.57	59.25	52.68	45.88	38.83	32.03	28.87
	10%	140.89	170.51	143.30	131.14	118.49	105.36	91.76	77.67	64.06	57.74
	15%	211.34	255.77	214.95	196.70	177.74	158.05	137.63	116.50	96.09	86.60
	20%	281.78	341.03	286.60	262.27	236.98	210.73	183.51	155.33	128.12	115.47
	25%	352.23	426.29	358.25	327.84	296.23	263.41	229.39	194.17	160.15	144.34

Lucerne

Total area (notional) **1000** % area affected 10% Hectares affected 1000

	% Grass in sward	100%	95%	90%	80%	70%	60%	50%	40%	20%	0%
	% lucerne in sward	0%	5%	10%	20%	30%	40%	50%	60%	80%	100%
	Value/ha	2555	2538	2522	2489	2456	2423	2390	2357	2292	2226
% loss	5%	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.12	0.11	0.11
	10%	0.26	0.25	0.25	0.25	0.25	0.24	0.24	0.24	0.23	0.22
	15%	0.38	0.38	0.38	0.37	0.37	0.36	0.36	0.35	0.34	0.33
	20%	0.51	0.51	0.50	0.50	0.49	0.48	0.48	0.47	0.46	0.45
	25%	0.64	0.63	0.63	0.62	0.61	0.61	0.60	0.59	0.57	0.56

Red clover

Total area (notional) **10000** % area affected 10% Hectares affected 1000

	% Grass in sward	100%	95%	90%	80%	70%	60%	50%	40%	20%	0%
	% red clover in sward	0%	5%	10%	20%	30%	40%	50%	60%	80%	100%
	Mean value/ha	1703	1855	2005	1966	1927	1888	1849	1810	1877	1793
% loss	5%	0.09	0.09	0.10	0.10	0.10	0.09	0.09	0.09	0.09	0.09
	10%	0.17	0.19	0.20	0.20	0.19	0.19	0.18	0.18	0.19	0.18
	15%	0.26	0.28	0.30	0.29	0.29	0.28	0.28	0.27	0.28	0.27
	20%	0.34	0.37	0.40	0.39	0.39	0.38	0.37	0.36	0.38	0.36
	25%	0.43	0.46	0.50	0.49	0.48	0.47	0.46	0.45	0.47	0.45

Appendix 6

Bracken control in Rough Grazing

Weed control under bracken highlights the impact of the diverse types of land under permanent grass. In many National Parks, Areas of Outstanding Natural Beauty and non-intensively farmed areas permanent grassland is the 'default' land cover, displaced by forest, woodland and other vegetation as nature and man have dictated over history. Weed control in these areas can offer little economic gain. In some cases weeds like Japanese knotweed (*Reynoutria japonica*) Giant Hogweed (*Heracleum mantegazzianum*) and even Rhododendron (*R. ponticum)* become established in permanent grassland often around field margins. The immediate economic loss in terms of lost grassland is initially small but if left uncontrolled (e.g. Rhododendrons in parts of Snowdonia) they assume a greater economic significance. The possible loss of glyphosate under the Water Framework Directive will have an effect on the economic impact of these and similar weeds where its use on young growing plants provides effective control. Triclopyr provides an alternative for the control of woody weeds, but it use in formulated products with 2,4-D and clopyralid will be affected by possible losses due to the WFD (Table 4).

However some of these weeds, especially bracken may be on common land or water catchments where chemical methods of control are impracticable. Soil under bracken is generally of quite good quality, so although accessibility can limit its utilisation to grazing only, the grass production can be valuable particularly on hill farms. Using the financial value in Table 1 the current loss of feed value due to bracken is approximately £220M. With a decline of 55,000 ha between 1998 and 2007 it is difficult to say how much more of the area could be cleared if pesticides were retained due to above comments about access and other land uses. Asulam is affected by its list 3 voluntary withdrawal as further data to support its use is brought forward, so there is a degree of uncertainty about its final availability. The loss of appropriate treatments (and changing economics) could see an advance of bracken with the 55,000 being recolonised.