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Pesticide availability for cereals and oilseeds following revision of Directive 91/414/EEC; effects of losses and new research priorities

by

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Summary

Pesticides are fundamental to the way combinable crops are currently grown in the UK. They provide us with a relatively cheap and efficient way of controlling the major weeds, pests and diseases that affect combinable crops. These pesticides are currently under pressure as a result of changing legislation in Europe (revision of 91/414/EEC) and the implementation of the Water Framework Directive. 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 wheat, winter barley, spring barley, oats and oilseed rape. 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 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, plus lodging, 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 wording has not been agreed, 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 report released in December 2008, were assessed to determine the effect on combinable crops. After a vote in the European Parliament (13^{th} January 2009), it is likely that the least severe of the four PSD scenarios (scenario 2c) will be close to the final outcome, however, much will depend on final implementation. If this is the case 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, 15 are used in the production of wheat, barley, oats or oilseed rape. Of the UK approved actives that are at risk 11 are fungicides, 6 herbicides, 2 insecticides and 1 rodenticide.

The greatest economic losses to cereals that occur as a result of scenario 2c are due to the loss of pendimethalin. This is a keystone of black-grass resistance management and also an important general herbicide. Although there are generally plenty of alternatives for broad-leaved weed control, the control of grass weeds, black-grass in particular, will become more difficult with resistance likely to become more of a problem. The loss of important triazole fungicides will make the control of foliar diseases such as Septoria and Yellow rust in wheat more difficult, as the remaining

chemistry is not as robust as some of the active ingredients that will be lost. This will lead to slight reductions in production (about 1%). As relatively few insecticides are lost, and there are plenty of alternatives, the effect of this scenario on pests is minimal.

In oilseed rape the losses of pesticides to scenario 2c are unlikely to cause significant losses to production. There remain plenty of alternatives for the control of major weeds, pests and diseases.

It is not just the revision of 91/414/EEC that is likely to cause large scale losses of pesticide actives. 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 and or used at high rates. This makes herbicides particularly vulnerable as large areas of combinable crops have high rates of active substance applied to them in the form of herbicides. As a result, about 10 herbicides are causing concerns with relation to the WFD. This includes a number of important actives for the control of grass weeds in oilseed rape (propyzamide, carbetamide and metazachlor). If restrictions or withdrawals for the use of these chemicals occur it could make the control of black-grass and other grass weeds almost impossible. If cropping systems remained the same, in affected areas, this could lead to yield losses similar to those seen in untreated crops of about 35%.

Oilseed rape is currently the main break crop used in cereal rotations. The herbicides that are available for the control of black-grass in rape have different modes of action compared to those that can be used in wheat. This makes the rape break crop a useful tool for cleaning black-grass infested fields prior to planting with cereals. This alternative chemistry is also an important part of the resistance strategy used to control black-grass. In the absence of effective herbicides in the break-crop, with alternative chemistry, there is the risk that herbicide resistance could develop more rapidly than at present and spread further. This therefore will lead to indirect losses of wheat and cereal yields as a result of resistance build-up.

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. At present, the level of pest infestation seen tends to cause minimal damage at an industry scale, the exception being aphids carrying virus and slugs. Slugs in particular could be difficult to control as metaldehyde is already under scrutiny because it is being found in water. If it is lost the area that is treated with methiocarb is likely to increase, putting it at similar risk of starting to appear in water. This could potentially leave growers with no good molluscicides for the control of slugs.

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 2009, 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 they are not included in Annex 1 before 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 tefluthrin used as a seed dressing for wheat bulb fly control.

There are certain pesticides that are used on a wide range of crops are relatively high rates that are starting to show up in residue tests on certain food stuffs, e.g. glyphosate and chlormequat in cereals. If these pesticides continue to show up in food at levels that are considered unsafe then restrictions could be put on their use, but in any case there are pressures to reduce the levels found, such as through minimising use.

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, Lepidoptera and sucking pests in a range of crops and additional boscalid like fungicides which are likely to provide extra control options for *Septoria tritici.* There are also some new breeding technologies being developed by BASF to produce non-genetically modified herbicide resistant crop plants. These are still in early development in North America with only limited crops available, the herbicide they are resistant to, imidazolinone, does not however give high levels of control of black-grass so would be of limited use in UK situations.

Table ES1 - 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 (see Table 76 for details)
	epoxiconazole and other triazoles	Septoria and yellow rust	2011-2020 (see Table 78 for details)
Failure to achieve Annex 1 listing	metaldehyde	Slugs	By December 2010
	tefluthrin Older grass weed herbicides	Wheat bulb fly Volunteer cereal control	
WFD	propyzamide carbetamide metazachlor	Grass-weeds in OSR	2009 onwards
	metaldehyde	Slugs	Now
	chlorothalonil Insecticides	Septoria All pests	2009 onwards 2009 onwards
Market acceptability	chlormequat	Lodging	Now
	glyphosate	Harvest aid Weed control	Now

The main economic impacts of the important weeds, pest and diseases, plus lodging, are summarised in Table ES2.

The major impacts are in wheat, because of its dominant significance. Totalled across all cereals and oilseed rape the following potential impacts (£M per year) have been identified:

- Improvements over Business as Usual – assuming no current options are lost
    - Reduction in crop lodging is the largest potential opportunity for increases in production (£94M) as a result of reducing existing losses.
    - Improvements in take all control are estimated to be worth £68M.
    - Weeds and oilseed rape account for other significant opportunities
- Losses due to revision on 91/414/EEC
    - The largest overall impact is in loss of black-grass control (£185M). Other weed control will also cause significant losses (cleavers £34M, annual meadow-grass (£41M) and rye-grass (£22M)
    - Losses from disease are highest for yellow rust (£27M)
- Water Framework Directive – could potentially have the most significant impact:
    - Reduction in black-grass control could cost over £500M per year. Rye-grass over £200M and £89M for annual meadow-grass.
    - Loss of septoria control could cost £57M.
    - Inability to control slugs could amount to nearly £50M per year

Table ES3 summarises in a matrix the major areas of loss and priority. These have been mapped into the existing HGCA R&D Strategy where possible. Headings that were not relevant have been excluded, and we have highlighted where we have amalgamated (nutrition), amended (formulation) or added (pesticide risk) headings. This table includes the major implications, which we have prioritised using the existing 1-3 scale based on importance and likelihood of success. The relevant research and knowledge transfer opportunities are included.

Table ES2 – Estimated annual losses to UK cereals and oilseeds industry from weeds, pests, diseases and lodging (£M)

Losses to industry £M		Weeds					Pests						Diseases													PGRs
Crop	Scenario	Black-grass	Cleavers	Annual Meadow Grass	Rye-grass	Volunteer cereals	Aphids autumn	Slugs	OWBM	Wheat Bulb Fly	CSFB	Pollen beetle	S. tritici	Take all	Yellow rust	Eyespot	Fusarium	Net blotch	Mildew	Rhynchosporium	BYDV	Phoma (L. maculans)	Light Leaf spot	Turnip yellows	Sclerotinia	Lodging
Wheat	Revision 91/414/EEC (2c)	151.9	24.0	25.8	18.5								16.2		27.7	6.9										
	WFD	352.4		48.8	129.2		18.9	30.7	6.2	1.4			57.7		4.6											
	Untreated	398.7	113.1	62.8	147.7		26.0	22.2	5.7	1.6			100.3	7.9	-15.2	-61.3										63.5
	Business as usual	35.1	20.1	18.2	14.2		18.9	2.5	2.1	0.7			6.9	57.7	6.9	11.5										40.4
Winter Barley	Revision 91/414/EEC (2c)	33.0	4.9	5.3	4.0											1.2	1.2									
	WFD	76.5		9.9	28.1		4.1	4.7																		
	Untreated	61.2	18.1	10.8	22.7		4.7	1.3						2.7		-8.4	-9.5	-4.8								17.7
	Business as usual	5.3	3.1	2.8	2.2		2.8	0.4						10.5		2.8	3.2	1.5								8.8
Spring Barley	Revision 91/414/EEC (2c)		4.3	7.6																0.7						
	WFD	9.9		28.9	3.9		0.5													0.5						
	Untreated	11.3	5.4	5.4	4.6		0.4												-4.2	-3.5	-6.4					7.2
	Business as usual	1.0	1.4	3.8	0.4		0.1												2.9	2.4	1.7					6.0
Oats	Revision 91/414/EEC (2c)	0.1	1.5	3.2																	0.0					
	WFD	2.1		1.5	0.8		0.9														0.0					
	Untreated	2.5	1.1	4.2	1.0		0.4												-0.9		-0.5					3.5
	Business as usual	0.2	0.3	0.8	0.1		0.3												0.2		0.1					2.6
OSR	Revision 91/414/EEC (2c)																									
	WFD	88.2			42.2		6.6	13.8			2.0	0.9														
	Untreated	41.5	-32.7		-3.4	185.2	4.7	9.5			-0.9	-1.7										36.4	30.3	15.5	8.4	48.3
	Business as usual	2.9	1.3		1.8	1.3	1.3	1.7			2.0	0.2										26.3	17.5	17.5	8.4	36.6
Total	Revision 91/414/EEC (2c)	185.0	34.7	41.9	22.4								16.2		27.7	8.1	1.2			0.7						
	WFD	529.2		89.2	204.2		30.9	49.3	6.2	1.4	2.0	0.9	57.7		4.6					0.5						
	Untreated	515.2	104.9	83.2	172.5	185.2	36.1	33.0	5.7	1.6	-0.9	-1.7	100.3	10.7	-15.2	-69.8	-9.5	-4.8	-5.1	-3.5	-6.8	36.4	30.3	15.5	8.4	140.1
	Business as usual	44.5	26.2	25.6	18.7	1.3	23.4	4.6	2.1	0.7	2.0	0.2	6.9	68.2	6.9	14.4	3.2	1.5	3.0	2.4	1.8	26.3	17.5	17.5	8.4	94.4

Significant losses of: £50-£100M; £100-£200M; £200M+

Table ES3 - Crop protection priorities: summary matrix

	Crop protection priorities - cereals and oilseeds	Weeds				Pests						Diseases													PGRs	Research activities	Knowledge transfer
		Black-grass	Cleavers	Annual Meadow Grass	Rye-grass	Aphids autumn	Slugs	OWBM	Wheat Bulb Fly	CSFB	Pollen beetle	S. tritici	Take all	Yellow rust	Eyespot	Fusarium	Net blotch	Mildew	Rhynchosporium	BYDV	Phoma (L. maculans)	Light Leaf spot	Turnip yellows	Sclerotinia	Lodging		
	HGCA recommended lists	3			3							1	2	2							2	2	2		1	Develop measurement for competitive ability of varieties against major weeds	Include competitivity score in RL Ensure relevant scores to reduce lodging risk in RL
	Breeding and genetics					3		*	?			1	2	2							2	2	2		1	Improve genetic resistance to pests & disease Transfer traits already identified in previous work into varieties	Highlight priorities to plant breeding companies Ensure resistance scores are included in RL
AMALGAMATED	Nutrition	3			3							3		3			3	3	3		3	3		3		Understand impact of reduced nutrient levels on need for weed, pest and disease control	
	Disease management											1*	1	1							2*	2	2			Improve control of take-all, septoria and oilseed rape diseases Determining the priorities for chlorothalonil use within a crop rotation to minimise the risk of it reaching water.	Highlight the need for constraining the total use of chlorothalonil
	Soil management	2			2																					Develop decision tools to allow better integration of soil and weed management	Highlight interactions between soil management and weed management
	Pest management					2	1*																			Improve ability to target and maximise effectiveness of slug control Ensure new insecticides are protected from development of resistance Improve control of autumn aphids	Communicate existing best practice and interact with metaldehyde stewardship. Monitor annex 1 listings to ensure metaldehyde and tefluthrin are added to list
	Weed management	1	2	2	2																					Improve ability to predict and manage grass weeds within a rotation Identify new opportunities for grass weed control in oilseed rape	
AMENDED	Pesticide application & formulation	1		1	1		1																			Develop opportunities for improved formulation and application to minimise risk of water contamination Understand major routes by which pesticides reach water	
	Precision farming	1		1	1		1																			Enable better targeting (both spatial and temporal) of high risk actives such as herbicides and slug pellets	Promote existing knowledge and technology to better target applications
NEW	Pesticide risk management	1		1	1		1					1													1	Develop tools to ensure total pesticide use in a catchment meets both efficacy and water quality requirements Develop improved prediction tools to reduce unnecessary pesticide applications Improve linking of crop state and variety to risk of lodging	Promote existing knowledge on the need for pesticide applications Promote existing knowledge and include emerging infoimation

KEY
based on economic impact and likelihood of achievement

1 First priority; 2 Second priority; 3 Third priority
* Existing work; ? needs discussion

1. Introduction

The availability, efficacy and suitability of pesticides (Plant Protection Products – PPPs) for the control of weeds, pests and disease in UK cereals and oilseeds is under pressure. Legislative changes, such as the proposals from the EU Commission and Parliament to move from risk based approvals to hazard based approvals could severely limit the choice of pesticides in some key areas, if approved. Environmental legislation such as the Water Framework Directive may also lead to reduced availability, as seen with the withdrawal of IPU and trifluralin, in order to meet EU water quality targets. Alongside this is the development of resistance in target organisms such as black-grass and pollen beetles which could have major impacts on productivity and farming systems. In addition, market requirements are often aiming for ever lower levels of pesticide residues, much lower than limits which have been set in Maximum Residue Levels (MRLs) and which are predicted to cause any safety issue. This includes actives such as chlormequat and glyphosate in cereals which can be found at detectable levels in grain samples post-harvest. These changes will affect UK combinable crop production and economics and it is vital to understand the impacts in order to prioritise levy investment to address the threats.

2. Objectives

The overall aim of the project was to identify, the most economically significant threats to production, in cereals and oilseeds, due to the reduced availability of pesticides in the next 5-10 years, in order to inform priorities for levy investments. Specific objectives included:

1. Estimation of the current economic impact of the most important diseases, weeds and pests.
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

3. Approach

The recent report by ADAS for ECPA (European Crop Protection Association) (Clarke *et al.*, 2008) developed a methodology and a framework for evaluating the yields and quality implications, and subsequent impacts on gross margin, due to reduced availability of pesticides. The report included an assessment of wheat based on the limited availability of pesticides determined by the proposals for a replacement of 91/414/EEC. The analysis focused on the change in yields and quality and the area affected, taking into account simple changes in management to mitigate the problems, such as changes in cultivations, varieties, seed rate and planting date. It did not look at the possible large scale changes in farming systems such as changes in rotation, switch to spring cropping, changes in machinery and labour, other technological developments etc. and other sector impacts such as increased feed prices in the livestock sectors. Information to support the analysis was sourced from experts in weeds, pests and disease control along with supporting information from

PSD weeds, pests and disease incidence reports, ADAS crop development reports for Defra and supported by information in the Pesticide Usage Surveys and validated through informal industry contacts.

The ECPA report was a good basis for extending the work to cover more weed pest and disease species and other crops. The crops covered in this report are winter wheat, winter barley, spring barley, oats and oilseed rape.

3.1. Economic impacts of key weeds, pests and diseases

In the ECPA work the start point was loss of actives, while this project had an earlier start point of the identification of the economically most important weeds, pests and diseases. The framework was modified for this purpose; however, there was additional work to get to this baseline point. This involved the identification of the main weeds, pests and diseases for each of the crops and evaluation of the area affected, the yield loss in the absence of chemical control measures and individual economic impact. It was also important to identify if there were any geographical variations. This helped to prioritise the problems with the largest impact. Some of this was done for wheat in the ECPA report, for those problems affected by the changes in pesticide availability due to 91/414/EEC, but this needed to be extended to include other weeds, pests and diseases and the other crops. The information was based on input from ADAS experts in weeds, pests and diseases and other contacts in the industry.

3.2. Evaluation of alternative control methods

In the absence of chemical control, there may be other options available such as changing planting dates, or crop rotations. These options may mitigate the impacts of loss of actives, but may also have other consequences, and their impact and cost-effectiveness were evaluated.

3.3. Assessment of future status of pesticide availability

A comprehensive review of actives currently used on wheat, barley, oats and oilseed rape was made to identify the reasons for, and likelihood of reduced availability. The ECPA report included a review of actives likely to become unavailable for wheat production due to 91/414/EEC. The list of active substances that are likely to become unavailable has since changed as a result of discussions in Europe. This revised list, provided by PSD in December 2008, has been used to calculate the impact of product losses on wheat and the additional crops. There are 4 different scenarios covered in this report;

1. 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.

2. 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.

3. 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.

4. Annex **3** - Additional substances that may not be approved according the ENVI Committee amended criteria.

See http://www.pesticides.gov.uk/environment.asp?id=1980&link=%2Fuploadedfiles%2FWeb%5FAssets%2FPSD%2FRevised%5FImpact%5FReport%5F1%5FDec%5F2008%28final%29%2Epdf

<u>At end January 2009, annex 2c is now thought to represent the most likely scenario to occur.</u>

Other reasons for pesticide losses were also examined, such as build up of resistance, Water Framework Directive and market requirements, to provide a full picture of availability and timescale. Input came from ADAS experts in weeds, pests and disease, and environment, and was supported by informal consultation with the industry.

3.3.1. Analysis framework

One of the key aspects of this work was the development of the analysis framework which then allowed figures to be added or updated as information became available or to try 'what if' scenarios. The framework used key statistics on area, yield and production from Defra statistics and costs and prices from J. Nix (2009). The impacts were calculated at a UK industry wide level.

The analysis framework had separate assessments for the main crop groups – winter wheat, winter barley, spring barley, winter oats and winter oilseed rape. For each crop there was an analysis for individual species of weeds, pests and disease. Each analysis was conducted at an industry level covering the following aspects:

- Standard gross margin in the 'business as usual' scenario including seed, fertiliser, pesticides and cultivation costs.
- Yield impact for each weed, pest or disease, expressed as % yield loss at UK level.
- Changes to input costs in order to mitigate impacts of weed, pest or disease.
- Overall impact on total yield and % change.
- Overall impact on total gross margin and % change.
- Number of additional hectares required to maintain current production levels.

The framework was structured so that the yield and quality impacts of individual weeds, pests and diseases could be assessed and compared under different scenarios (see example in Table 1).

- 'business as usual'
- Untreated
- Replacement of 91/414/EEC – Council Common Position (annex 2, three different interpretations) and ENVI annex 3.
- Water Framework Directive impacts

Whilst looking at the above scenarios we also took into account;

- Resistance impacts
- Reduced pesticide availability through market acceptability
- Other

Information from the individual effects were then 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.

Effect of Scenario 2a on Septoria in Wheat		
% area affected	%	100%
Area affected	ha	2,072,900
Total reduction in yield in year affected	%	7.50%
Change in yield in year affected	%	7.20%
Value of affected product	£/t	135
Yield Loss	t	1,231,303
Total Yield	t	15,870,122
Value	**£**	**2,142,466,524**
% of original value achieved		93%
Change in inputs		
Seed	£/ha	
Fertiliser	£/ha	
Herbicides	£/ha	
Insecticides	£/ha	
Fungicides	£/ha	
Cultivation costs	£/ha	
Other - additional spray application	£/ha	11
Increase / decrease in inputs	£	23,631,060
Total inputs	**£**	**1,460,434,056**
New gross margin	**£**	**682,032,468**
Change in margin	£	-189,856,911
	%	78%
Gross margin / ha	£/ha	329
Total area needed to maintain production	ha	2,233,728
	ha	**160,828**
Yield / ha		7.7

Table 1 – Example calculation sheet for *Septoria tritici* in wheat under scenario 2a – see Table 2 for comparison

3.3.2. Identifying area affected and yield impacts

Specialists identified the key weeds, pests and diseases affecting the combinable 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.

Initial assessments of areas affected by each of the weeds, pests and diseases were sent out to agronomists for validation, to ensure these figures fitted in with what they were seeing in the field. Five agronomists returned these validation forms and their forms were used to adjust some figures where consistently higher or lower incidences were reported than had been calculated by ADAS experts. It is worth noting however that these replies resulted in very variable assessments based on personal experience and whenever possible, although data are limited and often not very recent, we have relied on survey information.

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.

3.3.3. Economic analysis

For each crop a 'business as usual' gross margin was developed based on costs from J. Nix (2009) (see Table 2 and Appendix 4 – Business as usual gross margins) and the Defra crop area statistics.

Table 2 – Example Wheat Gross Margin

Business as normal - with standard spray applications (2008)		
Total UK Wheat area (from DEFRA Stats)	2,072,900	
UK average wheat yield	8.25	t/ha
Price	135	£/t
Total UK wheat production	17,101,425	t
Total value UK wheat	**2,308,692,375**	**£**
Seed	49	£/ha
Fertiliser	323	£/ha
Herbicides	60	£/ha
Insecticides	7	£/ha
Fungicides	63	£/ha
Cultivation costs	113	£/ha
Other	78	£/ha
Total cost of inputs	**1,435,421,063**	**£**
UK Wheat Gross Margin	**873,271,312**	**£**
Gross margin / ha	421	£/ha

The production losses calculated for each scenario, along with any changes in input costs (including mitigating measures) were used to calculate the effect on the sector gross margin of each of the different weeds, pests and diseases in each of the scenarios. This was then compared with the 'business as usual' figure to establish the change in margin. In this way the weeds, pests and diseases could be ranked in order of economic impact.

3.3.4. Assessment of future pesticide availability

Changes to pesticide availability in the future falls into a number of categories:

- Replacement of 91/414/EEC
- Resistance development
- Water quality and Water Framework Directive

- Market acceptability, such as levels of MRLs
- Failure to get onto Annex 1 before end December 2010
- Withdrawal of active/products by manufacturers for commercial reasons
- New actives/products under development

We have drawn up a list of availability issues based on resistance, water quality and market acceptability which is presented in the results section below.

Understanding of the activities of the agrochemical manufacturers is important in assessing final outcomes as replacement products may alleviate the problems caused by loss of actives. There are commercial sensitivities which have been respected, however all major companies took part in individual informal consultations on changes in their portfolio which helped to inform and steer the results.

Evaluation of alternative control measures

The costs associated with mitigating measures were taken into account in the analysis of the gross margins. Mitigating measures tend to provide support for control, rather than be a control measure in its own right such as delaying sowing, increasing seed rates and changing cultivation practices.

Alternative control measures may be an option in some cases and these were identified and evaluated.

3.4. Summary matrix

The final stage was to prioritise the impacts of reduced availability of pesticides, or combinations of pesticides, based on economic importance, key combinations of problems, and likelihood of loss and cost-effectiveness of mitigation strategies, displayed in a matrix format which identifies the major priorities for attention.

4. Economic impact of current weeds, pests, diseases in the growing crop and storage

4.1. Background Statistics

4.1.1. Yield and production

Table 3 Arable crop production

Crop	UK Crop area 2008 * Ha	UK Production ** t	UK average harvested yield *** t/ha
Wheat	2072900	17101425	8.25
Winter Barley	421000	2420750	5.75
Spring Barley	609000	3197250	5.25
Oats	130200	846300	6.5
Oilseed Rape	599100	1947075	3.25

* Values from Defra June Agricultural Survey 2008 (UK figures)

** Defra figures multiplied by NIX 2009 yields
*** average yields from NIX 2009

4.1.2. Prices

Table 4 Price of crops used for gross margin calculations

Crop	Average price 2008 * £
Wheat	135
Winter Barley	145
Spring Barley	150
Oats	125
Oilseed Rape	300

* Prices from NIX 2009

Area of crop affected and impact on yield

The area of crops affected by weeds, pests and disease will vary each year depending on a range of factors including rotation, weather etc. The impacts of weeds, pests and diseases can reduce yields.

The area affected by any one weed, pest or disease will vary each year, depending on a number of factors which are discussed in each section.

In establishing the area and yield/quality impacts of the different weeds, pests and diseases, information has been sourced from:

- Weeds, pests and disease incidence reports (PSD)
- Pesticide usage survey (CSL) which can indicate areas sprayed with certain active substances for specific reasons
- Other specific research
- Expert opinion

4.2. Weeds

Weed incidence in arable crops is determined by land management, crop rotations and recent weed control strategies and as such can vary significantly within short distances within farms, regions and across the country. The number and type of weeds is influenced by several factors:

- Soil type
- Crop rotation
- Recent weed control strategies
- Cultivations and cultural control
- Drilling dates and conditions
- Crop competition
- Herbicide choice, cost and timing
- Weather
- Agronomist/farmers perceptions

Weed populations vary across different parts of the country with some weed species being more important in one region than another. Black-grass, for example is present in about 38% of fields (Whitehead & Wright, 1989). In these fields if it is not well controlled it can cause high yield losses varying from 4% yield losses in treated populations up to 50% yield losses in untreated populations. The remaining 63% of fields are unaffected by black-grass, although other weeds may cause some problems in these fields. Winter cereal rotations are particularly prone to the build up of grass-weed populations, as these weeds are more difficult to control in cereals than in broad-leaved crops such as spring sown potatoes or sugar beet. Other grass weeds that cause problems in cereal rotations include rye-grass, brome and wild oats, these grass weeds are generally not as wide spread as black-grass, but where present they can cause high yield losses if left untreated of 50% for rye-grass and up to 10% for brome and wild oats.

Yield losses in cereals, as a result of weed populations generally occur as a result of direct competition. Grass weed populations can be very high and are able to out compete the crop during establishment and early growth, reducing the amount of nutrients and sunlight that the crop is able to gain access to.

Broad-leaved weeds, although present across large proportions of the cereal growing areas, are generally easy to control in cereals with currently available herbicides. The more common broad-leaved weeds, left untreated, will reduce yields but not by a large amount, often less than 5%, however cleavers and poppies are more competitive and will reduce yields by an estimated 15% and about 10% respectively. Cleavers don't just compete with the crop, they also cause problems during harvest.

They can remain green after the crop has ripened so when harvested cause the combine to block reducing harvest efficiency. This problem can be reduced through the use of a pre-harvest desiccant. In oilseed rape related weeds, such as charlock, can cause problems at harvest as the seeds are very similar in size to rape seeds and therefore difficult to separate. The presence of charlock seeds, in a post harvest grain sample, will reduce its value.

All calculations of yield losses from weeds are based on weeds per m^2 multiplied by a competition factor calculated by Blair, Cussans & Lutman (1999). Estimates of typical plants per metre square were made by ADAS experts and validated by a number of Agronomists.

4.2.1. Wheat

From Table 6 it can be seen that the weed that has the biggest impact on wheat production is black-grass. Although only 38% of wheat fields are likely to be affected by black-grass those fields that are can have high yield losses.
In a series of experiments Ingle, Blair & Cussans demonstrated that on average 23 black-grass plants per m^2 would lead to a 5% yield loss in wheat, but populations ranging from 6-81 plants per m^2 caused the same effect in different trial situations. This demonstrates how difficult it can be to predict crop losses from weed populations. In our assumptions it was considered that in a typical treated field, that is known to have a black grass population, there would be an average of 10 black-grass plants per m^2, giving a treated yield loss of 4% based on Blair, Cussans & Lutman (1999) competitive weed index. If these fields were left untreated the expected number of black-grass plants per m^2 would raise to about 130 plants per m^2, giving a yield loss of just over 50%.

Some fields where infestations are particularly high may no longer be able to be used for the production of wheat as the yield losses would be so high it would not be economically feasible to produce wheat on them. The yield losses from these 38% of wheat fields would result in just over a 19% reduction in the total production of wheat (if the area of wheat grown remained stable), this is equivalent to a 3.25 million tonne reduction in the amount of wheat available.

The second most important weed species is cleavers, this weed is present in 58% of wheat fields and causes and average yield loss, compared to potential (when treated) of 1.5% on affect fields. If left untreated yield losses can increase to an average of 15% in affected fields. This is equivalent to just under a 9% reduction in production across the whole wheat area, a loss of just under 1.5 million tonnes of wheat.

Annual meadow grass and ryegrass also cause large losses in production of 7.9% and 7% respectively. With annual meadow grass this is because although each field has an untreated yields loss of 10% there are a large number of fields that are affected (about 80%). Rye-grass causes similar yield losses, where it occurs, to black-grass, but it is present in a more limited area, hence the loss of production is lower.

In winter wheat broad-leaved weeds are generally less of a problem than grass-weeds, however Young *et al*. (1984) showed that 150 plants/m^2 poppy and 15 cleavers/m² reduced yield by 15%. In spring wheat high populations, up to 1200/m², of orache, scarlet pimpernel, charlock and black bindweed reduced yield by 21% (Young *et al*., 1984).

Table 5 – Wheat: Effects of weeds on production and yields untreated

Wheat (yield loss on affected area & total loss of production)				
Weed	**% area affected***	**% yield loss untreated**	**Loss of production untreated (t)**	**% loss of production (untreated)**
Black-grass	38%	52.0%	3,249,000	19.11%
Cleavers	58%	15.0%	1,488,000	8.75%
Annual Meadow Grass	79%	10.0%	1,351,000	7.95%
Rye-grass	14%	52.3%	1,197,000	7.04%
Wild Oats	42%	10.0%	718,000	4.22%
Mayweed	67%	6.0%	687,000	4.04%
Chickweed	94%	4.0%	643,000	3.78%
Poppy	18%	9.0%	277,000	1.63%
Shepherds Purse	23%	6.0%	236,000	1.39%
Charlock	36%	3.2%	197,000	1.16%
Field Speedwell	72%	1.2%	148,000	0.87%
Barren Bome	13%	6.3%	139,000	0.82%
Volunteer Rape	23%	3.2%	126,000	0.74%
Couch	21%	3.3%	119,000	0.70%
Rough Meadow Grass	7%	8.3%	99,000	0.58%
Red Dead Nettle	47%	1.2%	96,000	0.56%
Parsley-Piert	12%	4.0%	82,000	0.48%
Fumitory	17%	2.4%	70,000	0.41%
Ivy-leaved Speedwell	30%	1.2%	62,000	0.36%
Field Pansy	45%	<1%	38,000	0.22%
Fat Hen	13%	1.6%	36,000	0.21%
Geranium sp.	11%	1.6%	30,000	0.18%
Thistles (creeping)	4%	1.5%	10,261	0.06%
Volunteer cereals	7%	<1%	0	0.00%

* Whitehead R.& Wright HC.(1989)

5-10% loss of production	>10% loss of production

Table 6 – Wheat: Effects of weeds on production and yields when treated using currently available actives

Wheat (yield loss on affected area & total loss of production)					
Weed	Baseline UK production (t)	% area affected*	% yield loss with currently available treatments	Loss of potential production business as usual (t)	% loss of potential production (business as usual)
Black-grass	**17,000,000**	38%	4.0%	260,000	1.53%
Cleavers		58%	1.5%	149,000	0.88%
Annual Meadow Grass		79%	<1%	135,000	0.79%
Rye-grass		14%	4.4%	105,000	0.62%
Wild Oats		42%	<1%	72,000	0.42%
Mayweed		67%	<1%	92,000	0.54%
Chickweed		94%	<1%	96,000	0.56%
Poppy		18%	<1%	18,000	0.11%
Shepherds Purse		23%	<1%	5,000	0.03%
Charlock		36%	<1%	25,000	0.15%
Field Speedwell		72%	<1%	10,000	0.06%
Barren Bome		13%	<1%	3,000	0.02%
Volunteer Rape		23%	<1%	16,000	0.09%
Couch		21%	<1%	12,000	0.07%
Rough Meadow Grass		7%	<1%	8,000	0.05%
Red Dead Nettle		47%	<1%	6,000	0.04%
Parsley-Piert		12%	<1%	8,000	0.05%
Fumitory		17%	<1%	5,000	0.03%
Ivy-leaved Speedwell		30%	<1%	4,000	0.02%
Field Pansy		45%	<1%	6,000	0.04%
Fat Hen		13%	<1%	4,000	0.02%
Geranium sp.		11%	<1%	8,000	0.05%
Thistles (creeping)		4%	<1%	1,000	0.01%
Volunteer cereals		7%	<1%	0	0.00%

* Whitehead R.& Wright HC.(1989)

4.2.2. Winter Barley

High weed populations in winter barley can have significant effects on yield; a mixed population of poppy, cleavers and forget-e-not up to 43 plants/m² reduced yield by 8%. Cleavers and poppies (32 plants/m²) reduced yield by 5%. Both were compared to conventional crops (Young *et al.*, 1984).

The situation for the impacts of weeds on winter barley is similar as for wheat (Table 7 & Table 8). The figures that are available for weed distribution in cereals are not specific for wheat and barley, so the distribution of weeds used for these calculations is the same. In reality if a field is heavily infested with black-grass it is unlikely that barley would be grown there as black-grass is more difficult to control in barley than in wheat. This means that the percentage of fields affected by black-grass may be slightly lower than the figure presented.

Table 7 - Winter barley: Effects of weeds on production and yields untreated

Winter Barley (yield loss on affected area & total loss of production)				
Weed	**% area affected***	**% yield loss untreated**	**Loss of production untreated (t)**	**% loss of production (untreated)**
Black-grass	38%	52.0%	460,000	19.01%
Cleavers	58%	15.0%	211,000	8.72%
Annual Meadow Grass	79%	10.0%	191,000	7.89%
Rye-grass	14%	52.3%	169,000	6.98%
Wild Oats	42%	10.0%	102,000	4.21%
Mayweed	67%	6.0%	97,000	4.01%
Chickweed	94%	4.0%	91,000	3.76%
Poppy	18%	9.0%	39,000	1.61%
Shepherd Purse	23%	6.0%	33,000	1.36%
Charlock	36%	3.2%	28,000	1.16%
Field Speedwell	72%	1.2%	21,000	0.87%
Barren Bome	13%	6.3%	20,000	0.83%
Volunteer Rape	23%	3.2%	18,000	0.74%
Couch	21%	3.3%	17,000	0.70%
Red Dead Nettle	47%	1.2%	14,000	0.58%
Rough Meadow Grass	7%	8.3%	14,000	0.58%
Parsley-Piert	12%	4.0%	12,000	0.50%
Fumitory	17%	2.4%	10,000	0.41%
Ivy-leaved Speedwell	30%	1.2%	9,000	0.37%
Field Pansy	45%	<1%	5,000	0.21%
Fat Hen	13%	1.6%	5,000	0.21%
Geranium sp.	11%	1.6%	4,000	0.17%
Thistles (creeping)	2%	<1%	73	0.00%
Volunteer cereals	7%	<1%	0	0.00%

*Whitehead R & Wright HC (1989)

5-10% loss of production	>10% loss of production

Table 8 - Winter barley: Effects of weeds on production and yields treated currently available actives

Winter Barley (yield loss on affected area & total loss of production)					
Weed	Baseline UK production (t)	% area affected*	% yield loss with currently available treatments	Loss of potential production business as usual (t)	% loss of potential production (business as usual)
Black-grass	**2,420,000**	38%	4.0%	37,000	1.53%
Cleavers		58%	1.5%	21,000	0.87%
Annual Meadow Grass		79%	<1%	19,000	0.79%
Rye-grass		14%	4.4%	15,000	0.62%
Wild Oats		42%	<1%	10,000	0.41%
Mayweed		67%	<1%	13,000	0.54%
Chickweed		94%	<1%	14,000	0.58%
Poppy		18%	<1%	3,000	0.12%
Shepherd Purse		23%	<1%	1,000	0.04%
Charlock		36%	<1%	3,000	0.12%
Field Speedwell		72%	<1%	1,000	0.04%
Barren Bome		13%	<1%	390	0.02%
Volunteer Rape		23%	<1%	2,000	0.08%
Couch		21%	<1%	2,000	0.08%
Red Dead Nettle		47%	<1%	1,000	0.04%
Rough Meadow Grass		7%	<1%	1,000	0.04%
Parsley-Piert		12%	<1%	1,000	0.04%
Fumitory		17%	<1%	1,000	0.04%
Ivy-leaved Speedwell		30%	<1%	1,000	0.04%
Field Pansy		45%	<1%	1,000	0.04%
Fat Hen		13%	<1%	1,000	0.04%
Geranium sp.		11%	<1%	1,000	0.04%
Thistles (creeping)		2%	<1%	70	0.00%
Volunteer cereals		7%	<1%	0	0.00%

* Whitehead R & Wright HC (1989)

4.2.3. Spring Barley

In spring barley a mixed population of cleavers, chickweed, black bindweed and poppy at 75 plants/m² caused a 7% yield decrease when compared to the conventionally treated crop (Young *et al*., 1984).

No separate figures are available for spring distribution of weeds, therefore the figures from Whitehead and Wright have been used for spring barley as well (Table 9 & Table 10). Areas for black-grass and cleavers have been scaled back to reflect the fact that these weeds are less of a problem in spring crops.

Table 9 - Spring barley: Effects of weeds on production and yields untreated

Spring Barley (yield loss on affected area & total loss of production)				
Weed	**% area affected***	**% yield loss untreated**	**Loss of production untreated (t)**	**% loss of production (untreated)**
Annual Meadow Grass	79%	10.0%	253,000	7.91%
Wild Oats	42%	10.0%	134,000	4.19%
Mayweed	67%	6.0%	129,000	4.03%
Chickweed	94%	4.0%	120,000	3.75%
Cleavers 1	40%	15.0%	96,000	3.00%
Black-grass 1	5%	52.0%	83,000	2.59%
Poppy	18%	9.0%	52,000	1.63%
Shepherd Purse	23%	6.0%	44,000	1.38%
Charlock	36%	3.2%	37,000	1.16%
Rye-grass 1	2%	52.3%	33,000	1.03%
Field Speedwell	72%	1.2%	28,000	0.88%
Barren Bome	13%	6.3%	26,000	0.81%
Volunteer Rape	23%	3.2%	24,000	0.75%
Couch	21%	3.3%	22,000	0.69%
Red Dead Nettle	47%	1.2%	18,000	0.56%
Rough Meadow Grass	7%	8.3%	18,000	0.56%
Parsley-Piert	12%	4.0%	15,000	0.47%
Fumitory	17%	2.4%	13,000	0.41%
Ivy-leaved Speedwell	30%	1.2%	12,000	0.38%
Field Pansy	45%	<1%	7,000	0.22%
Fat Hen	13%	1.6%	7,000	0.22%
Geranium sp.	11%	1.6%	6,000	0.19%
Thistles (creeping)	2%	1.5%	959	0.03%
Volunteer cereals	7%	<1%	0	0.00%

* Whitehead R. & Wright HC (1989)

[1] – areas adjusted from Whitehead R. & Wright HC (1989)

5-10% loss of production	>10% loss of production

Table 10- Spring barley: Effects of weeds on production and yields treated currently available actives

Weed	Baseline UK production (t)	% area affected*	% yield loss with currently available treatments	Loss of potential production business as usual (t)	% loss of potential production (business as usual)
Spring Barley (yield loss on affected area & total loss of production)					
Annual Meadow Grass	**3,200,000**	79%	<1%	25,000	0.78%
Wild Oats		42%	<1%	13,000	0.41%
Mayweed		67%	<1%	17,000	0.53%
Chickweed		94%	<1%	18,000	0.56%
Cleavers 1		40%	1.5%	10,000	0.31%
Black-grass 1		5%	4.0%	6,000	0.19%
Poppy		18%	<1%	3,000	0.09%
Shepherd Purse		23%	<1%	1,000	0.03%
Charlock		36%	<1%	5,000	0.16%
Rye-grass 1		14%	4.4%	3,000	0.09%
Field Speedwell		72%	<1%	2,000	0.06%
Barren Bome		13%	<1%	1,000	0.03%
Volunteer Rape		23%	<1%	3,000	0.09%
Couch		21%	<1%	2,000	0.06%
Red Dead Nettle		47%	<1%	1,000	0.03%
Rough Meadow Grass		7%	<1%	1,000	0.03%
Parsley-Piert		12%	<1%	2,000	0.06%
Fumitory		17%	<1%	1,000	0.03%
Ivy-leaved Speedwell		30%	<1%	1,000	0.03%
Field Pansy		45%	<1%	1,000	0.03%
Fat Hen		13%	<1%	1,000	0.03%
Geranium sp.		11%	<1%	1,000	0.03%
Thistles (creeping)		2%	<1%	0	0.00%
Volunteer cereals		7%	<1%	0	0.00%

* Whitehead R. & Wright HC (1989)
[1] – areas adjusted from Whitehead R. & Wright HC (1989)

4.2.4. Oats

There is very little survey data available for oats. In order to estimate the level of weeds present in the oat crop figures for wheat have been used as a starting point. As black-grass and cleavers tend to be less of a problem in oats, than in wheat, the areas affected by these weeds have been reduced. The pesticide usage survey shows that just 1% of oat crops are specifically treated for black-grass, compared to 18% of the wheat crop.

Table 11 – Oats; Effects of weeds on production and yields untreated

Oats (yield loss on affected area & total loss of production)				
Weed	**% area affected***	**% yield loss untreated**	**Loss of production untreated (t)**	**% loss of production (untreated)**
Black-grass1	5%	52.0%	22,000	2.59%
Cleavers1	40%	15.0%	25,000	2.94%
Annual Meadow Grass	79%	10.0%	67,000	7.88%
Rye-grass1	2%	52.3%	9,000	1.06%
Wild Oats	42%	10.0%	36,000	4.24%
Mayweed	67%	6.0%	34,000	4.00%
Chickweed	94%	4.0%	32,000	3.76%
Poppy	18%	9.0%	14,000	1.65%
Shepherd Purse	23%	6.0%	12,000	1.41%
Charlock	36%	3.2%	10,000	1.18%
Field Speedwell	72%	1.2%	7,000	0.82%
Barren Bome	13%	6.3%	7,000	0.82%
Volunteer Rape	23%	3.2%	6,000	0.71%
Couch	21%	3.3%	6,000	0.71%
Red Dead Nettle	47%	1.2%	5,000	0.59%
Rough Meadow Grass	7%	8.3%	5,000	0.59%
Parsley-Piert	12%	4.0%	4,000	0.47%
Ivy-leaved Speedwell	30%	1.2%	3,000	0.35%
Fumitory	17%	2.4%	3,000	0.35%
Field Pansy	45%	<1%	2,000	0.24%
Fat Hen	13%	1.6%	2,000	0.24%
Geranium sp.	11%	1.6%	1,000	0.12%
Thistles (creeping)	2%	1.5%	254	0.03%
Volunteer cereals	7%	<1%	0	0.00%

* Whitehead R. & Wright HC (1989)

[1] – areas adjusted from Whitehead R. & Wright HC (1989)

5-10% loss of production	>10% loss of production

Table 12 – Oats: Effects of weeds on production and yields treated with currently available actives

Oats (yield loss on affected area & total loss of production)					
Weed	Baseline UK production (t)	% area affected*	% yield loss with currently available treatments	Loss of potential production business as usual (t)	% loss of potential production (business as usual)
Black-grass1	**850,000**	5%	4.0%	2,000	0.24%
Cleavers1		40%	1.5%	3,000	0.35%
Annual Meadow Grass		79%	<1%	7,000	0.82%
Rye-grass1		14%	4.4%	1,000	0.12%
Wild Oats		42%	<1%	4,000	0.47%
Mayweed		67%	<1%	5,000	0.59%
Chickweed		94%	<1%	5,000	0.59%
Poppy		18%	<1%	1,000	0.12%
Shepherd Purse		23%	<1%	1,000	0.12%
Charlock		36%	<1%	1,000	0.12%
Field Speedwell		72%	<1%	490	0.06%
Barren Bome		13%	<1%	140	0.02%
Volunteer Rape		23%	<1%	1,000	0.12%
Couch		21%	<1%	590	0.07%
Red Dead Nettle		47%	<1%	320	0.04%
Rough Meadow Grass		7%	<1%	390	0.05%
Parsley-Piert		12%	<1%	410	0.05%
Ivy-leaved Speedwell		30%	<1%	200	0.02%
Fumitory		17%	<1%	230	0.03%
Field Pansy		45%	<1%	300	0.04%
Fat Hen		13%	<1%	220	0.03%
Geranium sp.		11%	<1%	370	0.04%
Thistles (creeping)		2%	<1%	50	0.01%
Volunteer cereals		7%	<1%	0	0.00%

Whitehead R. & Wright HC (1989)

[1] – areas adjusted from Whitehead R. & Wright HC (1989)

4.2.5. Oilseed Rape

The most important weeds in oilseed rape are volunteer cereals (Table 15). In TALISMAN (Young *et al.*, 2001) cereal volunteers were insufficiently controlled by a reduced rate of fluazifop –p-butyl. Cereal volunteers (81/m²) competed with the crop and yield was decreased by 61%. Ogilvy (1989) reported yield losses due to barley volunteers (100/m²) in competitive crops caused yield losses of between 7.2 and 22.9%. In slower growing crops the losses were greater 40.5-42.7%. Other work indicates that vigorous crops can tolerate high populations but yield losses can be severe in less competitive crops (Orson, 1984; Lutman, 1984; Lutman and Dixon, 1985).

Under current practice volunteer cereals cause a <1% yield loss, compared to potential yields, on affected crops. If left untreated this yield loss increases to about 45% (Table 14) on affected fields. Because the majority of oilseed rape crops are grown on land following cereal crops there is a high proportion of fields that are affected (88%). This means that if volunteer cereals were to be left untreated there could be about a 40% reduction in production of oilseed rape. This is equivalent to just under 0.9 million tonnes of rape seed.

After volunteer cereals, black-grass is the next most important weed in oilseed rape. The yield losses in treated fields are higher than for volunteer cereals, at 1.3%. In untreated situations yield losses could increase to 37.5%. Because the area affected is less than for volunteer cereals the total loss of production is just under 20%, equivalent to just under 0.4 million tonnes of rapeseed.

The third most important weed is cleavers causing a 13% reduction of production if left untreated (0.25 million tonnes of rapeseed). Poppies cause high potential losses of yield 5.3% in affected fields, even when treated, however they are not widely distributed so the final affect on production of not controlling poppies is a less than 1% reduction. Although broad-leaved weeds are not a huge problem in oilseed rape high populations of broad-leaved weeds (65/m²) decreased the yield of a less competitive crop of oilseed rape by 33% (Young *et al*, 2001). The effects of broad-leaved weeds are dependent upon how vigorous the crop is. A larger more vigorous crop suffers far less yield loss from weed competition than a smaller, slow growing crop (Table 13).

Table 13 - Yield loss in winter oilseed rape from weeds

Oilseed rape	Yield loss range (%)				
	Chickweed	Speedwell	Pansy	Mayweed	cleavers
Very vigorous	2-3	0	0	-	-
Vigorous	35	11	-	0	5-15
Moderate vigour	14-63	54	3-38	0-23	40-49
Low vigour	73	63	-	18	-

(Lutman, 1999)

Table 14 – Oilseed rape: Effects of weeds on production and yields untreated

Oilseed Rape (yield loss on affected area & total loss of production)				
Weed	**% area affected***	**% yield loss untreated**	**Loss of production untreated (t)**	**% loss of production (untreated)**
Volunteer cereals	88%	45.0%	771,000	39.54%
Black-grass	40%	37.5%	389,000	19.95%
Cleavers	46%	28.5%	255,000	13.08%
Annual Meadow Grass	80%	7.0%	109,000	5.59%
Chickweed	98%	4.6%	88,000	4.51%
Wild Oats	40%	10.0%	78,000	4.00%
Charlock	34%	7.0%	47,000	2.41%
Poppy	23%	9.0%	40,000	2.05%
Field Speedwell	71%	2.4%	33,000	1.69%
Red Dead Nettle	53%	2.1%	22,000	1.13%
Mayweed	81%	1.4%	21,000	1.08%
Shepherd Purse	39%	2.8%	21,000	1.08%
Field Pansy	38%	1.8%	13,000	0.67%
Ivy-leaved Speedwell	25%	1.2%	6,000	0.31%
Geranium sp.	11%	1.6%	3,000	0.15%
Thistles (creeping)	5%	<1%	974	0.05%

* Whitehead R.& Wright HC.(1989)

5-10% loss of production	>10% loss of production

Table 15 – Oilseed rape: Effects of weeds on production and yields treated with currently available actives

Oilseed Rape (yield loss on affected area & total loss of production)					
Weed	Baseline UK production (t)	% area affected*	% yield loss with currently available treatments	Loss of potential production business as usual (t)	% loss of potential production (business as usual)
Volunteer cereals	1,950,000	88%	<1%	4,000	0.21%
Black-grass		40%	1.3%	10,000	0.51%
Cleavers		46%	<1%	4,000	0.21%
Annual Meadow Grass		80%	<1%	2,000	0.10%
Chickweed		98%	<1%	17,000	0.87%
Wild Oats		40%	<1%	2,000	0.10%
Charlock		34%	<1%	3,000	0.15%
Poppy		23%	5.3%	3,000	0.15%
Field Speedwell		71%	<1%	0	0.00%
Red Dead Nettle		53%	<1%	310	0.02%
Mayweed		81%	<1%	2,000	0.10%
Shepherd Purse		39%	<1%	460	0.02%
Field Pansy		38%	<1%	1,000	0.05%
Ivy-leaved Speedwell		25%	<1%	150	0.01%
Geranium sp.		11%	<1%	1,000	0.05%
Thistles (creeping)		5%	<1%	1,000	0.05%

* Whitehead R & Wright HC (1989)

4.3. Pests

In general there is little if any data on the average national yield loss of crops due to pest. There have been a number of surveys of pest incidence in a range of crops throughout the UK. The Central Science Laboratory hold data bases of such information and various agrochemical companies have conducted pest surveys as part of product stewardship. However, these data are usually used to predict the risk of pest attack and yield data is rarely if ever collected. The only estimates of yield loss come from trial data, particularly where untreated control plots are included. However this is an unreliable estimate of the effect of particular pests as in order to demonstrate the differences between treatments trial sites will be chosen at which there are high numbers of pests. As pest numbers will vary significantly between the years, data from trials in only one year cannot be used to represent the average potential yields loss.

In the absence of reliable data on the impacts of pests on crop yield and alternative approach was used. In general this involved collating expert opinion from a number of sources. Firstly pests were ranked in terms of their perceived importance on crop yield. The ranking was determined using anecdotal evidence from the industry, including fellow entomologists, agronomists, farmers and the agricultural press. For example in winter wheat the greatest risk of yield loss was considered to come from slugs and aphids as these pests are probably the most widespread across the UK.

Although slugs can potentially destroy sufficient plants to justify re-drilling, the average yield loss is significantly less than this. On the basis that an average yield loss of 10% on the annual wheat crop due to a pest would be unlikely, individual pests were ascribed a yield loss value relative to their perceived ranking. Not surprisingly these estimates were significantly less than have been measured in trials.

4.3.1. Winter wheat

With currently available treatments, yield losses from pest attacks in winter wheat are usually very low. The most widespread threat comes from aphid transmission of BYDV, with 82% of the crop area treated with either seed treatment, foliar sprays or both depending on the drilling date. It is difficult to provide accurate figures due to the existence of various isolates and their fluctuating incidence. In wheat losses in the range of 30-60% have been estimated in winter wheat (Bassett, 1985). In most years, with good timing of sprays this will reduce yield average yield losses to around 1% (Table 17). If crops were not treated this yield loss could be as much as 8% or 0.64t/ha (Table 16), but could be much higher in seasons with a mild autumn and continued secondary transfer. The southern parts of the UK are also likely to be more severely affected due to earlier sowing dates and milder temperatures.

Around 20-25% of the wheat crop area is treated for slugs every year. Slugs can cause significant damage to establishing crops, with the worst cases requiring re-drilling. Yield losses from slug activity can range from 100% where the crop has to be re-drilled, to just a small amount of damage. On average affected crops would lose 5% of their yield if left untreated. Treatment typically involves the application of metaldehyde slug pellets, using a small broadcast spreader, to the surface of emerging crops.

For summer aphids a 20% yield loss has been suggested for a threshold aphid population (2/3 ears infested) (Gratwick, 1992). However, this level of loss would not be expected every year, across the whole crop, so yield losses closer to 2% in affected crops are more likely.

Cereal cyst nematodes are rarely reported as a pest species today. Estimate of yield loss is 375-875 kg/ha (Empson & Gair, 1982). This represents a range of 5%-11% of a 8.25t/ha crop.

Frit fly yield loss estimates were calculated from trials conducted by French *et al*., 1988. Results suggest a 10% increase in yield as a result of application of Dursban.

Following the outbreak of orange wheat blossom midge (OWBM) in 1993 it was estimated that there was a 4% yield reduction in the national wheat yield. Some crops suffered up to 10% loss. (Ref internal ADAS Information Notes February 1994). This level of outbreak is not an annual occurrence; therefore the estimated yield loss to OWBM has been reduced to 2% untreated.

In trials the average yield response to control of wheat bulb fly was 31% (Young & Ellis, 1995).

Heavy infestations of wireworms can lead to a yield loss of 0.6t/ha or 7% of a 8.25t/ha crop.

There is little experimental data on the effects of slugs or leatherjackets on crop yields. Thrips and cutworms are not important pests of winter wheat.

Table 16 – Wheat: Effects of pests on production and yields untreated

Wheat (yield loss on affected area & total loss of production				
Pest	% area affected	% yield loss untreated	Loss of production untreated (t)	% loss of production (untreated)
Aphids autumn BYDV	82%	2.00%	280,000	1.6%
Slugs	22%	5.00%	188,000	1.1%
Orange Wheat Blossom Midge	18%	2.00%	62,000	<1%
Wheat Bulb Fly	3%	3.00%	15,000	<1%
Aphids Summer	1%	2.00%	3,000	<1%
Gout fly	1%	0.50%	900	<1%
Leatherjackets	1%	0.50%	900	<1%
Frit Fly	1%	0.50%	400	<1%
Cereal cyst Eelworm	0%	0.00%	0	<1%

Table 17 – Wheat: Effects of pests on production and yields with currently available actives

Wheat (yield loss on affected area & total loss of production)					
Pest	% area affected	Baseline UK production (t)	% yield loss with currently available treatments	Loss of potential production business as usual (t)	% loss of potential production (business as usual)
Aphids autumn BYDV	82%	17,000,000	1.00%	140,000	<1%
Slugs	22%		0.50%	19,000	<1%
Orange Wheat Blossom Midge	18%		0.50%	15,000	<1%
Wheat Bulb Fly	3%		1.00%	5,000	<1%
Aphids Summer	1%		0.50%	1,000	<1%
Leatherjackets	1%		0.10%	170	<1%
Gout fly	1%		0.10%	170	<1%
Frit Fly	1%		0.10%	90	<1%
Cereal cyst Eelworm	0%		0.00%	0	<1%

4.3.2. Winter barley

As with wheat the most important pest on winter barley is aphids with 81% of the winter barley area affected. Plumb *et al.*, (Internal Rothamsted Publication) suggest autumn sown barley can lose 50% of yield as a result of BYDV caused by aphid feeding. This is however a worst case scenario and it is estimated that without treatment aphids could result in a 2% yields loss on the affected area, leading to a

1.6% reduction in production (Table 18). However, the currently available foliar treatments and seed treatments provide reasonable control with just a 0.8% reduction in potential production from aphids (Table 19).

Table 18 - Winter barley: Effects of pests on production and yields untreated

Winter Barley (yield loss on affected area & total loss of pro				
Pest	% area affected	% yield loss untreated	Loss of production untreated (t)	% loss of production (untreated)
Aphids	81%	2.00%	39,000	1.6%
Slugs	22%	2.00%	11,000	<1%
Frit Fly	1%	1.00%	120	<1%
Gout Fly	1%	1.00%	120	<1%
Leather jackets	1%	1.00%	120	<1%

Table 19 - Winter barley: Effects of pests on production and yields treated with currently available actives

Winter Barley (yield loss on affected area & total loss of production)					
Pest	% area affected	Baseline UK production (t)	% yield loss with currently available treatments	Loss of potential production business as usual (t)	% loss of potential production (business as usual)
Aphids	81%	2,420,000	1.00%	20,000	<1%
Slugs	22%		0.50%	3,000	<1%
Frit Fly	1%		0.10%	10	<1%
Gout Fly	1%		0.10%	10	<1%
Leather jackets	1%		0.10%	10	<1%

4.3.3. Spring barley

Due to the timing of drilling spring barley is less at risk from pest species than winter barley, generally only small areas are affected by pest species (Table 20) those areas that are affected generally only suffer low levels of yields loss, even when untreated <1% of production is lost to each of the important pest species. Spring crops are rarely treated against BYDV as aphid migration continues right through the spring and summer. To prevent any virus transmission would require regular and frequent aphicide sprays which would be uneconomic and environmentally damaging.

Where treatment of pests is required the level of control is good, with minimal losses (Table 21).

Table 20 – Spring barley: Effects of pests on production and yields untreated

Spring Barley				
Pest	% area affected	% yield loss untreated	Loss of production untreated (t)	% loss of production (untreated)
Aphids	11%	1.00%	3,520	<1%
Leather jackets	2%	0.50%	320	<1%
Slugs	2%	0.50%	320	<1%
Gout Fly	1%	1.00%	160	<1%
Frit Fly	1%	0.50%	80	<1%

Table 21 – Spring barley: Effects of pests on production and yields treated with currently available actives

Spring Barley					
Pest	% area affected	Baseline UK production (t)	% yield loss with currently available treatments	Loss of potential production business as usual (t)	% loss of potential production (business as usual)
Aphids	11%	3,200,000	0.10%	350	<1%
Leather jackets	2%		0.10%	60	<1%
Slugs	2%		0.10%	60	<1%
Gout Fly	1%		0.10%	20	<1%
Frit Fly	1%		0.10%	20	<1%

4.3.4. Winter oats

Pests in oats are of limited importance. The majority of pests are only found on 1-2% of crops (Table 22) and even if left untreated the loss of production is typically less than 1%. Of the pest species that affect oats Aphids are the most widespread (54% of crops) and can potentially cause the greatest yield losses. If left untreated average yield losses are about 2%, although this may be higher on specifically affected crops. Despite currently available treatments aphids cause a slight loss of potential yield, but the reduction in production is less than 1% (Table 23).

Incidence of damage from stem nematodes has declined due to the introduction of resistant varieties.

Heavy infestations of wireworms can lead to a yield loss of 0.6t/ha or 9% of a 6.5t/ha crop.

Table 22 – Oats: Effects of pests on production and yields untreated

Oats (yield loss on affected area & total loss of production)				
Pest	% area affected	% yield loss untreated	Loss of production untreated (t)	% loss of production (untreated)
Aphids	54%	2.00%	9,140	1.1%
Slugs	2%	0.50%	85	<1%
Frit Fly	1%	0.50%	20	<1%
Leather jackets	1%	0.50%	20	<1%
Wireworm	1%	0.50%	20	<1%
Nematodes - stem	0%	0.50%	0	<1%

Table 23 – Oats: Effects of pests on production and yields treated with currently available actives

Oats (yield loss on affected area & total loss of production)					
Pest	% area affected	Baseline UK production (t)	% yield loss with currently available treatments	Loss of potential production business as usual (t)	% loss of potential production (business as usual)
Aphids	54%	850,000	0.50%	2,000	<1%
Slugs	2%		0.10%	17	<1%
Frit Fly	1%		0.10%	4	<1%
Leather jackets	1%		0.10%	4	<1%
Wireworm	1%		0.10%	4	<1%
Nematodes - stem	0%		0.00%	0	<1%

4.3.5. Winter oilseed rape

Unlike cereal crops pests have a much greater effect upon oilseed rape crops. The common pests are widespread with cabbage stem flea beetle affecting 67% of crops, slugs 59%, aphids 45% and pollen beetle 40% (Table 24). The highest untreated yield losses come from slugs, which could cause a 2.4% reduction in production if fields were left untreated. Aphids carrying turnip yellows can cause yields to be decreased by 26% (Stevens *et al.*, 2008), although a 3% yield loss across all affected crops is more likely. This would cause a 1.3% reduction in production. The other pests are likely cause less than 1% reduction in production. With current levels of insecticide treatments it is possible to gain reasonably good control of all these pests with typical losses of production of less than 1% under current practice (Table 25).

Yield responses, to treatments for summer aphids, in spring crops ranged from 3-46% and in winter crops from 0.3-11% (Ellis, *et al.*, 1999). A yield loss of 6% was chosen due to the very small area of spring rape grown in the UK, however only a very small area of the crop is affected by this pest so the impact on production is relatively small.

Cabbage root fly is not considered to be a major pest of oilseed rape. Seed weevil rarely exceeds current thresholds. Feeding and egg laying punctures can provide and entry point for brassica pod midge.

Table 24 – Oilseed rape: Effects of pests on production and yields untreated

Oilseed Rape (yield loss on affected area & total loss of proc				
Pest	% area affected	% yield loss untreated	Loss of production untreated (t)	% loss of production (untreated)
Cabbage stem flea beetle	67%	1.00%	13,000	<1%
Slugs	59%	4.00%	46,000	2.4%
Aphids & turnip yellows	45%	3.00%	26,000	1.3%
Pollen beetle	40%	0.50%	4,000	<1%
Seed weevil	20%	0.50%	2,000	<1%
Aphid direct feeding	1%	6.00%	1,170	<1%
Brassica pod midge	1%	0.50%	100	<1%

Table 25 – Oilseed rape: Effects of pests on production and yields treated with currently available actives

Oilseed Rape (yield loss on affected area & total loss of production)					
Pest	% area affected	Baseline UK production (t)	% yield loss with currently available treatments	Loss of potential production business as usual (t)	% loss of potential production (business as usual)
Cabbage stem flea beetle	67%	1,950,000	0.50%	7,000	<1%
Slugs	59%		0.50%	6,000	<1%
Aphids & turnip yellows	45%		0.50%	4,000	<1%
Pollen beetle	40%		0.10%	0	<1%
Seed weevil	20%		0.10%	0	<1%
Aphid direct feeding	1%		0.10%	0	<1%
Brassica pod midge	1%		0.10%	0	<1%

4.4. Diseases

Disease distribution is more difficult to quantify as the disease has the potential to move and spread rapidly. There are large variations in the severity of diseases from year to year, in different areas (at regional and sub-regional scales) and in different varieties. There are some diseases that are more likely to occur in certain areas, light leaf spot of oilseed rape is more common in the north and Scotland than in Southern regions, but it is widely distributed and can still cause problems in southern fields. Most diseases have the potential to occur anywhere in the country and several diseases affect each individual crop.

Disease spread and severity is also affected by the weather and other environmental and agronomic conditions. This means that for the purpose of this study average severity has been used, assuming that there will continue to be seasonal and regional variation and that varieties used will vary in their disease susceptibility. In some years the level of disease pressure could be high leading to large yield losses from one or two diseases, whilst in other years disease pressure could be reduced leading to small yield losses. This seasonal variation would apply to rust diseases in cereals.

4.4.1. Wheat

Wheat diseases losses were estimated at 3.6% by Hardwick *et al*., 2000, which was slightly lower than the 5.3% in the 1970's when fungicide use was more limited. Losses are subject to seasonal variation and this is shown in Hardwick *et al*., 2001. More recently in 2007, brown rust and fusarium ear diseases have been more severe than during the 1990's and may reflect larger variation in weather associated with climate change. New legislation in 2007 requires farmers to assess the mycotoxin risk and have samples analysed prior to sale. EU mycotoxin limits now have an economic impact on some farms where grain cannot be sold and has created more interest in fungicide applications to the ear.

Losses in fungicide experiments provide good evidence for the damage caused by diseases. In a series of Defra-funded experiments done by ADAS and CSL, four wheat cultivars Apollo, Hereward, Riband and Slejpner were grown with and without a full fungicide programme in harvest years 1994-1997 on a total of 42 sites in England. Average % losses were 13 % on Haven, 14% on Apollo, 19% on Riband and 25% on Slejpner. Actual losses ranged (from 1.17 to 2.19 t/ha). Riband was susceptible to *S. tritici* and Slejpner was very susceptible to yellow rust. Both Haven and Apollo were also susceptible to yellow rust but were less often affected because of their resistance to the most widely occurring races. Yield losses from foliar diseases are therefore estimated to be 13-25% with variation according to varietal resistance, year and location. There will be further losses from stem base diseases particularly eyespot either directly or indirectly if crops are sown later to reduce eyespot risks. Losses from fusarium and mycotoxins in grain are expected to increase without any fungicides to control stem base and ear infection. Take-all remains a significant problem in current practice as it accounts for much of the yield difference of about 1 t/ha between first and second wheats. More continuous wheat might be grown to prevent serious losses from take-all in second or third wheats.

The most important diseases in wheat crops are *Septoria tritici* followed by take all and yellow rust (Table 26 & Table 27). These diseases can generally occur anywhere in the country, although their incidence in any one particular year may be patchy. *S. tritici* is present in virtually all crops. Its presence causes a reduction in yield, from the potential, of 0.3% even when applications of current fungicide sprays are made. If left untreated this yield reduction increases to 10%, equivalent to 1.7 million tonnes of wheat. Take all causes an estimated 2.5% yield loss, even in treated crops; this increases to a 6% yield loss if left untreated. Yellow rust causes a 0.3% yield loss when treated, which increases to 5% if left untreated, equivalent to just under 0.9 million tonnes of wheat. Fusarium, eyespot, brown rust, glume blotch (*Septoria nodorum)* and powdery mildew all cause between 2 and 3% yield losses if left untreated.

Table 26– Wheat: Effects of diseases on production and yields untreated

Wheat (yield loss on affected area & total loss of production)				
Disease	% area affected	% yield loss untreated	Loss of production untreated (t)	% loss of production (untreated)
All diseases	100%	31.7%	5,421,000	31.70%
diseases (excluding take all)	100%	25.7%	4,395,000	25.70%
S. tritici	100%	10.0%	1,710,000	10.00%
Take all	80%	6.0%	1,026,000	6.00%
Yellow rust	40%	5.0%	855,000	5.00%
Eyespot	90%	3.0%	513,000	3.00%
Fusarium (ear)	70%	3.0%	513,000	3.00%
Brown Rust	60%	2.5%	428,000	2.50%
Powdery mildew	80%	2.0%	342,000	2.00%
S nodorum	50%	2.0%	342,000	2.00%
Sharp Eyespot	75%	<1%	34,000	<1%

5-10% loss of production	>10% loss of production

Table 27– Wheat: Effects of diseases on production and yields treated with currently available actives

Wheat (yield loss on affected area & total loss of production)						
Disease	% area affected	Baseline UK production (t)	% yield loss with currently available treatments	Loss of potential production business as usual (t)	Loss of potential production business as usual (t)	% loss of potential production (business as usual)
All diseases	100%	17,000,000	6.1%	1,043,187	1,043,000	6.14%
diseases (excluding take all)	100%		3.6%	615,651	616,000	3.62%
S. tritici	100%		<1%	51,304	51,000	0.30%
Take all	80%		2.5%	427,536	428,000	2.52%
Yellow rust	40%		<1%	51,304	51,000	0.30%
Eyespot	90%		<1%	85,507	86,000	0.51%
Fusarium (ear)	70%		<1%	51,304	51,000	0.30%
Brown Rust	60%		<1%	34,203	34,000	0.20%
Powdery mildew	80%		<1%	51,304	51,000	0.30%
S nodorum	50%		<1%	34,203	34,000	0.20%
Sharp Eyespot	75%		<1%	17,101	17,000	0.10%

5-10% loss of production	>10% loss of production

4.4.2. Winter Barley

In winter barley, the most important disease in terms of loss of production is take-all (Table 28 & Table 29). This affects 60% of crops and causes yield losses of 5% on affected crops, as fungicide treatments are rarely used or have little impact. However there is little use of fungicides for the control of take-all in winter barley, so yield losses are no worse if crops are left untreated. This leads to an overall reduction in production of 4.3%, just over 100,000t of barley. For other diseases, untreated losses are drawn from effects of fungicides on yields in HGCA Recommended List trials and ADAS experimental data. Fusarium stem base browning causes a 2.6% reduction in winter barley production if left untreated, this is partly due to the fact that this disease is very widespread (90% of winter barley survey crops are affected). Rhynchosporium causes the highest yield loss (after take-all) if left untreated, of 3%. However, it is only seen on 60% of crops and very high losses only occur in a few crops. The loss of production with fungicides is 2.15% (just over 50,000t barley), reflecting difficulties in achieving good control. Eyespot is present across a larger area than Rhynchosporium, at 80% of fields affected, but it causes untreated yield losses of 2%. This leads to a total loss of production of 2.3%.

Table 28 – Winter barley: Effects of diseases on production and yields untreated

Winter Barley (yield loss on affected area & total loss of production)				
Disease	% area affected	% yield loss untreated	Loss of production untreated (t)	% loss of production (untreated)
Take all	60%	5.0%	104,000	4.30%
Fusarium	90%	2.0%	63,000	2.60%
Eyespot	80%	2.0%	56,000	2.31%
Net Blotch	60%	2.5%	52,000	2.15%
Rhynchosporium	60%	3.0%	52,000	2.15%
Brown Rust	60%	2.0%	42,000	1.73%
Mildew	60%	2.0%	42,000	1.73%
BYDV	30%	<1%	10,000	<1%
Ramularia	25%	<1%	9,000	<1%
Mosaic viruses	20%	<1%	7,000	<1%
Others includes y. rust, halo spot, loose smut, snow rot	20%	<1%	7,000	<1%
Ergot	1%	<1%	0	<1%

Table 29 – Winter barley: Effects of diseases on production and yields treated with currently available actives

Winter Barley (yield loss on affected area & total loss of production)						
Disease	% area affected	Baseline UK production (t)	% yield loss with currently available treatments	Loss of potential production business as usual	Loss of potential production business as usual (t)	% loss of potential production (business as usual)
Take all	60%	2,420,000	5.0%	72,623	73,000	3.02%
Fusarium	90%		<1%	21,787	22,000	0.91%
Eyespot	80%		<1%	19,366	19,000	0.79%
Net Blotch	60%		<1%	10,167	10,000	0.41%
Rhynchosporium	60%		<1%	12,104	12,000	0.50%
Brown Rust	60%		<1%	7,262	7,000	0.29%
Mildew	60%		<1%	7,262	7,000	0.29%
BYDV	30%		<1%	3,631	4,000	0.17%
Ramularia	25%		<1%	1,816	2,000	0.08%
Mosaic viruses	20%		<1%	4,842	5,000	0.21%
Others includes y. rust, halo spot, loose smut, snow rot	20%		<1%	2,421	2,000	0.08%
Ergot	1%		<1%	0	0	0.00%

4.4.3. Spring Barley

Disease is generally of less importance in spring barley (Table 30 & Table 31) compared to winter barley. Spring barley disease surveys were last done in 1980

(Polley *et al.*, 1993). Untreated losses are drawn from effects of fungicides on yields in HGCA Recommended List trials. The situation is strongly influenced by the availability of varieties with good disease resistance. The diseases that are present are less widespread, and therefore as a result the impact on production is much less, no single disease causes over a 2% yield reduction. Of the diseases that are present the most important one is powdery mildew, which can cause a 3% yield reduction (if left untreated) on 60% of the spring barley area, leading to a total loss of production of 1.8%, or 58,000t of spring barley. Rhynchosporium and brown rust respectively are then the next two most important diseases with production losses of 1.5% and 1.2% respectively if left untreated.

Table 30 - Spring barley: Effects of diseases on production and yields untreated

Spring Barley (yield loss on affected area & total loss of production)				
Disease	% area affected	% yield loss untreated	Loss of production untreated (t)	% loss of production (untreated)
Mildew	60%	3.0%	58,000	1.81%
Rhynchosporium	60%	3.0%	48,000	1.50%
Brown Rust	60%	2.0%	38,000	1.19%
BYDV	35%	1.5%	22,000	<1%
Ramularia	25%	2.0%	16,000	<1%
Take all	20%	2.0%	13,000	<1%
Fusarium	20%	<1%	11,000	<1%
Net Blotch	60%	<1%	10,000	<1%
Others includes y. rust, halo spot, loose smut, snow rot, mosaic viruses	10%	1.5%	5,000	<1%
Eyespot	20%	<1%	3,000	<1%
Ergot	1%	<1%	0	<1%

Table 31 - Spring barley: Effects of diseases on production and yields treated with currently available actives

Spring Barley (yield loss on affected area & total loss of production)						
Disease	% area affected	Baseline UK production (t)	% yield loss with currently available treatments	Loss of potential production business as usual	Loss of potential production business as usual (t)	% loss of potential production (business as usual)
Mildew	60%	3,200,000	<1%	19,184	19,000	0.59%
Rhynchosporium	60%		<1%	15,986	16,000	0.50%
Brown Rust	60%		<1%	9,592	10,000	0.31%
BYDV	35%		<1%	11,190	11,000	0.34%
Ramularia	25%		<1%	7,993	8,000	0.25%
Take all	20%		2.0%	12,789	13,000	0.41%
Fusarium	20%		<1%	7,993	8,000	0.25%
Net Blotch	60%		<1%	3,837	4,000	0.13%
Others includes y. rust, halo spot, loose smut, snow rot, mosaic viruses	10%		<1%	1,599	2,000	0.06%
Eyespot	20%		<1%	1,918	2,000	0.06%
Ergot	1%		<1%	0	0	0.00%

4.4.4. Oats

In both winter and spring oats, the most important disease is crown rust (Table 32 & Table 33). No disease survey data are available and distribution is based on ADAS and other expert field experience. Untreated losses are based on effects of fungicides on yields in HGCA Recommended List trials and limited specific experimental data. When treated crown rust can still cause a yield loss of 1%, compared to potential yields, rising to 5% if left untreated. It affects 60% of the oat area and therefore there is a 3.8% reduction in production if crown rust is left untreated (32,000t of oats). The other diseases cause less than a 1% reduction in production.

Table 32 – Oats: Effects of diseases on production and yields untreated

Oats (yield loss on affected area & total loss of production)				
Disease	% area affected	% yield loss untreated	Loss of production untreated (t)	% loss of production (untreated)
Crown Rust	65%	5.0%	32,000	3.78%
Mildew	60%	<1%	5,000	0.59%
BYDV	25%	<1%	3,000	<1%
Take all	25%	<1%	2,000	<1%
Fusarium spp	50%	<1%	1,000	<1%
Other stem base diseases	40%	<1%	1,000	<1%
Mosaic viruses	5%	2.0%	1,000	<1%

Table 33 – Oats: Effects of diseases on production and yields treated with currently available actives

Oats (yield loss on affected area & total loss of production)						
Disease	% area affected	Baseline UK production (t)	% yield loss with currently available treatments	Loss of potential production business as usual	Loss of potential production business as usual (t)	% loss of potential production (business as usual)
Crown Rust	65%	850,000	<1%	5,078	5,000	0.59%
Mildew	60%		<1%	1,269	1,000	0.12%
BYDV	25%		<1%	1,058	1,000	0.12%
Take all	25%		<1%	2,116	2,000	0.24%
Fusarium spp	50%		<1%	846	1,000	0.12%
Other stem base diseases	40%		<1%	1,016	1,000	0.12%
Mosaic viruses	5%		<1%	212	0	0.00%

4.4.5. Oilseed rape

The most important disease in oilseed rape is phoma stem canker (Table 34 & Table 35) in treated situations it can cause an average of a 5% yield loss compared to potential, if left untreated this leads to a 10% reduction in yield. As 90% of the oilseed rape area is affected by phoma this leads to a reduction in production, if left untreated of almost 9% (175,000t of rapeseed). The next most important disease is light leaf spot. This causes a 4% reduction in yield, even when treated, rising to 10% if left untreated. As 75% of the rape area is affected by light leaf spot this leads to a 7.5% loss of production if left untreated. Turnip yellows causes a 5% yield loss when treated, and 7.5% yield loss untreated. It affects 60% of the rape area, leading to a potential reduction in production of 4.5% if left untreated.

Table 34 – Oilseed rape: Effects of diseases on production and yields untreated

Oilseed Rape (yield loss on affected area & total loss of production)				
Disease	% area affected	% yield loss untreated	Loss of production untreated (t)	% loss of production (untreated)
Phoma (L. maculans)	90%	10.0%	175,000	8.99%
Light Leaf spot	75%	10.0%	146,000	7.50%
Turnip yellows	60%	7.5%	88,000	4.52%
Sclerotinia	75%	5.0%	73,000	3.75%
Botrytis	75%	2.0%	29,000	1.49%
Downy mildew	100%	<1%	19,000	<1%
Alternaria	35%	2.0%	14,000	<1%
Verticillium	25%	2.0%	10,000	<1%
Phoma b (L. biglobosa)	80%	<1%	6,000	<1%
Powdery mildew	30%	<1%	6,000	<1%
Clubroot	2%	<1%	0	<1%

5-10% loss of production	>10% loss of production

Table 35 – Oilseed rape: Effects of diseases on production and yields treated with currently available actives

Oilseed Rape (yield loss on affected area & total loss of production)						
Disease	% area affected	Baseline UK production (t)	% yield loss with currently available treatments	Loss of potential production business as usual	Loss of potential production business as usual (t)	% loss of potential production (business as usual)
Phoma (L. maculans)	90%	1,950,000	5.0%	87,618	88,000	4.51%
Light Leaf spot	75%		4.0%	58,412	58,000	2.97%
Turnip yellows	60%		5.0%	58,412	58,000	2.97%
Sclerotinia	75%		1.5%	21,905	22,000	1.13%
Botrytis	75%		<1%	14,603	15,000	0.77%
Downy mildew	100%		<1%	19,471	19,000	0.97%
Alternaria	35%		<1%	3,407	3,000	0.15%
Verticillium	25%		2.0%	9,735	10,000	0.51%
Phoma b (L. biglobosa)	80%		<1%	3,115	3,000	0.15%
Powdery mildew	30%		<1%	5,841	6,000	0.31%
Clubroot	2%		<1%	195	0	0.00%

4.5. Lodging control

4.5.1. Winter wheat

Business as usual

89% of wheat is treated with PGRs, the majority of which are applied in a single application at the beginning of stem extension (Pesticide Usage Survey for 2006 www.csl.gov.uk/science/organ/pvm/puskm/pusg.cfm)).HGCA Report No 169 (Berry *et al*., 1998) estimated the frequency of lodging and lodging associated yield losses. This project showed that over the last 3 decades severe lodging has occurred on average once every 3 to 4 years. An aerial survey of 3,000 ha of wheat around England carried out in one of these severe lodging years (1992) showed that 16% of the wheat area was lodged. If it is assumed that a severe lodging year occurs every 3.5 years, 16% of wheat lodges in a severe lodging year and 4% lodges in other years, then the average percentage area lodged in an average year is estimated to be 7%. Yield losses due to lodging can be up to 100% and depends on the timing of lodging and the angle of lodging (Berry *et al*., 2004). On average a typical yield loss from a lodged patch amounts to 25% (Berry *et al*., 1998).

Untreated

Data on the effect of a single growth regulator application on the plant characteristics associated with lodging (Berry *et al*., 2000) have been used with a tested model of lodging (Berry *et al*., 2003) to estimate that not using a single growth regulator would increase the % area lodged from 7% to 11%.

Knock-on effects of lodging

Lodging significantly increases the chance of reduced Hagberg falling number, increases the amount of drying required and increases combining time. If it is assumed that lodging prevents the milling premium from being attained, increases the moisture content by 3% and lengthens combining time by 30% then it has been estimated that the costs of the knock-on effects of lodging are as much as the costs of reduced yield (Berry *et al*., 1998).

4.5.2. Winter barley

Business as usual

76% of winter barley is treated with a PGR (Pesticide Usage Survey). It is generally accepted that lodging in winter barley is more frequent than in wheat. Surveys by BASF have estimated that 30% of the winter barley area can be lodged in a severe lodging year. If it is assumed that a severe lodging year occurs every 3 years, 20% of winter barley lodges in a severe lodging year and 5% lodges in other years, then the average percentage area lodged in an average year is estimated to be 10%. Several studies have measured lodging-induced yield losses in barley ranging from 28% to 65% (Berry *et al*., 2004). These studies generally assessed the effects of severe early lodging which results in greater yield losses. A representative yield loss from a lodged patch of barley is estimated to be 25%.

Untreated

Unpublished data on the effect of growth regulators on the plant characteristics associated with lodging have been used with a model of barley lodging (Berry *et al*., 2006) to estimate that not using growth regulators would increase the percentage area lodged from 10% to 14% (after accounting for the fact that 76% of winter barley is treated in the business as usual scenario).

4.5.3. Spring barley

Business as usual

Only 17% of spring barley is treated with PGRs. Surveys by BASF have estimated that 10% of the spring barley area can be lodged in a severe lodging year. If it is assumed that a severe lodging years occurs every 3 years, 10% of winter barley lodges in a severe lodging year and 2% lodges in other years, then the average percentage area of untreated spring barley lodged in an average year is estimated to be 5%. A representative yield loss from a lodged patch of barley is estimated to be 25%.

Untreated
It is not known how much PGRs reduce the lodging risk of spring barley by. If it is similar to winter barley then the average % area lodged in treated crops is estimated to be 6% (after accounting for the fact that only 17% of winter barley is treated in the business as usual scenario).

4.5.4. Oats

Business as usual
67% of oats are treated with PGRs. Little information can be found regarding the area of oats that lodge. It is generally accepted that lodging is more widespread in oats than wheat. It is therefore assumed that the incidence of oat lodging is similar to winter barley and a severe lodging year occurs every 3 years, 20% of oats lodge in a severe lodging year and 5% lodges in other years, giving an average percentage area lodged of 10%. Little information exists on the yield losses associated with oat lodging. Lodging losses in spring oats have been estimated at 37% (Pendleton, 1954). Lodging losses are assumed to be the same as for other cereals at 25%.

Untreated
There is no data from which to estimate the effect of PGRs on the lodging risk of oats. If it assumed to be similar to winter barley then it is estimated that not using growth regulators would increase the percentage area lodged from 10% to 13% (after accounting for the fact that 67% of oats is treated in the business as usual scenario).

4.5.5. Oilseed rape

Business as usual
About 30% of oilseed rape area is treated with a fungicide with PGR activity (metconazole or tebuconazole). It is estimated that about 25% of the oilseed rape area lodges (defined as lodging at an angle of more than 45^{o}). Lodging induced yield losses have been estimated at 13% for modest amounts of lodging to 50% for severe lodging events (Bayliss and Wright, 1990). Early lodging or lodging at a more severe angle are associated with greater yield losses. Over a wide range of experiments it has shown that the PGR metconazole reduced the percentage area lodged from 50% to 22% and this increased yield by 5% (Lunn *et al*., 2003). It is possible that metconazole may have increased yield by other mechanisms in addition to reduced lodging. It is assumed here that lodging at 45^{o} from the vertical or more results in yield losses of 25%.

Untreated
If PGRs reduce the percentage area lodged by half, then it is estimated that not using them will increase the % area lodged from 25% to 33%.

Table 36 – Effect of lodging on yield BAU and untreated

Crop	Average % yield loss from lodging	% area lodge d	Loss of producti on BAU (t)	% loss of producti on BAU	% area lodged if untreat	Loss of productio n untreate	% loss of producti on
Wheat	25%	7%	299,000	1.7%	11%	470,000	2.7%
Winter Barley	25%	10%	61,000	2.5%	14%	122,000	5.0%
Spring Barley	25%	5%	40,000	1.3%	6%	48,000	1.5%
Oats	25%	10%	21,000	2.5%	13%	28,000	3.3%
OSR	25%	25%	122,000	6.3%	33%	161,000	8.3%

5. Evaluation of alternative control measures

There are a number of mitigating measures that can be used to help control weeds, pests and diseases – many of these measures are already practiced to a certain extent to help reduce the current requirements for pesticides and to help reduce the build up of resistance to pesticides.

Many of the mitigation measures can combat more than one weed, pest or disease, for example; late drilling of crops can help with weed control as it allows many weed seeds to germinate prior to drilling, it can also help to reduce pest problems from autumn aphids, causing BYDV, and gout fly. But there can also be disadvantages associated such as the potential to miss drilling windows and lower yield as a result of late establishment.

There are a number of basic agronomic strategies that can be used to mitigate against weeds, pests and diseases. These strategies require an understanding of the field, crop and pests as well as the rotation in order to make suitable decisions.

Field selection

- Selecting fields that have no prior history of the weed, pest or disease. For certain crops it is best to avoid fields that have a known weed, pest or disease problem that is difficult to treat in that crop. Barley already tends to be grown on land that has low black-grass populations because even with current pesticides the level of control achievable in barley is limited. Where pests such as nematodes and soil borne diseases are present in the soil if pesticides are no longer available then it may be best to avoid growing affected crops on those fields. After a period of time without sufficient levels of controls these weeds, pests and diseases could spread into a greater number of fields reducing the availability of fields for growing particular crops.

Cultivations

- Ploughing - This can be used to bury weed seeds that have fallen on the surface to a depth from which they cannot germinate. It can also be used to bury pest or disease residues to reduce the carry over into the following crop. Ploughing can have negative effects on soils structure.
- Rolling – This can create firmer more even seed beds, reducing the number of clods present. This provides better conditions for the application of pre-emergence herbicides as the coverage is more even. It also means that any emerging weed seedlings are likely to be coming from a similar soil depth and will therefore be easier to control than populations that are of different sizes as a result of uneven establishment. Cloddy seed beds provide hollows and damp places for slugs to hide. By rolling seed beds slug populations can be reduced and more easily controlled. Rolling is not always possible if seed beds are particularly wet.

Drilling date

- Delayed drilling – This allows stale seed beds to be used prior to the establishment of the following crops. Weed seeds germinate and can then be controlled through the application of a general herbicide such as glyphosate, through cultivation or through a combination of the two. Later drilling dates also allow the crop to become established at a time when aphid numbers are low and gout fly less active, reducing the damage that is likely to be caused by these pests. In oilseed rape crops it may not be possible to actually drill late enough to miss aphid migrations and get a satisfactory crop. Delaying drilling can increase the risk of poor establishment as soils can become colder and wetter providing poor conditions for establishment. To compensate crops should be drilled at higher seed rates, this has an associated increased cost. If weather conditions become unfavourable there is the risk that some fields might not be drilled. Later drilled oilseed rape crops are particularly at risk from pigeon damage.
- Early drilling – This allows crops to become established during the warmer weather of early autumn allowing rapid growth. This is beneficial if slug populations are high as the crop will be growing rapidly enough to grow away from slug munching. Later sown crops grow more slowly and are more at risk from severe damage from slug grazing. Earlier sowing also allows crops to withstand wheat bulb fly damage better. However, early drilled cereal crops are then at greater risk from BYDV as aphids are more likely to be active at this time.

Variety choice

- Plant breeding – plant breeding can be used to introduce resistance traits into crop varieties. This is an often expensive and slow process. Despite best effort most resistance traits actually struggle to completely overcome and pest or disease problem, and are completely ineffective against weeds. Most UK crops are actually relatively small in global terms, which means that the amount of money for investment in plant breeding for these crops is often restricted unless attributes provide very significant monetary reward.
- Resistant varieties – there are certain varieties that have been specially developed by breeders to contain genes that provide resistance to certain pests or diseases. There are resistance genes in wheat for orange wheat blossom midge, septoria and rusts; in oats there are varieties that are resistant to stem nematodes. There are potential yield penalties associated with some of these varieties, and not all forms of resistance are present in the same variety. Careful decisions have to be made as to what pests or diseases are of most importance in that field, and what the end market for the product is before final variety decisions can be made.

Nitrogen applications

- The timing and rate of nitrogen applications can have an effect on the level of crop losses to weeds, pests and diseases. The more vigorous a crop is the more likely it is to be able to compete with the weed, pest or disease.

Biological control

- Natural enemies – The reduction in insecticide usage, as a result of some of the scenarios could lead to an increase in populations of natural enemies. These in turn may help to keep the numbers of cereal and rape pests under control. The level of control that is achieved by these natural enemies is usually unpredictable compared to insecticides. Natural control can also be reduced by other farming operations.

Introduced biological control agents – Biological control is widely used in glasshouse and covered situations for the control of insect pests. It is more difficult in the field as maintaining sufficiently high populations of predators can be difficult. There is also a risk of introducing a foreign predator into a natural ecosystem and the damage that can occur to non-target species. However, there are some biological controls that can be used in the field, such as that used to control sclerotinia in oilseed rape. Spores of the fungus *Coniothyrium mintans* (product is Contans) may be applied to soil or crop residues for biological control of sclerotinia. The product can be used postharvest or at sowing, though more than one application may be required to achieve satisfactory decreases in sclerotial populations.

Pesticide strategies

- Changing pesticide availability will lead to changes in the pesticide regimes used. Disease control is likely to become more reliant on weaker active substances, resulting in an increase in the number of spray applications or rates of application required.
- Increased use of sulphur and copper compounds for the control of diseases is a possibility as growers strive to maintain yields in absence of pesticides.

5.1. Weeds

Where fewer herbicides are used a higher seed rate and hence a more competitive crop, can mitigate against some of the yield loss caused by higher weed populations (Leake, 1996) this can be combined with later drilling.

Table 37 - Comparison of sowing date, rate and herbicide treatment on wheat yield in three farming systems.

Sow date	Sow rate	Plants/m²	Weeds/m²	Treated yield (t/ha)	Untreated yield (t/ha)	Yield loss due to weeds (%)
Conventional 21/9	190	292	789	12.80	4.66	64
Integrated 21/10	220	431	1045	11.46	8.05	30
Organic 28/10	220	303	640	-	7.90	-

Winter wheat crops can tolerate modest weed levels 50g/m² without loss of yield but the results can be variable (AR0408, 2005).

Table 38 - Mitigating effect of delayed drilling on weeds in winter wheat (Coutts and Prew, 1996)

	26 Oct	24 Nov
Black-grass	19	27 (probably dormancy!)
Cleavers	4	0
Poppy	42	16
Chickweed	79	1
Speedwell (*Veronica persica*)	40	1
Pansy	537	40

5.1.1. Cereals

Table 39 - Mitigating measures to control weeds in cereals

Weeds	Treatment	Mitigating measures	Issues with mitigating measures
Black-grass		Ploughing	Great cost, can lead to poor soil conditions and increased erosion risk
		Stale seed bed Late sowing	Need increased seed rate, risk of not drilling some fields
Broad-leaved weeds	Limited effect		

5.1.2. Oilseed Rape

Table 40 – Mitigating measures for controlling weeds in oilseed rape

Weeds	Treatment	Mitigating measures	Issues with mitigating measures
Black-grass		Plough	Need increased seed rate, risk of not drilling some fields
Broad-leaved weeds		Plough	Later drilling risk of crop failure due to moisture loss Increased cost
		Increase seedrate	

5.2. Pests

5.2.1. Wheat

Table 41 – Mitigating measures to protect against pests on wheat

Pests	Treatment	Mitigating measures	Issues with mitigating measures
Autumn aphids	Seed treatment/ foliar spray	Late sowing	Need increased seed rate, risk of not drilling some fields
Slugs	Pellets	Sow early, roll, increase seed rate	Increase BYDV risk
Cereal cyst nematode	None	Don't grow in infested field	Problems finding alternative field
Frit Fly	Foliar spray	Plough early to minimise transfer from old sward	Delays to drilling
Gout fly	Foliar spray	Sow winter crops after late September. Sow spring crops as early as practicable	Delays to autumn drilling
Orange wheat blossom midge	Foliar spray	Grow resistant cv's	Yield penalties?
Wheat bulb fly	Seed treatment/ egg hatch spray/ deadheart spray	Sow early	Increases BYDV risk
Leatherjackets	Foliar spray	Plough early in July/ early August before most eggs laid to reduce carry over	Loss of seedbed moisture?

5.2.2. Winter Barley

Table 42 – Mitigating measures to protect against pests in winter barley

Pests	Treatment	Mitigating measures	Issues with mitigating measures
Autumn aphids	Seed treatment/foliar spray	Late sowing	Need increased seed rate, risk of not drilling some fields
Frit Fly	Foliar spray	Plough early to minimise transfer from old sward	Delays to drilling
Gout fly	Foliar spray	Sow winter crops after late September. Sow spring crops as early as practicable	Delays to autumn drilling
Slugs	Pellets	Sow early, roll, increase seed rate	Increase BYDV risk
Leatherjackets	Foliar spray	Plough early in July/early August before most eggs laid to reduce carry over	Loss of seedbed moisture?

5.2.3. Spring Barley

Table 43 – Mitigating measures to protect against pests in spring barley

Pests	Treatment	Mitigating measures	Issues with mitigating measures
Aphids and BYDV	Rarely any treatment		
Frit fly	Foliar spray	Plough early to minimise transfer from old sward	Delays to drilling
Gout fly		Sow spring crops as early as practicable	
Leatherjackets	Foliar spray	Plough early in July/early August before most eggs laid to reduce carry over	Loss of seedbed moisture?
Slugs	Pellets	Ensure rapid establishment	

5.2.4. Oats

Table 44 – Mitigating measures protecting oats against pests

Pests	Treatment	Mitigating measures	Issues with mitigating measures
Aphids	Foliar spray	Late sowing	Need increased seed rate, risk of not drilling some fields
Frit fly	Foliar spray	Plough early to minimise transfer from old sward	Delays to drilling
Stem nematode	None	Grow resistant varieties	
Wireworms	Seed treatment	Increase seed rate, encourage rapid establishment	Cost of extra seed
Slugs	Pellets	Sow early	Increase BYDV risk
Leatherjackets	Foliar spray	Plough early in July/early August before most eggs laid to reduce carry over	Loss of seedbed moisture?

5.2.5. Oilseed Rape

Table 45 – Mitigating measures protecting oilseed rape against pests

Pests	Treatment	Mitigating measures	Issues with mitigating measures
Aphids(virus)	Foliar spray	Later sowing	May not be able to sow late enough to avoid aphid migration
Flea beetles inc. cabbage stem flea beetle	Seed treatment/foliar spray	Later sowing for winter crops. Early sowing for spring crops	Need to increase seed rate?
Pollen beetle	Foliar spray	Sow spring crops as early as possible so past green/yellow bud before beetles arrive	
Seed weevil	Foliar spray	Delayed sowing reduces numbers of adults attracted and eggs laid	
Slugs	Pellets	Ensure good seedbed to encourage rapid establishment	

5.3. Diseases

Some adjustments to agronomy, such as more resistant varieties, date of sowing seed rates and fertiliser use might be undertaken to reduce disease risk.

In oilseed rape, ploughing or extra cultivations are likely to be required as part of stem canker and light leaf spot control where non-triazole fungicides are available. Biological control could be more widely adopted to assist management of sclerotinia stem rot. This is already done on some farms, but this will increase costs across the industry. If individuals experience serious problems, then farming systems and cropping may require substantial modification.

Several fungicides will be available, however, these may be less effective than some that are lost and may result in removal of some of the older cheaper product options.

5.3.1. Wheat

Table 46 – Mitigating measures protecting wheat against disease

Disease	Treatment	Mitigating measures	Issues with mitigating measures
Septoria	Foliar spray	Varieties Sow date More applications of weaker products	1 extra application per crop = £11.40/ha

5.3.2. Winter Barley

Table 47 – Mitigating measures protecting winter barley against disease

Disease	Treatment	Mitigating measures	Issues with mitigating measures
Foliar	Foliar spray	Variety Sow date N timing Fungicide dose	Cost of higher rates preferred to increased application timings. Extr £10/ha

5.3.3. Spring Barley

Table 48 – Mitigating measures protecting spring barley against disease

Disease	Treatment	Mitigating measures	Issues with mitigating measures
Foliar	Foliar spray	Variety Sow date N timing Fungicide dose	Cost of higher rates preferred to increased application timings. Extra £10/ha

5.3.4. Oats

Table 49 – Mitigating measures protecting oats against disease

Disease	Treatment	Mitigating measures	Issues with mitigating measures
Foliar	Foliar spray	Variety Fungicide dose	Cost of higher rates or more expensive products preferred to increased application timings. Less important than on other cereals £2/ha

5.3.5. Oilseed Rape

Table 50 – Mitigating measures protecting oilseed rape against disease

Disease	Treatment	Mitigating measures	Issues with mitigating measures
Phoma and light leaf spot	Foliar spray lost	Plough more OSR stubbles	Cost of ploughing on 30% OSR area less savings in phoma/ LLS fungicides of £20/ha and possibly an application cost of £11.20 assuming herbicide and insecticide are applied
Sclerotinia	Foliar spray options Reduced – poor control	Biocontrol treatment post harvest and/or pre-cropping	Cost (£60/ha) and partial effectiveness only used on 5% crop area

5.4. Lodging control

Table 51 – Mitigating measures protecting combinable crops against lodging

Lodging control	Mitigating measures	Yield losses associated with mitigating measures
Later drilling	Lower yield potential	For wheat about 0.2 t/ha less yield per week of delay after mid Oct
Variety choice	May not be able to choose the highest yielding variety or the best quality spec	Yield losses of 1-3%

6. Assessment of future status of pesticide availability

6.1. Current pesticides approved for use in combinable crops

There are currently a wide range of pesticides that are approved for use on combinable crops see Table 52. The full details of which active substances are available on each crop are in Appendix 2 – Loss of Active Substances

Table 52 – Number of active substance approved for use on each crop

Crop	Number of pesticides approved	Herbicides	Insecticides	Fungicides
Wheat	98	41	21	36
Winter Barley	83	36	14	33
Spring Barley	77	35	13	29
Oats	55	23	9	23
OSR	48	21	13	14

Current combinable crop plant protection products offer a reasonable range of actives for the control of most problems in UK combinable crop production. The weakest areas are in the control of black-grass and OSR diseases such as phoma and light leaf spot, where resistance to some actives is increasing and resistance management strategies are important.

6.2. Drivers for change in pesticide availability

There are a number of reasons why the availability of pesticides could change, these are summarised in Table 53.

Table 53 – Drivers for change in pesticide availability

Reason for change	Main effects	Pesticides affected
Revision of 91/414/EEC	Change in approval system	Wide range affecting weed, pest and 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 Tefluthrin – used as a seed dressing for WBF control Older grass-weed herbicides used for volunteer cereal control
Water Framework Directive	Minimising pesticides in water	Mainly affecting herbicides e.g. • propyzamide • carbetamide • chlorotoluron • metaldehyde
Resistance	Build up in resistance to some active substances	• Black-grass • Septoria • Aphids • Pollen beetle
Market acceptability	Residues of particular active substances	• chlormequat • glyphosate
Operator safety	None specifically identified	
Cost	None specifically identified	
New product development	Replacing older actives	

6.2.1. 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 would 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. 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 led 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 with 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 2010 at the earliest. 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 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 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.

In each of these situations there are a number of actives that could be affected by the article 4(7) derogation. This allows the approval of active substances for a period of five years where it is necessary to 'control a serious danger to plant health which cannot be contained by other means' even if it does not satisfy the requirements on carcinogenic or reproductive toxicity category 2 or endocrine disruptors. The implication is that this derogation would only be used in exceptional circumstances. Therefore, for the main part of this assessment it has been assumed that all active substances that are affected by a certain set of criteria will be lost (PSD 2008). For details of what active substances are lost in each scenario see Appendix 2 and Table 54 for details of annex 2c in PSD report.

Table 54 – Active substances most likely to be lost - under annex 2c

Substance	Date of expiry of Annex 1	Approved in UK	Function	Annex 2c	Approved for use on				
					W	WB	O	SB	OSR
amitrole	2011	Y	H	Derogation					
bifenthrin	2018	Y	I	no	Y	y		y	
bitertanol	2020	Y	F	Derogation					
carbendazim	2009	Y	F	no	Y	y		y	y
cyproconazole	2020	Y	F	Derogation	y	y	y	y	y
dinocap	2009	N	F	Derogation					
epoxiconazole	2018	Y	F	Derogation	Y	y	y	y	
esfenvalerate	2011	Y	I	no	Y	y		y	
fenbuconazole	2020	Y	F	Derogation					
flufenoxuron	2020	N	I	no					
flumioxazin	2012	Y	H	Derogation	Y				
flusilazole	suspended by ECJ	Y	F	Derogation	y	y		y	y
glufosinate	2017	Y	H	Derogation					y
ioxynil	2014	Y	H	Derogation	Y	y	y	y	
linuron	2013	Y	H	Derogation	Y	y	y	y	
lufenuron	2018	N	I	no					
mancozeb	2015	Y	F	Derogation	Y	y		y	y
maneb	2015	Y	F	Derogation					
metconazole	2017	Y	F	Derogation	Y	y		y	y
pendimethalin	2013	Y	H	no	Y	y	y	y	
quinoxyfen	2014	Y	F	no	Y	y	y	y	
tebuconazole	2018	Y	F	Derogation	Y	y	y	y	y
warfarin	2016	Y	Rodent	no					

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).

6.2.2. Failure to achieve Annex 1 listing

There are some existing approvals which have not yet achieved Annex 1 listing. If they fail to get listed before end December 2010 they will cease to be available.

Table 55 – Active substances that have yet to achieve annex 1 listing

Substance	Status	Date of expiry of Annex 1	Approved in UK	Function	W	WB	SB	O	OSR
bromuconazole	list 3		Y	F	Y	y			
cyproconazole	list 3 VW	2020	Y	F	y	y	y	y	y
fluquinconazole	list 3 VW	2020	Y	F	y	y			
guazatine	list 3 VW		Y	F	Y	y	y	y	
prochloraz	list 3 VW	2020	Y	F	Y	y	y		y
tetraconazole	list 3	2018	Y	F	Y	y	y	y	
carbetamide	list 3 VW		Y	H					y
carboxin	list 3 VW		Y	H	Y				
cycloxydim	list 3 VW		Y	H					y
fluazifop-p	list 3 VW		Y	H					y
napropamide	list 3		Y	H					y
propachlor	list 3		Y	H					y
propaquizafop	list 3		Y	H					y
quinmerac	list 3 VW		Y	H					y
quizalofop-p-ethyl	list 3		Y	H					y
quizalofop-p-tefuryl	list 3		Y	H					y
terbuthylazine	list 3 VW		Y	H	y	y	y		
triallate	list 3		Y	H	Y	y	y		
triflusulfuron	list 3	2018	Y	H			y		
bifenthrin	list 3	2018	Y	I	Y	y	y		
tau fluvalinate	list 3 VW	2020	Y	I	Y	y	y		y
tefluthrin	list 3	2020	Y	I	Y	y	y	y	
zeta-cypermethrin	list 3	2018	Y	I	Y	y	y	y	y
metaldehyde	list 3 VW		Y	Mollusc	Y	y	y	y	y
chlormequat	list 3		Y	PGR	Y	y	y	y	

There are a number of triazole fungicides that have yet to achieve annex 1 listing. If these substances were to fail to be approved it would reduce the number of triazole fungicides available to control septoria. In combination with the losses seen at 2c this could increase the losses to septoria by a couple of percent as there would be even fewer options for septoria control.

Most of the herbicides that are affected are used for the control of volunteer cereals and grass weeds. If these were to fail there would still be some alternatives allowing control to be maintained. The reduction in actives could however, mean and increase in price of the remaining actives due to lack of competition.

If these insecticides were to fail to make annex 1 listing it would bifenthrin, zeta-cypermethrin and tau fluvalinate are general pyrethoids, so 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 wheat bulb fly. This could affect late sown wheat and spring wheats making control of wheat bulb fly possible only through the use of foliar sprays. These sprays are less environmentally friendly so this would potentially have an increased environmental impact as well as potential yield impact.

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

6.2.3. 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 (http://www.defra.gov.uk/farm/environment/water/csf/delivery-initiative.htm). The Voluntary Initiative aims to reduce environmental impact of pesticides through education and awareness of farmers and spray operators http://www.voluntaryinitiative.org.uk/Content/Water_WP.asp.

An EA monitoring programme is in place for the nine pesticides most commonly found in surface water. 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 http://www.voluntaryinitiative.org.uk/Content/Water_WP.asp. 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.

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 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 – propyzamide, chlorotoluron, mecoprop, isoproturon – and more recently, since a test was developed, metaldehyde. High levels of isoproturon found in water led to calls to ban the active substance, and despite stewardship programmes, it was eventually withdrawn and will no longer be legal to use after June 2009.

Based on findings from EA indicator testing and Drinking Water Inspectorate reports from water companies there are a number of actives used in cereals and rape that could be at risk from the Water Framework Directive ttp://www.dwi.gov.uk/pubs/annrep07/contents.shtm.

There may be bigger impacts due to ecological quality requirements with all insecticides at risk, along with chlorothalonil (due in part to the high usage in other crops) see list below for possible active substances affected. Please note that EQSs are not yet agreed or determined and this list is the project opinion of some likely at risk active substances.

Chemical status	**Ecological status**
carbetamide	2,4-D
chlorotoluron	bentazone
clopyralid	carbendazim
glyphosate	chlorothalonil
metaldehyde	chlorpyriphos
metazachlor	Mecoprop-p
propyzamide	insecticides

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 worst case scenario, in which all of these substances marked in WFD will be banned from use completely.

6.2.4. Changes in marketing of actives

During the course of the project visits were made to several of the major pesticide manufacturers. Very positive interaction was achieved and this has helped significantly with the work. Of particular note is the information shared on potential new actives. The report has also been 'flavoured' by responses received, often in confidence, and these have been used to add, or remove, emphasis where relevant. No major changes in marketing plans were identified other than those due to the regulatory and political pressures identified elsewhere in the report.

6.2.5. 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 not human health implications. There is a testing regime organised and reported on by the Pesticides Residue Committee (http://www.pesticides.gov.uk/prc_home.asp). In their 2007 Quarter 4 report there were a number of oat samples that exceeded the MRL for chlormequat. The 2007 Quarter 3 report tested bread samples and found glyphosate and chlormequat residues in a proportion of samples.

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, as is the supply of Conservation Grade oats to Jordans. These standards are a marketing decision by the grower, however if consumer requirements for these products becomes widespread, this may limit the pesticides available.

6.2.6. 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 available to prevent and manage resistance. When resistance forms it tends to be to a particular mode of action. In black-grass there are two main forms of resistance target site resistance and enhanced metabolism. In target site resistance there is a particular site of activity in the black-grass that the specific herbicide normally binds to in order to kill the weed. But in resistant populations this target site has mutated so that the herbicide cannot bind and kill the weed. If however another herbicide that binds to a different site in the black-grass is applied it can still be effective. In enhanced metabolism the resistant population of black-grass is able to rapidly metabolise the herbicide into a form that is not able to kill the plant. This type of resistance tends to affect multiple types of herbicides. The more a population of black-grass is sprayed with a particular type of herbicide the greater the chance of herbicide resistance developing.

Resistance in black-grass is already a problem in many counties of the UK, with widespread resistance to ‘fop’ and ‘dim’ chemistry and developing resistance to newer sulfonylurea chemistry. If the number of herbicide options for use in cereals and their break crops is reduced growers will be forced to apply more treatments of the same chemistry and risk exacerbating what is already a fairly large problem for some growers. Black-grass resistance to herbicides already causes a 4% loss of production in wheat as full control cannot be achieved in some situations.

Fungicide resistance will be of increasing concern if the diversity of fungicides is reduced overall and within groups of the same mode of action. The loss of broad-spectrum actives such as mancozeb and chlorothalonil that have not been affected by fungicide resistance, despite many years of use, would reduce options to use fungicide mixtures as part of a strategy to reduce the risks of fungicide resistance. Members of the azole group differ in their mode of action and loss of some products will increase the risk of resistance to the remaining products when they are used more widely and/or more frequently. Performance of azole products declines progressively as indicated by studies on *Septoria tritici*. Resistance to strobilurins is common in S. *tritici*, *Botrytis cinerea* and cereal powdery mildews. Strobilurin performance against rusts has not yet been affected but the first resistance in leaf blotch (Rhynchosporium) has now been reported. There is concern that other pathogens will develop resistance to strobilurins more quickly if products with different modes of action are not available. There are similar concerns for carboxamide products such as boscalid that also have a single site mode of action. Cereal powdery mildews have a high propensity for developing fungicide resistance and all products targeted against them are at risk.

Insect pests are under continued selection pressure from insecticides and ultimately this may lead to the development insecticide resistance. Such resistance either negates or reduces the efficacy insecticidal products. Existing resistance problems include pyrethroid and pirimicarb resistance in species of aphid such as the peach-potato aphid *(Myzus persicae)*, while pyrethroid resistance in the pollen beetle (*Meligethes aeneus*) has become widespread in various European countries. Currently neonicotinoids are considered important for the control of insecticide resistant peach-potato aphids. However, this species of aphid is known to have the potential to develop significant resistance to this group of compounds. Increased exposure of peach-potato aphids to neonicotinoids, and therefore increased risk of resistance developing, may occur is pyrethroid resistant pollen beetles become established in the UK. Careful resistance management is, therefore, required in order to preserve the effectiveness of this important class of insecticides. Indeed, in future there is the potential to establish resistance management for new classes of chemicals before significant field use.

6.3. Weeds – Impact of changes

6.3.1. Wheat

Table 56 – Wheat - effect of loss of herbicide actives on yield losses and production

Wheat (yield loss on affected area & total loss of production)										
Weed	2a - % yield loss	2a - Production loss (t)	2b - % yield loss	2b - Production loss (t)	2c - % yield loss	2c - Production loss (t)	3 - % yield loss	3 - Production loss (t)	WFD - % yield loss	WFD - Production loss (t)
Black-grass	###	1,040,000	###	1,040,000	###	1,040,000	###	1,040,000	37.6%	2,443,000
Cleavers	<1%	0	<1%	0	<1%	0	2.1%	208,000	<1%	0
Annual Meadow Grass	<1%	14,000	<1%	14,000	<1%	14,000	<1%	14,000	<1%	14,000
Rye-grass	4.4%	105,000	4.4%	105,000	4.4%	105,000	4.4%	105,000	37.4%	895,000
Wild Oats	<1%	72,000	<1%	72,000	<1%	72,000	<1%	72,000	9.0%	646,000
Mayweed	<1%	0	<1%	0	<1%	0	<1%	55,000	<1%	0
Chickweed	<1%	0	<1%	0	<1%	0	<1%	64,000	<1%	0
Poppy	<1%	0	<1%	0	<1%	0	1.7%	51,000	<1%	0
Shepherds Purse	<1%	0	<1%	0	<1%	0	<1%	5,000	<1%	0
Charlock	<1%	0	<1%	0	<1%	0	<1%	25,000	<1%	0
Field Speedwell	<1%	0	<1%	0	<1%	0	<1%	22,000	<1%	0
Barren Bome	<1%	3,000	<1%	3,000	<1%	3,000	<1%	3,000	4.9%	108,000
Volunteer Rape	<1%	0	<1%	0	<1%	0	<1%	16,000	<1%	0
Couch	<1%	12,000	<1%	12,000	<1%	12,000	<1%	12,000	3.0%	107,000
Rough Meadow Grass	<1%	4,000	<1%	4,000	<1%	4,000	<1%	4,000	<1%	4,000
Red Dead Nettle	<1%	0	<1%	0	<1%	0	<1%	14,000	<1%	0
Parsley-Piert	<1%	0	<1%	0	<1%	0	<1%	8,000	<1%	0
Fumitory	<1%	0	<1%	0	<1%	0	<1%	13,000	<1%	0
Ivy-leaved Speedwell	<1%	0	<1%	0	<1%	0	<1%	9,000	<1%	0
Field Pansy	<1%	0	<1%	0	<1%	0	<1%	3,000	<1%	0
Fat Hen	<1%	0	<1%	0	<1%	0	<1%	4,000	<1%	0
Geranium sp.	<1%	0	<1%	0	<1%	0	<1%	-2,000	<1%	0
Thistles (creeping)	<1%	0	<1%	0	<1%	0	<1%	0	1.4%	9,000
Volunteer cereals	<1%	0	<1%	0	<1%	0	<1%	0	<1%	0

5-10% loss of production   >10% loss of production

Scenario 2a, 2b and 2c CCP impacts
Active substances affected;

Pendimethalin
Flumioxazine
Ioxynil
Linuron
2,4-D

- The key active substance affected to weed control in wheat is pendimethalin. This herbicide forms an important part of resistance strategies against black-grass. In 2006, 239 tonnes of pendimethalin (as active substance) were applied to wheat crops, plus an additional 317 tonnes in combination with flufenacet and 119 tonnes in combination with picolinafen (PUS, 2006). This covers a total area of just under 750,000 ha, about 40% of the wheat crop.
- Pendimethalin can be replaced with other pre-emergence herbicides such as diflufenican and flufenacet or prosulfocarb. These herbicides generally give a lower level of control than pendimethalin mixtures and have much more limited post-emergence activity.
- Flumioxazin is a relatively new active substance, added in 2007. Alone it has a limited spectrum of control of grass weeds but can be mixed with a range of pre- or early post-emergence herbicides. It has a wide spectrum for broad-leaf weed control. Currently its loss would have a negligible effect of winter wheat production as alternatives are available.
- Ioxynil is not sold as a stand-alone product for use in winter wheat and is always in mixture with other active substances. It is a longstanding broad-leaved weed herbicide used post-emergence. Currently there are a range of alternatives, although often more expensive. Where broad-leaved weed resistance to sulfonylurea herbicides is seen it could be a valuable alternative mode of action, although others are available, but could be at risk from appearing in water.
- Linuron is available only in mixtures for broad-leaved weed control. In the wheat crop the effect of its loss would be minimal as many alternatives exist.
- 2,4-D a similar situation as for linuron but is available alone. This loss would increase costs by a small amount, but alternatives exist.
- Broad-leaved weed control should still be possible under these proposals. The cost may increase for some growers.

Scenario 3 ENVI impacts
Active substances affected

2,4-DB
Dichlorprop-P
MCPA
MCPB
Mecoprop-p

- Under this proposal the major loss would be mecoprop-p, a major herbicide used on 420,000 treated ha in 2006. Mecoprop-p provides good control of larger weeds and is usually mixed with other herbicides. It can be replaced by more expensive active substances but shifts reliance onto sulfonylurea herbicides.

- The range of active substances for the treatment of undersown spring wheat crops becomes severely limited with only 2 actives, bromoxynil and dicamba remaining available.
- Control of creeping thistle becomes limited to one remaining in crop active. However, these are generally adequately controlled in modern rotations through cultivation and the application of glyphosate to stubbles prior to drilling.

WFD impacts

Active substances affected;

chlorotoluron
clopyralid
glyphosate

- Loss of chlorotoluron could result in an increase in the area affected by rye-grass.
- One of the major losses would be glyphosate, important in the cleaning of stubbles prior to cultivation and drilling of the new crop. In the absence of this chemical, or any alternatives, it would be very difficult to prepare clean seed beds for the new crop, including removing volunteers from the previous crop causing severe weed problems and increasing disease pressure.
- Control of creeping thistle would be lost through the loss of clopyralid and glyphosate.
- Control of other broad-leaved weed control would still be possible under this proposal.

6.3.2. Winter Barley

Table 57 – Winter barley - effect of loss of herbicide actives on yield losses and production

Winter Barley (yield loss on affected area & total loss of production)										
Weed	2a - % yield loss	2a - Production loss (t)	2b - % yield loss	2b - Production loss (t)	2c - % yield loss	2c - Production loss (t)	3 - % yield loss	3 - Production loss (t)	WFD - % yield loss	WFD - Production loss (t)
Black-grass	###	211,000	###	211,000	###	211,000	###	211,000	37.6%	496,000
Cleavers	<1%	0	<1%	0	<1%	0	2.1%	42,000	<1%	0
Annual Meadow Grass	<1%	3,000	<1%	3,000	<1%	3,000	<1%	3,000	<1%	3,000
Rye-grass	4.4%	21,000	4.4%	21,000	4.4%	2,000	4.4%	21,000	37.4%	182,000
Wild Oats	<1%	15,000	<1%	15,000	<1%	15,000	<1%	15,000	7.0%	102,000
Mayweed	<1%	0	<1%	0	<1%	0	<1%	11,000	<1%	0
Chickweed	<1%	0	<1%	20,000	<1%	0	<1%	13,000	<1%	0
Poppy	<1%	0	<1%	0	<1%	0	1.7%	10,000	<1%	0
Shepherd Purse	<1%	0	<1%	0	<1%	0	<1%	1,000	<1%	0
Charlock	<1%	0	<1%	0	<1%	0	<1%	5,000	<1%	0
Field Speedwell	<1%	0	<1%	0	<1%	0	<1%	4,000	<1%	0
Barren Bome	<1%	1,000	<1%	1,000	<1%	21,000	<1%	1,000	4.9%	22,000
Volunteer Rape	<1%	0	<1%	0	<1%	0	<1%	3,000	<1%	0
Couch	<1%	2,000	<1%	2,000	<1%	2,000	<1%	2,000	3.0%	22,000
Red Dead Nettle	<1%	0	<1%	0	<1%	0	<1%	3,000	<1%	0
Rough Meadow Grass	<1%	1,000	<1%	1,000	<1%	1,000	<1%	1,000	<1%	1,000
Parsley-Piert	<1%	0	<1%	0	<1%	0	<1%	2,000	<1%	0
Fumitory	<1%	0	<1%	0	<1%	0	<1%	3,000	<1%	0
Ivy-leaved Speedwell	<1%	0	<1%	0	<1%	0	<1%	2,000	<1%	0
Field Pansy	<1%	0	<1%	0	<1%	0	<1%	1,000	<1%	0
Fat Hen	<1%	0	<1%	0	<1%	0	<1%	1,000	<1%	0
Geranium sp.	<1%	0	<1%	0	<1%	0	<1%	0	<1%	0
Thistles (creeping)	<1%	104	<1%	0	<1%	0	<1%	8,420	1.4%	1,000
Volunteer cereals	<1%	0	<1%	0	<1%	1,000	<1%	0	<1%	0

5-10% loss of production	>10% loss of production

Scenario 2a, 2b, 2c CCP impacts

Actives substances affected

Pendimethalin

Ioxynil

Linuron

2,4-D

- The key active substance lost to weed control in barley is pendimethalin. As in wheat this herbicide forms an important part of resistance strategies against black-grass. In 2006, 239 tonnes of pendimethalin alone were applied to barley crops, plus an additional 56 tonnes in combination with flufenacet and 29 tonnes in combination with picolinafen (PUS, 2006). This covers a total area of just under 139,000 ha, about 36% of the barley crop.
- Pendimethalin can be replaced with other pre-emergence herbicides such as diflufenican and flufenacet or prosulfocarb. These herbicides generally give a lower level of control than pendimethalin mixtures, especially if applications are delayed.
- Ioxynil is not sold as a stand-alone product for use in winter barley and is always in mixture with other active substances. It is a longstanding broad-leaved weed

herbicide used post-emergence. Currently there are a range of alternatives often more expensive. Where broad-leaved weed resistance to sulfonylurea herbicides is seen it provides a valuable alternative mode of action.

- 2,4-D, the effect of its loss would be minimal as many alternatives exist.
- Broad-leaved weed control would still be possible under these proposals. The cost may increase for some growers.

Scenario3 ENVI impacts

Active substances affected

2,4-DB
Dichlorprop-P
MCPA
MCPB
Mecoprop-p

- Under this proposal the major loss would be mecoprop-p, a major herbicide used on 60,000 treated ha in 2006. Gives good control of larger weeds and is usually mixed with other herbicides. It can be replaced by more expensive active substances but shifts reliance onto sulfonylurea herbicides.
- The range of active substances for the treatment broad-leaved weeds becomes more limited with more reliance on sulfonylureas.
- Control of creeping thistle becomes limited to one active, although control could be achieved through cultivations and the use of glyphosate prior to drilling

WFD impacts

Active substances affected

chlorotoluron
clopyralid
glyphosate

- Loss of chlorotoluron could result in an increase in the area affected by rye-grass.
- Control of creeping thistle would be lost through the loss of clopyralid and glyphosate.
- One of the major losses would be glyphosate, important in the cleaning of stubbles prior to cultivation and drilling of the new crop. In the absence of this chemical, or any alternatives, it would be very difficult to prepare clean seed beds for the new crop, including removing volunteers from the previous crop causing severe weed problems and increasing disease pressure.
- Control of other broad-leaved weeds would still be possible under this proposal.

6.3.3. Spring Barley

Table 58 - Spring barley - effect of loss of herbicide actives on yield losses and production

Spring Barley (yield loss on affected area & total loss of production)										
Weed	2a - % yield loss	2a - Production loss (t)	2b - % yield loss	2b - Production loss (t)	2c - % yield loss	2c - Production loss (t)	3 - % yield loss	3 - Production loss (t)	WFD - % yield loss	WFD - Production loss (t)
Annual Meadow Grass	2.0%	51,000	2.0%	51,000	2.0%	51,000	3.0%	76,000	4.0%	101,000
Wild Oats	<1%	0	<1%	0	<1%	0	<1%	13,000	7.0%	94,000
Mayweed	<1%	17,000	<1%	17,000	<1%	17,000	2.4%	51,000	<1%	0
Chickweed	<1%	18,000	<1%	18,000	<1%	18,000	1.4%	42,000	<1%	0
Cleavers	2.3%	29,000	2.3%	29,000	2.3%	29,000	5.3%	67,000	<1%	0
Black-grass	<1%	0	<1%	0	<1%	0	###	26,000	37.6%	60,000
Poppy	<1%	3,000	<1%	3,000	<1%	3,000	1.2%	7,000	<1%	0
Shepherd Purse	<1%	1,000	<1%	1,000	<1%	1,000	<1%	2,000	<1%	0
Charlock	<1%	5,000	<1%	5,000	<1%	5,000	1.2%	14,000	<1%	0
Rye-grass	<1%	0	<1%	0	<1%	0	4.4%	3,000	37.4%	24,000
Field Speedwell	<1%	2,000	<1%	2,000	<1%	2,000	<1%	6,000	<1%	0
Barren Bome	<1%	0	<1%	0	<1%	0	<1%	1,000	4.9%	20,000
Volunteer Rape	<1%	3,000	<1%	3,000	<1%	3,000	1.2%	9,000	<1%	0
Couch	<1%	0	<1%	0	<1%	0	<1%	2,000	3.0%	20,000
Red Dead Nettle	<1%	1,000	<1%	1,000	<1%	1,000	<1%	4,000	<1%	0
Rough Meadow Grass	<1%	0	<1%	0	<1%	0	<1%	1,000	<1%	0
Parsley-Piert	<1%	2,000	<1%	2,000	<1%	2,000	<1%	3,000	<1%	0
Fumitory	<1%	1,000	<1%	1,000	<1%	1,000	<1%	2,000	<1%	0
Ivy-leaved Speedwell	<1%	1,000	<1%	1,000	<1%	1,000	<1%	2,000	<1%	0
Field Pansy	<1%	1,000	<1%	1,000	<1%	1,000	<1%	2,000	<1%	0
Fat Hen	<1%	1,000	<1%	1,000	<1%	1,000	<1%	2,000	<1%	0
Geranium sp.	<1%	1,000	<1%	1,000	<1%	1,000	<1%	2,000	<1%	0
Thistles (creeping)	<1%	0	<1%	0	<1%	0	<1%	0	1.4%	860
Volunteer cereals	<1%	0	<1%	0	<1%	0	<1%	0	<1%	0

5-10% loss of production   >10% loss of production

Scenarios 2a, 2b, 2c CCP impacts

Active substances affected

Pendimethalin

Ioxynil

Linuron

2,4-D

- Pendimethalin use in spring barley is not widespread, limited to 2,000 treated hectares. Use is limited because of dry conditions at drilling which limits its effectiveness. Primarily used for annual meadow-grass control. Loss of this active will leave only one active for its control.
- Ioxynil is not sold as a stand-alone product for use in spring barley and is always in mixture with other active substances. It is a longstanding broad-leaved weed herbicide used post-emergence. Currently there are a range of alternatives often more expensive. Where broad-leaved weed resistance to sulfonylurea herbicides is present it provides a valuable alternative mode of action.
- 2,4-D, the effect of its loss would be minimal as many alternatives exist for broad-leaved weeds. Control of creeping buttercup would be limited to less effective actives and the control of docks limited to control from sulfonylureas only.

- Broad-leaved weed control would still be possible under these proposals. The cost may increase for some growers.

Scenario3 ENVI impacts

Active substances affected

2,4-DB
Dichlorprop-P
MCPA
MCPB
Mecoprop-p

- Under this proposal the major loss would be mecoprop-p, a major herbicide used on 225,000 treated ha in 2006, alone or in mixture with dicamba. This accounted for 47% of the area of spring barley. Mecoprop-p gives good control of weeds. It can be replaced by more expensive active substances but shifts reliance onto sulfonylurea herbicides and increases resistance risk.
- The range of active substances for the treatment of undersown spring barley crops becomes severely limited.

WFD impacts

Active substances affected

clopyralid
glyphosate

- Clopyralid is a broad-leaved weed herbicide important for the control of creeping thistles.
- One of the major losses would be glyphosate, important in the cleaning of stubbles prior to cultivation and drilling of the new crop. In the absence of this chemical, or any alternatives, it would be very difficult to prepare clean seed beds for the new crop, including removing volunteers from the previous crop causing severe weed problems and increasing disease pressure.
- Broad-leaved weed control would still be possible under this proposal.

6.3.4. Oats

Table 59 - Oats- effect of loss of herbicide actives on yield losses and production

Oats (yield loss on affected area & total loss of production)

Weed	2a - % yield loss	2a - Production loss (t)	2b - % yield loss	2b - Production loss (t)	2c - % yield loss	2c - Production loss (t)	3 - % yield loss	3 - Production loss (t)	WFD - % yield loss	WFD - Production loss (t)
Black-grass	<1%	0	<1%	0	<1%	0	###	7,000	37.6%	16,000
Cleavers	2.3%	8,000	2.3%	8,000	2.3%	8,000	5.3%	18,000	<1%	0
Annual Meadow Grass	2.0%	13,000	2.0%	13,000	2.0%	13,000	3.0%	20,000	<1%	0
Rye-grass	<1%	0	<1%	0	<1%	0	4.4%	1,000	37.4%	6,000
Wild Oats	<1%	0	<1%	0	<1%	0	<1%	4,000	9.0%	32,000
Mayweed	<1%	5,000	<1%	5,000	<1%	5,000	2.4%	14,000	<1%	0
Chickweed	<1%	5,000	<1%	5,000	<1%	5,000	1.4%	11,000	<1%	0
Poppy	<1%	1,000	<1%	1,000	<1%	1,000	1.2%	2,000	<1%	0
Shepherd Purse	<1%	1,000	<1%	1,000	<1%	1,000	1.2%	2,000	<1%	0
Charlock	<1%	1,000	<1%	1,000	<1%	1,000	1.2%	4,000	<1%	0
Field Speedwell	<1%	490	<1%	490	<1%	490	<1%	1,460	<1%	0
Barren Bome	<1%	0	<1%	0	<1%	0	<1%	140	4.9%	5,360
Volunteer Rape	<1%	1,000	<1%	1,000	<1%	1,000	1.2%	2,000	<1%	0
Couch	<1%	0	<1%	0	<1%	0	<1%	590	3.0%	5,280
Red Dead Nettle	<1%	320	<1%	320	<1%	320	<1%	950	<1%	0
Rough Meadow Grass	<1%	0	<1%	0	<1%	0	<1%	200	<1%	0
Parsley-Piert	<1%	410	<1%	410	<1%	410	<1%	810	<1%	0
Ivy-leaved Speedwell	<1%	200	<1%	200	<1%	200	<1%	610	<1%	0
Fumitory	<1%	230	<1%	230	<1%	230	<1%	460	<1%	0
Field Pansy	<1%	300	<1%	300	<1%	300	<1%	460	<1%	0
Fat Hen	<1%	220	<1%	220	<1%	220	<1%	660	<1%	0
Geranium sp.	<1%	370	<1%	370	<1%	370	<1%	520	<1%	0
Thistles (creeping)	<1%	0	<1%	0	<1%	0	<1%	0	1.2%	200
Volunteer cereals	<1%	0	<1%	0	<1%	0	<1%	0	<1%	0

5-10% loss of production | >10% loss of production

Scenario 2a, 2b, 2c CCP impacts

Active substances affected

Ioxynil

Linuron

2,4-D

- Ioxynil is not sold as a stand-alone product for use in oats and is always in mixture with other active substances. It is a longstanding broad-leaved weed herbicide used post-emergence. Currently there are a range of alternatives, often more expensive. Where broad-leaved weed resistance to sulfonylurea herbicides is seen it provides a valuable alternative mode of action.
- 2,4-D, the effect of its loss would be minimal as many alternatives exist for broad-leaved weeds. Control of creeping buttercup would be limited to less effective actives and the control of docks limited to control from sulfonylureas only.
- Broad-leaved weed control would still be possible under these proposals. The oat crop would be relatively unaffected by the loss of these actives.

Scenario 3 ENVI impacts
Active substances affected

2,4-DB
Dichlorprop-P
MCPA
MCPB
Mecoprop-p

- Under this proposal the major loss would be mecoprop-p, a major herbicide used on 26,000 treated ha in 2006, alone or in mixture with dicamba; this use accounted for 22% of the area of oats. Mecoprop-p gives good control of weeds. It can be replaced by more expensive active substances but shifts reliance further onto sulfonylurea herbicides.
- Others minimal use.

WFD impacts
Active substances affected

clopyralid
glyphosate

- Clopyralid is a broad-leaved herbicide important for the control of creeping thistles.
- As with other crops one of the major losses would be glyphosate, important in the cleaning of stubbles prior to cultivation and drilling of the new crop. In the absence of this chemical, or any alternatives, it would be very difficult to prepare clean seed beds for the new crop, including removing volunteers from the previous crop causing severe weed problems and increasing disease pressure.
- Broad-leaved weed control would still be possible under this proposal.

6.3.5. Oilseed Rape

Table 60 – Oilseed rape- effect of loss of herbicide actives on yield losses and production

Oilseed Rape (yield loss on affected area & total loss of production)										
Weed	2a - % yield loss	2a - Production loss (t)	2b - % yield loss	2b - Production loss (t)	2c - % yield loss	2c - Production loss (t)	3 - % yield loss	3 - Production loss (t)	WFD - % yield loss	WFD - Production loss (t)
Volunteer cereals	<1%	0	<1%	0	<1%	0	<1%	0	<1%	0
Black-grass	<1%	0	<1%	0	<1%	0	<1%	0	36.3%	282,000
Cleavers	<1%	0	<1%	0	<1%	0	<1%	0	<1%	0
Annual Meadow Grass	<1%	0	<1%	0	<1%	0	<1%	0	2.3%	35,000
Chickweed	<1%	0	<1%	0	<1%	0	<1%	0	<1%	0
Wild Oats	<1%	0	<1%	0	<1%	0	<1%	0	1.8%	14,000
Charlock	<1%	0	<1%	0	<1%	0	<1%	0	<1%	0
Poppy	<1%	0	<1%	0	<1%	0	<1%	0	<1%	0
Field Speedwell	<1%	0	<1%	0	<1%	0	<1%	0	<1%	0
Red Dead Nettle	<1%	0	<1%	0	<1%	0	<1%	0	<1%	0
Mayweed	<1%	0	<1%	0	<1%	0	<1%	0	<1%	0
Shepherd Purse	<1%	0	<1%	0	<1%	0	<1%	0	<1%	0
Field Pansy	<1%	0	<1%	0	<1%	0	<1%	0	<1%	0
Ivy-leaved Speedwell	<1%	0	<1%	0	<1%	0	<1%	0	<1%	0
Geranium sp.	<1%	0	<1%	0	<1%	0	<1%	0	<1%	0
Thistles (creeping)	<1%	0	<1%	0	<1%	0	<1%	0	<1%	974

5-10% loss of production | >10% loss of production

Scenario 2a, 2b, 2c CCP impacts
Active substance affected

Glufosinate

- Glufosinate is only used on a small area in oilseed rape and could be easily replaced by alternative products such as glyphosate.

Scenario 3 ENVI impacts
Active substance affected

Picloram

- Picloram in combination with clopyralid is the major herbicide for control of sowthistle in oilseed rape used on 54,000 treated hectares in 2006. Control of this weed would be difficult if picloram was not available.

WFD Impacts
Active substances affected

Glyphosate
Carbetamide
Clopyralid
Metazachlor
Propyzamide

- Glyphosate is used on 350,000 treated ha of oilseed rape, 78% of the total crop area (both autumn and spring sown). This is primarily used as a harvest aid. There is an alternative diquat which is not used as widely and which desiccates the crop more quickly. Alternatively in weed-free crops direct combining without desiccation is possible. Another alternative is swathing, but many farmers are not geared up with suitable equipment and it is not the favoured option of many in wet years.
- The major herbicide used on oilseed rape is metazachlor, 56% of the area or 282,000 treated hectares (PUS, 2006) either alone or in mixture with quinmerac. Metazachlor controls a wide range of broad-leaved weeds, cranesbill, parsley piert, poppy and mustard control will become problematical. Due to the nature of the rape crop production losses should be minimal <5%.
- Carbetamide and propyzamide are very valuable active substances used in oilseed rape and are effective on a wide range of grass and broad-leaved weeds. As part of a resistance management strategy they provide an alternative mode of action. Propyzamide and carbetamide are effective on resistant populations.
- Clopyralid in combination with picloram is the major herbicide for control of sow thistle in oilseed rape used on 54,000 spray hectares in 2006. Control of this weed would be difficult.
- Loss of these 5 actives would leave oilseed rape growers with few alternative active substances for broad-leaved weed control. Crop loss would be common.
- Control of resistant grass weeds would become difficult and the use of oilseed rape as a cleaning crop in the rotation would cease.
- **The loss of these active substances would cause considerable problems for oilseed rape growers and cause impacts elsewhere in the rotation.**

6.4. Pests – Impact of changes

- Loss of products will result in greater reliance on cultural control options and crop tolerance. Cultural control options will not always be practical and may also have cost implications.
- In general pest control will only become difficult under Scenario 3 ENVI. Under scenarios CCP 2a, 2b and 2c there are usually sufficient alternative products available. The main exception to this generalisation would be the loss of dimethoate as a dead heart spray for wheat bulb fly.
- It is possible that in some instances gross margins will see a small increase with the loss of insecticides. This is particularly the case where products are applied as insurance treatments and pests are at sub-threshold levels.
- The greatest risk of yield loss will be in years when factors conspire to produce severe pest infestations which will be particularly damaging under scenario 3 ENVI.
- Reduction in chemical usage may increase the importance and impact of natural enemies.
- If the range of available products decreases, their price is likely to increase. This in turn will increase the importance of risk assessment as a means of deciding when to treat and necessitate a greater understanding of crop tolerance to pest attack. This could be an important topic for future research.

6.4.1. Wheat

Table 61 – Wheat - effect of loss of insecticide actives on yield losses and production

Wheat (yield loss on affected area & total loss of production)

Pest	2a - % yield loss	2a - Production loss (t)	2b - % yield loss	2b - Production loss (t)	2c - % yield loss	2c - Production loss (t)	3 - % yield loss	3 - Production loss (t)	WFD - % yield loss	WFD - Production loss (t)
Aphids autumn BYDV	<1%	0	<1%	0	<1%	0	3.0%	421,000	<1%	140,000
Slugs	<1%	0	<1%	0	<1%	0	15%	56,000	4.5%	169,000
Orange Wheat Blossom Midge	<1%	0	<1%	0	<1%	0	<1%	15,000	15%	46,000
Wheat Bulb Fly	<1%	3,000	<1%	0	<1%	0	15%	8,000	2.0%	10,000
Aphids Summer	<1%	0	<1%	0	<1%	0	15%	2,570	15%	2,570
Gout fly	<1%	0	<1%	0	<1%	0	<1%	680	<1%	680
Leatherjackets	<1%	0	<1%	0	<1%	0	<1%	680	<1%	680
Frit Fly	<1%	0	<1%	0	<1%	0	<1%	340	<1%	340
Cereal cyst Eelworm	<1%	0	<1%	0	<1%	0	<1%	0	<1%	0

Scenario 2a impacts

Bifenthrin, esfenvalerate, deltamethrin and dimethoate will be lost under this scenario. A range of alternative pyrethroids will still be available so there is likely to be minimal if any impact of the loss of bifenthrin, esfenvalerate and deltamethrin. In some instances a pyrethroid may not be specifically approved for control of the pest although it is approved for use on winter wheat.

The loss of dimethoate will mean no deadheart sprays for control of wheat bulb fly larvae. Therefore control of this pest will be dependent upon seed treatments and egg hatch sprays. In practice these treatments are more likely to result in a yield response than deadheart sprays so although there may be some impact on the national yield it should be minimal (Table 61).

Scenario 2b impacts

A total of three pyrethroids will be lost (bifenthrin, deltamethrin esfenvalerate) but there should still be sufficient alternatives to control pests. In some instances the chemical may not be specifically approved for control of the pest although it is approved for use on winter wheat.

Scenario 2c impacts

The pyrethroids bifenthrin and esfenvalerate will be lost but there are sufficient alternatives available.

Scenario 3 impacts

The range of chemicals available for pest control will be significantly reduced. Ther are still options for control for aphids, orange wheat blossom midge (owbm) and slugs but not for wheat bulb fly. This will have an impact on the national yield.

There is likely to be greater reliance on clothianidin for aphid control. If migration is prolonged then further foliar sprays may be needed and the only option is flonicamid. This is likely to have cost implications with neonicotinoids being more expensive than pyrethroids.

Thiacloprid will be the only option for control of owbm so yields may suffer as it is not considered as effective as chlopyrifos. Thiacloprid could also be used against summer aphids even though it is not approved against the pest.

The loss of methiocarb means a greater reliance on metaldehyde for slug control.

WFD impacts

Water framework directive is likely to put a lot of pressure on most insecticides because due to their very nature they have the potential to do harm to aquatic invertebrates. This means that there is the chance that there would be restrictions to the use or losses of the majority of insecticide actives. This could lead to a situation where losses would be similar to those seen in untreated situations.

Metaldehyde is currently under a lot of pressure from the water frame work directive, and if it is not protected is likely to be lost but methiocarb will still be available. Consequently there is likely to be an increase in the use of methiocarb which will also result in increased costs. If the level of methiocarb usage increases to a level similar to that of metaldehyde now there is a risk that methiocarb might also start to be detected in water and become at risk from the water framework directive. If this is the case then the level of control would fall down to a level similar to that seen in an untreated situation.

6.4.2. Winter Barley

Table 62 – Winter barley: Effectsof loss of insecticide actives on yield losses and production

Winter Barley (yield loss on affected area & total loss of production)

Pest	2c - % yield loss	2a - Production loss (t)	2b - % yield loss	2b - Production loss (t)	2c - % yield loss	2c - Production loss (t)	3 - % yield loss	3 - Production loss (t)	WFD - % yield loss	WFD - Production loss (t)
Aphids	<1%	0	<1%	0	<1%	0	2.0%	56,000	<1%	28,000
Slugs	<1%	0	<1%	0	<1%	0	<1%	0	15%	11,000
Frit Fly	<1%	0	<1%	0	<1%	0	<1%	160	<1%	0
Gout Fly	<1%	0	<1%	0	<1%	0	<1%	160	<1%	0
Leather jackets	<1%	0	<1%	0	<1%	0	<1%	160	<1%	160

Scenario 2a & 2b impacts

The pyrethroids bifenthrin, esfenvalerate and deltamethrin will be lost but alternatives are available.

Scenario 2c impacts

There are sufficient alternative pyrethroids to cover the loss of bifenthrin and esfenvalerate.

Scenario 3 impacts

The range of products available for pest control will be significantly reduced. Aphid transmitted BYDV is probably the major pest control problem in winter barley. Control will be entirely reliant on seed treatments. No products are available as follow up foliar sprays where migration is prolonged. This will affect yield. Late sowing is an option so that the crop misses the main period of aphid migration but this might not be practical and may have yield implications. Some control of slugs and wireworms will be provided by seed treatments and metaldehyde will also be available for slugs.

WFD impacts
As per WFD for winter wheat

6.4.3. Spring Barley

Table 63 - Spring barley: Effects of loss of actives on yield losses and production

Spring Barley										
Pest	2c - % yield loss	2a - Production loss (t)	2b - % yield loss	2b - Production loss (t)	2c - % yield loss	2c - Production loss (t)	3 - % yield loss	3 - Production loss (t)	WFD - % yield loss	WFD - Production loss (t)
Aphids	<1%	0	<1%	0	<1%	0	<1%	3,000	<1%	3,000
Leather jackets	<1%	0	<1%	0	<1%	0	<1%	0	<1%	0
Slugs	<1%	0	<1%	0	<1%	0	<1%	260	<1%	0
Gout Fly	<1%	0	<1%	0	<1%	0	<1%	140	<1%	0
Frit Fly	<1%	0	<1%	0	<1%	0	<1%	60	<1%	60

Scenario 2a, 2b and 2c impacts
The loss of bifenthrin, esfenvalerate and deltamethrin will have limited if any impact as alternative products are available.

Scenario 3 impacts
Only metaldehyde will remain for control of slugs. On average other pests of spring barley have a limited effect on yield but there will be years when there are severe outbreaks which will be more damaging.

WFD impacts
As per WFD for winter wheat.

6.4.4. Oats

Table 64 – Oats: Effects of loss of insecticide actives on yield losses and production

Oats (yield loss on affected area & total loss of production)										
Pest	2c - % yield loss	2a - Production loss (t)	2b - % yield loss	2b - Production loss (t)	2c - % yield loss	2c - Production loss (t)	3 - % yield loss	3 - Production loss (t)	WFD - % yield loss	WFD - Production loss (t)
Aphids	<1%	0	<1%	0	<1%	130	15%	7,000	15%	7,000
Slugs	<1%	0	<1%	0	<1%	0	<1%	20	<1%	0
Frit Fly	<1%	0	<1%	0	<1%	0	<1%	20	<1%	0
Leather jackets	<1%	0	<1%	0	<1%	0	<1%	20	<1%	0
Wireworm	<1%	0	<1%	0	<1%	0	<1%	0	<1%	20
Nematodes - stem	<1%	0	<1%	0	<1%	0	<1%	0	<1%	0

Scenario 2a & 2b impacts
Only deltamethrin is lost under this scenario which will have limited, if any, impact as alternative pyrethroids are available.

Scenario 2c impacts
No products are lost so pest control options remains the same as in the 'business as usual scenario'

Scenario 3 impacts
The range of available products will be significantly reduced. Clothianidin will be available as a seed treatment which will give some control of aphids, slugs and wireworms. Metaldehyde is available for slug control. Generally, pests do not have a major impact on the yield of oats but there will be seasons when severe outbreaks will not be completely controlled by the available products.

WFD impacts
As per WFD for winter wheat.

6.4.5. Oilseed Rape

Table 65 – Oilseed rape: Effects of loss of actives on yield losses and production

Oilseed Rape (yield loss on affected area & total loss of production)

Pest	2c - % yield loss	2a - Production loss (t)	2b - % yield loss	2b - Production loss (t)	2c - % yield loss	2c - Production loss (t)	3 - % yield loss	3 - Production loss (t)	WFD - % yield loss	WFD - Production loss (t)
Cabbage stem flea beetle	<1%	0	<1%	0	<1%	0	<1%	7,000	<1%	7,000
Slugs	<1%	0	<1%	0	<1%	0	<1%	11,000	3.5%	40,000
Aphids & turnip yellows	<1%	0	<1%	0	<1%	0	2.5%	22,000	2.5%	22,000
Pollen beetle	<1%	0	<1%	0	<1%	0	<1%	1,560	<1%	3,120
Seed weevil	<1%	0	<1%	0	<1%	0	<1%	1,560	<1%	1,560
Aphid direct feeding	<1%	0	<1%	0	<1%	0	2.5%	80	<1%	80
Brassica pod midge	<1%	0	<1%	0	<1%	0	<1%	80	<1%	80

Scenario 2a and 2b impacts
Deltamethrin will be lost but there are a range of alternative pyrethroids available

Scenario 2c impacts
No products are lost so pest control options remain the same as in the 'business as usual scenario'

Scenario 3 impacts
The range of products is greatly reduced and only metaldehyde remains for slug control. Yield will suffer due to the impact of pollen beetle, seed weevil, pod midge and aphids.

WFD impacts
As per WFD for winter wheat.

6.5. Disease – Impact of changes

Cumulative effects of reductions in fungicides

In the first year or two after withdrawal of very effective fungicides, disease control will be impaired and higher levels of inoculum will be available to infect crops for the following season. Increased inoculum is not only likely to increase disease severity but also increase the risks of breakdown of cultivar resistance as new races of pathogens are selected. Higher pathogen populations also increase the risk of fungicide resistant strains being selected. Yellow rust has been well controlled by triazole and strobilurin fungicides for many years and this disease is likely to cause more economic damage when these control options are not available. The withdrawal of triazole products may mean that strobilurin products become ineffective because of fungicide resistance. Brown rust has been well controlled by some strobilurin products and might be less challenging to control unless milder winters such as 2006/07 recur and give early brown rust epidemics.

There are limited opportunities for mitigation without significant changes to farming systems. The assumption has been made that greater use will be made of resistant varieties and that early sowing will be reduced.

For a list of which actives will be lost in each scenario see Appendix 2 – Loss of Active Substances.

6.5.1. Wheat

The main impacts of the changes in fungicide availability can be seen in Table 66. This shows that the losses of fungicide active substances seen in scenarios 2a and 3 will have the biggest impacts on production. The fungicide active substances that are lost in scenarios 2b and 2c have limited effects due to plenty of alternatives remaining available. The only actives likely to be lost to the water framework directive are chlorothalonil and quinoxyfen. Chlorothalonil is an important part of fungicide regimes especially in the control of septoria. If it is lost in combination with one of the other scenarios it could have a greater impact that its loss on its own..

Table 66 – Wheat: Effects of loss of fungicide actives on yield losses and production

Wheat (yield loss on affected area & total loss of production)										
Disease	2a - % yield loss	2a - Production loss (t)	2b - % yield loss	2b - Production loss (t)	2c - % yield loss	2c - Production loss (t)	3 - % yield loss	3 - Production loss (t)	WFD - % yield loss	WFD - Production loss (t)
All diseases	20.4%	3,488,691	<1%	0	<1%	0	###	3,488,691	<1%	0
diseases (excluding take all)	16.9%	2,890,141	<1%	0	<1%	0	###	2,890,141	<1%	0
S. tritici	7.2%	1,231,303	<1%	119,710	<1%	119,710	7.2%	1,231,303	2.5%	427,536
Take all	3.5%	598,550	<1%	0	<1%	0	3.5%	598,550	<1%	0
Yellow rust	2.2%	376,231	1.2%	205,217	1.2%	205,217	2.2%	376,231	<1%	34,203
Eyespot	<1%	171,014	<1%	51,304	<1%	51,304	<1%	171,014	<1%	0
Fusarium (ear)	2.7%	461,738	<1%	0	<1%	0	2.7%	461,738	<1%	17,101
Brown Rust	<1%	136,811	<1%	51,304	<1%	51,304	<1%	136,811	<1%	34,203
Powdery mildew	<1%	119,710	<1%	0	<1%	0	<1%	119,710	<1%	0
S nodorum	<1%	136,811	<1%	51,304	<1%	51,304	<1%	136,811	<1%	0
Sharp Eyespot	<1%	17,101	<1%	0	<1%	0	<1%	171,014	<1%	0

5-10% loss of production | >10% loss of production

Scenario 2a CCP & 3 ENVI Impacts

- Loss of triazoles – high impact on efficacy, timing and duration of control of foliar and ear diseases, and very high pressure on strobilurins and remaining products. Would need to increase number of applications of remaining products particularly chlorothalonil to protect the upper leaf layers against septoria diseases as each of the leaves emerge
- Loss of prochloraz and prothioconazole weakens options for eyespot control, but could increase use of boscalid, cyprodinil and metrafenone
- Chlorothalonil is available and important disease control and resistance management for *S. tritici.* There is already widespread resistance to strobilurin products and protection of remaining azole products is vital.
- Loss of active powdery mildew products eg some azoles and quinoxyfen increases risk of further fungicide resistance problems to morpholine products and newer actives metrafenone and cyflufenamid. Increase use of sulphur as a weak fungicide
- Overall an increase in losses from foliar, stem and ear diseases with deterioration over successive years after the changes are implemented.
- Loss of fluquinconazole for take-all control can be replaced by silthiofam but this would not give early foliar disease control.
- Remaining actives allow continued control of rusts, at least in the short term. There are still seed treatment options.
- Loss of mancozeb – slightly increased resistance risk with remaining products.

In these two scenarios the loss of key azole fungicides is likely to lead to lead to increases in yield losses from all diseases; this has the biggest impact on Septoria where yield losses are expected to increase by 7.2%, leading to a loss of production equivalent to 1.2 million tonnes of wheat. If the water framework directive lead to the loss of chlorothalonil on top of this situation it could lead to an additional 3% yield loss, 2.5% from septoria and 0.5% from other diseases. With the additional loss of chlorothalonil it leaves just weak azoles for the control of these diseases.

Scenario 2b & 2c CCP Impacts

- The key feature compared with annex 2a and 3 is the retention of prothioconazole as this is a strong azole product. Increased use of prothioconazole would enable control to continue at current levels unless shifts in fungicide sensitivity erode its performance. In general, these scenarios would give performance similar to current practise and have low impact.
- However, if Water Framework directive leads to the loss of chlorothalonil in addition to the loss of some azoles, there will be increased pressure on the remaining azoles leading to a potential for the increase in resistance. This could lead to an additional 2.5% yield loss.

The data from 2006 shows the spray area for individual fungicides use alone or in tank mixtures and for the same products used in formulated products. The total sprayed area for wheat was 8.69 M haIf individual active ingredients are lost, adjustments to the use of other products will follow. This may require more frequent applications of weaker products and increased risks of fungicide resistant strains being selected and further decline in fungicide performance.

Fungicide performance data is available in the HGCA Wheat Disease Management Guide 2008 (www.hgca.com). The efficacy of the older azole products has declined and the most effective active compounds are epoxiconazole and prothioconazole. These are the most widely used fungicides, providing good curative and protectant activity against a range of diseases. In 2006 epoxiconazole was used on 1.98M ha, prothioconazole on 1.37 M ha and other azoles were also frequently used tebuconazole on 0.93 M ha, cyproconazole on 0.41 M ha. Chlorothalonil (2.09 M ha) is an important mixture partner with azole fungicides particularly since fungicide resistance in strobilurins has left few other options for control. Fenpropimorph (0.60 M ha) was used for powdery mildew and rust control, though the use of alternative new powdery mildew products is increasing.

Strobilurin products including azoxystrobin, dimoxystrobin, picoxystrobin, pyraclostrobin and trifloxystrobin have been widely used and remain effective against rust diseases. Fungicide resistance has reduced the effectiveness of strobilurin products against *Septoria tritici* and powdery mildew. They provide a warning that fungal pathogens can quickly overcome new fungicide products.

There are continuing changes to use of fungicides on wheat as new and more effective active ingredients are introduced. New products have been valued by farmers and taken up rapidly by industry. The 2006 data is already out of date as new products have been introduced and concerns about fungicide resistance have increased (Clark, 2006). In 2007, epoxiconazole was applied to 46% of crops at T1 (GS31-32), 77% of crops at T2 (GS39) and 43% of crops at T3 (GS 59) (data from www.cropmonitor.co.uk). The comparable usage for prothioconazole was 39% of crops at T1, 25% of crops at T2 and 20% of at T3 with tebuconazole used on 14% of crops at T2 and 37% of crops at T3.

WFD Impacts
The loss of chlorothalonil to the Water Framework Directive would lead to the loss of an important mixer used with many azole fungicides sprayed on large areas. It is part of an anti resistance strategy. If this occurred alongside the losses of a number of azole fungicides to the revision of 91/414/EEC it would reduce the effectiveness of fungicide programs significantly.

6.5.2. Winter Barley

The situation in winter barley closely follows that in winter wheat with allowance for the different range of diseases and some variation in the range of fungicides available for the crop.

Disease survey information is available for winter barley up to 2005 (see www.cropmonitor.co.uk) and there are some published survey reviews (Polley *et al.*, 1993b). There are large variations in disease severity from year to year as well between regions and varieties. Variety choice is influenced by yield, crop type and quality (malting types v. feed varieties). Fungicides are very effective when used in two spray programmes and can usually overcome disease problems with the possible exception of severe leaf blotch epidemics. Varieties are currently available with good resistance to leaf blotch and powdery mildew and this represents an improvement over recent years. There are concerns about trends for more varieties with brown rust susceptibility.

The changes in varieties and fungicides also means that historic data must be interpreted carefully as future disease patterns may be quite different. Eyespot has been a damaging but overlooked disease on barley that needs to be considered in future scenarios. Relatively new diseases such as Ramularia leaf spotting also need to be considered, though survey data is not available. Soil-borne barley yellow mosaic virus and barley mild mosaic virus problems are common, but managed with resistant varieties and not by fungicides.

Almost all winter barley crops receive fungicide treatment with broad-spectrum formulated mixtures or tank mixtures in early spring (GS 30-31) and when the flag leaf has emerged. The most widely used fungicide active ingredients used alone or in mixtures in 2006 included azoxystrobin (21% area treated), chlorothalonil (38%), epoxiconazole (27%), fenpropimorph (26%) and prothioconazole (83%).

Fungicide treatments can generally be expected to give yield responses of about 1 t/ha and larger responses >2 t/ha (30%) occur when diseases are severe on susceptible varieties. Untreated Recommended List trials in 2008 gave yields of 6.5 t/ha compared with 8.5 t/ha in treated experiments. These trials contain a range of varieties and provide support for yield responses of 2 t/ha at some locations. Broad-spectrum fungicides increase the retention of green area on the lower leaves and this benefits yield even where disease levels are low.

Table 67 – Winter barley: Effects of loss of actives on yield losses and production

Winter Barley (yield loss on affected area & total loss of production)

Disease	2a - % yield loss	2a - Production loss (t)	2b - % yield loss	2b - Production loss (t)	2c - % yield loss	2c - Production loss (t)	3 - % yield loss	3 - Production loss (t)	WFD - % yield loss	WFD - Production loss (t)
Take all	<1%	0	<1%	0	<1%	0	<1%	0	<1%	0
Fusarium	<1%	31,259	<1%	9,378	<1%	9,378	<1%	31,259	<1%	0
Eyespot	<1%	22,229	<1%	8,336	<1%	8,336	<1%	22,229	<1%	0
Net Blotch	1.1%	22,923	<1%	0	<1%	0	1.1%	22,923	<1%	0
Rhynchosporium	1.2%	20,840	<1%	3,473	<1%	3,473	1.2%	20,840	<1%	3,473
Brown Rust	<1%	2,084	<1%	0	<1%	0	<1%	2,084	<1%	0
Mildew	<1%	10,420	<1%	0	<1%	0	<1%	10,420	<1%	0
BYDV	<1%	5,210	<1%	5,210	<1%	5,210	<1%	5,210	<1%	0
Ramularia	<1%	2,605	<1%	5,210	<1%	5,210	<1%	2,605	<1%	0
Mosaic viruses	<1%	0	<1%	0	<1%	0	<1%	0	<1%	0
Others includes y. rust, halo spot, loose smut, snow rot	<1%	3,473	<1%	3,473	<1%	3,473	<1%	3,473	<1%	0
Ergot	<1%	0	<1%	0	<1%	0	<1%	0	<1%	0

Scenario 2a CCP & 3 ENVI Impacts

- Loss of triazoles – high impact on efficacy, timing and duration of control of foliar and ear diseases particularly leaf blotch (Rhynchosporium), and will result in very high pressure on strobilurins and remaining products. Would need to increase number of applications of remaining products.
- Loss of prochloraz and prothioconazole weakens options for eyespot control, but could increase use of cyprodinil and metrafenone. Boscalid is also valuable for eyespot, ramularia and foliar diseases generally when mixed with epoxiconazole so might form part of novel mixtures in future.
- Loss of active powdery mildew products eg quinoxyfen and possibly propinaquid (not assessed by PSD) increases risk of further fungicide resistance problems to morpholine products. Cyflufenamid use is expected to increase, and possibly that of metrafenone if new formulations are available, Increase use of sulphur as a weak fungicide
- The loss of carbenazim and iprodione will have little impact as these products are no longer used on a significant area.
- Remaining actives allow continued control of rusts and most leaf spots including net blotch and ramularia, at least in the short term.
- There are still seed treatment options.
- Overall an increase in losses from foliar, stem and ear diseases with deterioration over successive years after the changes are implemented.

The results of these losses would be that Fusarium, net blotch and Rhynchosporium would all become more difficult to treat with yield losses from each disease expected to be just over 1% in affected crops (Table 67) which equates to between 20,000 and 30,000 tonnes of winter barley, lost each disease. The other diseases typically cause less than 1% yield losses with low impacts on the level of production.

Scenario 2c & 2b CCP impacts

The key feature is the retention of prothioconazole as this is a strong azole product. Increased use of prothioconazole would enable control to continue at current levels unless shifts in fungicide sensitive erode its performance.

- Chlorothalonil is retained and should assist fungicide resistance management and control of leaf blotch its main target. Leaf blotch may develop resistance to strobilurin products.
- Cyprodinil is used for eyespot, mildew and leaf blotch control, usually in mixtures and it will help diversify programmes based largely on prothioconazole for high disease situations.
- Famoxadone has been quite widely used in mixtures and would still be available.
- Take-all is less important on barley than on wheat but silthiofam seed treatment will continue.
- Effective seed treatments remain.

The effects of the active substance lost in scenarios 2b and 2c are less than those seen in scenarios 2a and 3, with no disease causing more than 1% yield losses.

6.5.3. Spring Barley

A high proportion of spring barley is grown in Scotland. There is a wide range of sowing dates in England, with early sown crops (December/January) showing similar disease patterns to winter barley. There are no recent disease surveys, but there are some published survey reviews (Polley *et al.*, 1993a). Responses to disease and disease control in spring sown crops may differ from those on winter barley. There is good resistance to powdery mildew in current varieties, but weaknesses to brown rust and leaf blotch. Yellow rust is a potential threat but has been a minor disease to date. Ramularia problems are poorly documented in England, but it is clearly affecting yields in the north. Leaf blotch can be very severe in spring barley and is difficult to control in Scotland. Recommended list trials indicate that fungicide responses are about 10% but may exceed 20% on susceptible varieties such as Optic.

About 90% of all spring barley crops receive fungicide treatment with broad-spectrum formulated mixtures or tank mixtures in early spring (GS 30-31) and when the flag leaf has emerged. The most widely used fungicide active ingredients used alone or in mixtures in 2006 included azoxystrobin (11% area treated), chlorothalonil (42%), epoxiconazole (19%), fenpropimorph (36%) and prothioconazole (58%).

Table 68 - Spring barley: Effects of loss of actives on yield losses and production

Spring Barley (yield loss on affected area & total loss of production)										
Disease	2a - % yield loss	2a - Production loss (t)	2b - % yield loss	2b - Production loss (t)	2c - % yield loss	2c - Production loss (t)	3 - % yield loss	3 - Production loss (t)	WFD - % yield loss	WFD - Production loss (t)
Mildew	<1%	5,755	<1%	0	<1%	0	<1%	5,755	<1%	0
Rhynchosporium	<1%	15,986	<1%	4,796	<1%	4,796	<1%	15,986	<1%	3,197
Brown Rust	<1%	0	<1%	0	<1%	0	<1%	0	<1%	0
BYDV	<1%	0	<1%	0	<1%	0	<1%	0	<1%	0
Ramularia	<1%	2,398	<1%	0	<1%	0	<1%	2,398	<1%	0
Take all	<1%	0	<1%	0	<1%	0	<1%	0	<1%	0
Fusarium	<1%	0	<1%	0	<1%	0	<1%	0	<1%	0
Net Blotch	<1%	1,918	<1%	0	<1%	0	<1%	1,918	<1%	0
Others includes y. rust, halo spot, loose smut, snow rot, mosaic viruses	<1%	0	<1%	0	<1%	0	<1%	0	<1%	0
Eyespot	<1%	639	<1%	0	<1%	0	<1%	639	<1%	0
Ergot	<1%	0	<1%	0	<1%	0	<1%	0	<1%	0

Scenario 2a CCP & 3 ENVI Impacts

- Loss of triazoles – high impact on efficacy, timing and duration of control of foliar and ear diseases particularly leaf blotch (Rhynchosporium), and will result in very high pressure on strobilurins and remaining products. Would need to increase number and/or rates of applications of remaining products. Despite these mitigating measures being used it is likely that there will still be a 1% reduction in yield as a result of Rhynchosporium, equivalent to about 16,000 tonnes of spring barley.
- Loss of active powdery mildew products eg quinoxyfen and possibly propinaquid (not assessed by PSD) increases risk of further fungicide resistance problems to morpholine products. Cyflufenamid use is expected to increase, and possibly that of metrafenone if new formulations are available, Increase use of sulphur as a weak fungicide.
- Remaining strobilurin and morpholine actives will allow continued control of rusts and most leaf spots including net blotch and ramularia, at least in the short term.
- There are still seed treatment options.

In scenarios 2a and 3 the diseases that will become most difficult to control will be Rhychosporium, followed by mildew and Ramularia (each causing less than 1% yield loss (Table 68)

Scenario 2b & 2c CCP Impacts

- The key feature is the retention of prothioconazole as this is a strong azole product. Increased use of prothioconazole would enable control to continue at current levels unless shifts in fungicide sensitive erode its performance.
- Chlorothalonil is retained and should assist fungicide resistance management and control of leaf blotch its main target. Leaf blotch may develop resistance to strobilurin products.
- Cyprodinil is used for eyespot, mildew and leaf blotch control, usually in mixtures and it will help diversify programmes based largely on prothioconazole for high disease situations.
- Cyflufenamid use is expected to increase.
- Famoxadone and morpholine fungicides have been quite widely used in mixtures and would still be available.
- Effective seed treatments remain.

Despite the losses seen in scenarios 2b and 2c there will be very little impact on the level of control achievable for the majority of diseases affecting spring barley. The only disease that is likely to see slightly weakened levels of control is Rhynchosporium, where a 0.3% yield loss is expected, compared to the business as usual situation.

6.5.4. Oats

The area of oats is about 120,000 ha. Many varieties are susceptible to powdery mildew and/or crown rust. The newer varieties tend to have better resistance to these two important diseases. There are a number of other diseases to consider including BYDV, leaf spot, septoria, stem base disease, oat mosaic virus and take-all. These are difficult to quantify in the absence of survey data. Fusarium problems could be important in some years, especialy when mycotoxins are produced in grain.

In Recommended List trials the yield of varieties in treated experiments have been about 10-15% more than in untreated trials. Under high disease pressure foliar diseases can reduce yields by 30%. The most widely used fungicides on oats (all crops) are fenpropimorph (30,000 ha), cyproconazole (28,000 ha), epoxiconazole/ fenpropimorph/ kresoxym methyl (19,000 ha), azoxystrobin/ cyproconazole (16,000 ha) and quinoxyfen (14,000 ha). Pesticide usage data for 2006 indicated that 82% of crops received fungicide sprays with an average of 1.6 applications and 3.1 active ingredients. Most seed was treated with fungicides such fludioxonil and bitertanol/fuberidazole and only 25% was untreated.

Note the situation in spring oats is expected to be similar to winter oats as crown rust and powdery mildew are the two main diseases.

Table 69 – Oats: Effects of loss of fungicide actives on yield losses and production

Oats (yield loss on affected area & total loss of production)										
Disease	2a - % yield loss	2a - Production loss (t)	2b - % yield loss	2b - Production loss (t)	2c - % yield loss	2c - Production loss (t)	3 - % yield loss	3 - Production loss (t)	WFD - % yield loss	WFD - Production loss (t)
Crown Rust	<1%	5,078	<1%	0	<1%	0	1.5%	7,617	<1%	0
Mildew	4.7%	19,888	<1%	0	<1%	0	4.7%	19,888	<1%	0
BYDV	<1%	1,269	<1%	0	<1%	0	<1%	1,058	<1%	0
Take all	<1%	0	<1%	0	<1%	0	<1%	0	<1%	0
Fusarium spp	<1%	0	<1%	0	<1%	0	<1%	0	<1%	0
Other stem base diseases	<1%	0	<1%	0	<1%	0	<1%	0	<1%	0
Mosaic viruses	<1%	0	<1%	0	<1%	0	<1%	0	<1%	0

Scenario 2a CCP & 3 ENVI Impacts

- Loss of triazoles – cyproconazole, epoxiconazole and prothioconazole will impact on control of foliar diseases, but morpholine and strobilurin are substitutes that would need to be used more frequently
- Loss of the epoxiconazole /fenpropimorph /kresoxym methyl and epoxiconazole /boscalid mixtures and prothioconazole weakens options for eyespot control, but this is much less important than on other winter cereals
- Loss of the powdery mildew product quinoxyfen will have little impact as cyflufenamid, and morpholine products remain. This may increase the risk of further fungicide resistance problems to morpholine products. Increased use of sulphur as a weak fungicide may be required if susceptible varieties are grown.
- There are still seed treatment options.
- Overall an increase in losses from foliar, stem and ear diseases with deterioration over successive years after the changes are implemented.

Scenarios 2b & 2c CCP Impacts

- This scenario retains prothioconazole and may therefore have little impact on production if it is widely used in mixtures with fungicides with a different mode of action.
- Strobilurin and morpholine products are still retained along with cyflufenamid as a strong powdery mildew product.
- Standard seed treatments remain.

6.5.5. Oilseed Rape

Most oilseed rape crops (95%) receive an average of 2.1 fungicide applications and this is expected to increase after particularly severe sclerotinia stem rot problems in 2007 and 2008. The value of rapeseed increased to about £300/tonne and has declined to about £225/tonne. Inputs producing small yield responses of 0.1 t/ha are still cost-effective.

Yield losses from diseases have been reviewed by Fitt *et al.*, (1997) and reached £85million in 1994. This was estimated when rapeseed was £150/tonne. At current prices of £225/tonne, such losses would now be costing industry £125 million in a high disease year. Crop areas have increased from 400,000 in 1995 to about 600,000 ha giving adjusted losses of £190 million.

Phoma stem canker is the most important disease and control combines use of resistant varieties with azole fungicides. If prothioconazole is retained, an effective fungicide would be available and control could be maintained. The withdrawal of metconazole and tebuconazole would remove options to combine phoma control in autumn with pgr use on large crops. This autumn pgr option produces a benefit of about 0.1 t/ha from shoot and rooting effects.
Impact - mainly loss of PGR in autumn - 0.1 t x 150,000 ha = 15,000 t @£225/tonne = £3.37 million.

Light leaf spot
Resistant varieties and azole fungicides are required to achieve control under high disease pressure in the north and west, less so in the east and south. Prothioconazole is currently the most effective product so its availability is crucial for future production. Growers would be expected to increase the proportion of highly resistant varieties that are grown, though a reduced fungicide armoury may enable cultivar resistance to be overcome more rapidly.
Assume extra losses under high disease pressure average 0.5 t/ha x 60,000 ha (10% crop area) = 30,000 t= £9.0 million

Sclerotinia stem rot
Revised fungicide lists could leave boscalid the current standard product and azoxystrobin which is a good product plus thiophanate methyl a weaker fungicide. Prothioconazole is very effective.
No resistant varieties available. Concern that options are limited and fungicide resistance could develop more rapidly. Losses from sclerotinia have been high in 2007 and 2008 and approach 5% of the national crop:
5% x 600,000 ha x 3 t/ha = 90,000 tonnes x £225/t = £20.2million. Loss of prothioconazole may reduce efficacy against sclerotinia and light leaf spot on pods, but impact might be limited c. £2 million/annum. Biological control measures with Coniothyrium minitans may be taken up more widely where problems occur.

Alternaria pod spot
Limited importance at present and if azoxystrobin and boscalid remain available, there would be little impact.

Downy mildew
Usually little damage from this disease. With the loss of mancozeb but retention of chlorothalonil, little impact is expected even on late sown crops.

Seed treatments - thiram is lost along with prochloraz and iprodione, so seed-borne problems and damping-off could increase with some limited impact.

Table 70 – Oilseed rape: Effects of loss of fungicide actives on yield losses and production

Oilseed Rape (yield loss on affected area & total loss of production)										
Disease	2a - % yield loss	2a - Production loss (t)	2b - % yield loss	2b - Production loss (t)	2c - % yield loss	2c - Production loss (t)	3 - % yield loss	3 - Production loss (t)	WFD - % yield loss	WFD - Production loss (t)
Phoma (L. maculans)	5.0%	87,618	<1%	0	<1%	0	5.0%	87,618	<1%	0
Light Leaf spot	6.0%	87,618	<1%	0	<1%	0	6.0%	87,618	<1%	0
Turnip yellows	2.5%	29,206	<1%	0	<1%	0	2.5%	29,206	<1%	0
Sclerotinia	<1%	14,603	<1%	0	<1%	0	<1%	14,603	<1%	0
Botrytis	<1%	14,603	<1%	0	<1%	0	<1%	14,603	<1%	0
Downy mildew	<1%	0	<1%	0	<1%	0	<1%	0	<1%	0
Alternaria	<1%	3,407	<1%	0	<1%	0	<1%	3,407	<1%	0
Verticillium	<1%	0	<1%	0	<1%	0	<1%	0	<1%	0
Phoma b (L. biglobosa)	<1%	3,115	<1%	0	<1%	0	<1%	3,115	<1%	0
Powdery mildew	<1%	0	<1%	0	<1%	0	<1%	0	<1%	0
Clubroot	<1%	0	<1%	0	<1%	0	<1%	0	<1%	0

Scenario 2a CCP & 3 ENVI Impacts

- Loss of triazoles – difenoconazole, flusilazole, metconazole, prochloraz and tebuconazole removes the major established products best understood by farmers and advisers. The loss of prothioconazole is therefore also a vital factor leaving no options for control phoma canker and light leaf spot. Losses from phoma could increase to 5% and light leaf spot to 6% in affected crops (about 88 thousand tonnes lost to each disease).
- Loss of azoles also removes products with plant growth regulatory activity.
- Chlorothalonil could substitute for mancozeb for downy mildew control
- Sclerotinia stem rot control would depend on azoxystrobin and thiophanate methyl unless boscalid was retained. Much higher risk of fungicide resistance problems developing. Yield losses are expected to increase 1.5% compared to business as usual.
- Overall a substantial increase in losses from foliar, stem and pod diseases with deterioration over successive years after the changes are implemented.

Scenario 2b & 2c CCP Impacts

- This scenario retains prothioconazole and may therefore have little impact on production if it is widely used and replaces other triazoles.
- Under this scenario it is assumed that boscalid is also retained, improving options for sclerotinia and alternaria control.
- No seed treatments remain, so seed borne disease will become more important unless alternative seed treatments (eg heat, surface sterilants, biological agents) are used.

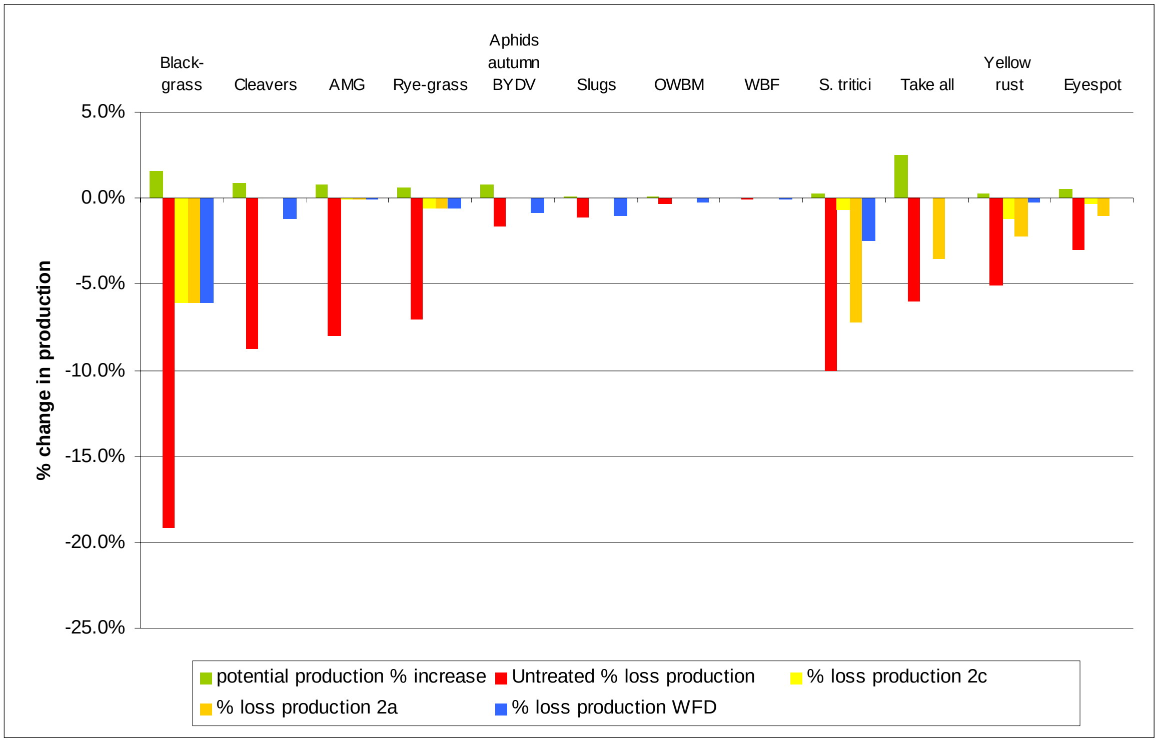

Figure 1 – The effect of each scenario on the production of wheat

6.6. Lodging

Under the revision of 91/414/EEC and the water framework directive chlormequat, the main PGR used in cereals is not affected. Lodging causes significant effects even in the business as usual situation and chlormequat is at risk for exceeding MRL levels. These are covered in full other sections.

However, metconazole and tebuconazole, used in oilseed rape are at risk from the 2c scenario. Metconazole has been demonstrated to give a 0.2 t/ha advantage when applied to crops with a GAI of over 0.8, in the absence of any disease (Berry & Spink, 2008). These yield advantages come as a result of increased rooting, improved seed set and a reduction in lodging. In the 2006 Pesticide Usage Survey metconazole was applied to about 50% of the rape area. If the yield loss on this area was 0.2 t/ha, this would equate to just over 58,000t of lost production or a 3% reduction in production. Tebuconazole is applied to about 20% of the rape area and if it had similar effects to metconazole the yield losses would increase to nearly 82,000t or 4% of production. However in 2006, there were a lot of very large crops around that caused an increase in use of PGRs, so these figures may be slightly exaggerated compared to an average year. In a cold year such as 2008/09 crops have tended to be much smaller and there is likely to be much less of a need for PGRs. Metconazole and tebuconazole are also applied for their fungicidal activity, so some of the usage may not have been targeted at lodging control. The disease control offered by these two actives can be replaced by some of the other active ingredients available for use on rape, but there are currently no alternatives for the PGR activeity.

6.7. Other pressures

There are a number of other pressures on availability of products and their use. These include:

- Generic product availability – it is difficult to determine what the impact will be. A major question will be how much additional data may be required to retain a recommendation and the cost of gaining such data. Because the margins are often lower in this area and there are often several manufacturers of a single active substance it is important that where possible they work together to maintain approvals, such as from pressures under WFD, to maintain long-term availability of older active substances.
- Potential for increased costs of products – with fewer products available and greater costs of maintain, and gaining original approval, it is likely there will be an upward pressure on product prices.
- More complex decision making – although a smaller product range could be argued as making decision making simpler, it is very likely to be more complicated. Farmers and agronomists will have to meet even greater demands for justification of use, there will need to be a balance of use which takes account of efficacy and environmental implications and choice of product to specific situation will become more complex.

6.8. New active substances

Discussions have been held in confidence with all of the major chemical companies. From these discussions a number of potential new products have been identified as likely to come to market soon, subject to meeting regulatory requirements. Most notable is that there are four new insecticides, of different modes of action, in the pipeline. These are targeting Lepidoptera and sucking pests although these are not currently approved for use on cereals. There are also three new carboximide fungicides that are being tested at the moment. As far as herbicides go there is very little in the way of new chemistry on the horizon. One new herbicide, a sulfonylurea, is under test in oilseed rape which is expected to control a limited but important range of weeds. In addition BASF have the Clearfield® technology under development in oilseed rape, this is a non-GM herbicide-resistant rape gene. At the time of writing (January 2009) none of these are yet available in UK.

http://www.agro.basf.com/p02/AP-internet/en_GB/function/conversions:/publish/upload/CLEARFIELD-Brochure.pdf

There may be the possibility that some active substances that have been developed in the past, but failed due to what was at the time seen as poor efficacy could be of value in a situation where our expectations of the level of control that is achievable is reduced.

6.8.1. New herbicides

DuPont - Ethametsulfuron

This sulfonylurea herbicide is approved in US, as Muster, and is expected to provide control options for charlock and cranesbill in oilseed rape.

BASF Clearfield® technology

This is a technology that introduces natural genetic mutations into crop lines (rice, wheat, oilseed rape, maize) that provide non-GM herbicide resistance to imidazolinone herbicides. These herbicides are able to control a wide range of weed species, although they are not particularly effective on black-grass.

6.8.2. New insecticides

Dupont - Indoxacarb:

Chemical class: indeno-oxadiazine

Mode of action: interferes with ion channels and in particular flow of Na to nerve cells leading to pest paralysis. The product targets pest through ingestion or contact with absorption through cuticle and is claimed to be effective against all larval stages. Product uses insect metabolism to become active (MetaActive).

Products: Advion

Target pests: for control of Lepidoptera (including budworm, armyworm, diamondback moth, codling moth and certain leaf rollers) and selected Coleoptera (Colorado potato beetle), Hempitera (including tarnished plant bug), Hymenoptera (including species of sawfly). Key crops; sweetcorn, grapes, leafy and fruiting vegetables e.g. brassicas, pome and stone fruit and potatoes. The product is currently registered for use (not in UK) for use in greenhouse, polytunnel and field conditions.

Toxicity: low acute and chronic toxicity, not mutagenic or carcinogenic and with no reported effects on development or reproduction. In mammalian studies majority of product was found to be excreted by lactating cows and laying hens.

Non-target: reported to be safe against beneficial arthropods

Environment: relatively low environmental loading due to low use rate i.e. 75 g a.i./ha for control of boll worm. Product is rapidly degraded in silt loam soil (half life of 2-3 days) with the metabolites in turn also generally degrading quickly.
http://www2.dupont.com/Production_Agriculture/en_US/products_services/insecticides/Rynaxypyr_insecticide.html

Dupont - Rynaxypyr:
Chemical class: anthranilic diamide

Mode of action: novel mode of action, targeting insect ryanodine receptors (RyRs). These receptors regulate release of calcium, which is required for muscle contraction. Rynaxypyr causes uncontrolled release and depletion of calcium preventing further muscle contraction. Insects rapidly stop feeding, become lethargic, regurgitate and become paralysed. Currently no cross resistance recorded and recommended for in insect resistance management.

Products: Altacor (350 g a.i./kg water-dispersible granules); Coragen (200 g a.i./l suspension concentrate); Ferterra (0.4 g a.i./kg granules); Prevathon (51.5 g a.i./l suspension concentrate).

Target pests: controls nearly all economically important Lepidoptera and selected other pests, including Coleoptera, Diptera, Hemiptera and Isoptera. The product works through contact or ingestion (chewing insects) by the pest, causing rapid cessation of feeding. Product is larvicidal and ovicidal, the latter being particularly effective when eggs laid on treated surfaces allowing neonates to be targeted as they hatch from eggs. Product claims to have strong residual activity as a result of being translaminar, rainfast and resistant to photo-degradation. Key crops; corn, cotton, grapes, leafy and fruiting vegetables, pome and stone fruit, potatoes, rice, sugar cane, tree nuts and turf.

Toxicity: exploits structural difference between insect and mammalian ryanodine receptors with insects 400-3000 times more sensitive. Low toxicity to mammals in acute and chronic studies.

Non-target: selective to non-target arthropods, low impact (<30% mortality) against a range of beneficials i.e. Neuroptera, Coleoptera, Hemiptera, Acari, Hymenoptera (including pollinators, *Apis mellifera*).

Environment: low recommended use rates reduces environmental load. The product has low toxicity to mammals, fish, birds, fish, earthworms, micro-organisms, algae and other plants. It is claimed that there is minimal potential for bio-accumulation and bio-magnification in animals. Degradation products are non-toxic while sequestration into soil matrix, low water solubility and non volatile nature of product suggest a low potential for movement to surface or ground water. However, aquatic invertebrates such as *Daphnia* are sensitive.
http://www2.dupont.com/Production_Agriculture/en_US/products_services/insecticides/Rynaxypyr_insecticide.html

Dupont in association with Syngenta - Cyazapyr:
Chemical class:
Mode of action:
Products:
Target pests: Lepidoptera & sucking pests
Toxicity:
Environment:

Bayer - Spirotetramat:(Safferling, 2008)
Chemical class: tetramic acid derivative.

Mode of action: inhibits lipid biosynthesis (inhibition of ACCase) and is related to the acaricides spirodiclofen (Envidor) and spiromesifen (Oberon). Development of larval stages is interrupted while the fecundity and fertility of adult stages is reduced. Product penetrates leaf surface and is distributed throughout the plant in the phloem and xylem via the spirotetramat-enol providing protection of both new shoots and roots. By contrast with the products translaminar and systemic efficacy, contact efficacy is limited. No reported cross resistance and so product may be used in insect resistance management.

Products: Movento SC, Movento OD

Target pests: sucking pests including aphids e.g. (*Dysaphis plantaginea*, *Aphis pomi*), psyllids, scales, mealybugs, whiteflies, thrips and root aphids. Key crops; pome fruits, stone fruits, citrus, grapes, almonds, nuts, hops, tea vegetables, cotton and tropical fruits.

Toxicity: No acute or chronic toxicity to birds or mammals, although some concern as to effect on ducks. Aquatic organisms show low acute or chronic sensitivity to this product. Soil organisms such as earthworms and soil micro-organisms showed either low or no sensitivity to the product.

Non-target: the product showed moderate side effects to predatory mites but predator-prey ratio was unaffected. The product was harmless to moderately harmful to ladybirds (*Coccinella* spp.). The product was considered harmless to slightly harmful for predatory bugs (*Orius* spp), lacewings (*Chrysopa* spp.), earwigs (*Forficula auricularia*). Hoverfly larvae (*Episyrphus* spp.) were unaffected. The product showed no acute toxicity to honeybees, however, under some tests (mimicking unrealistically high exposures) brood affects recorded.

Environment: breaks down rapidly in soil and surface water and there is no expectation that the product or its metabolites will accumulate in the environment. Unlikely to cause groundwater concentrations above the EU trigger value of 0.1 µg/L. In addition the product is not hydrolytically stable and is readily broken down in aquatic systems.

6.8.3. New fungicides

There are a number of new carboxamide fungicides that are being developed for use in wheat, which may become available in the next 2 or 3 years. This is the same mode of action as boscalid, which is already in the UK market. Early testing indicates these have activity on *Septoria tritici*. These products are believed to have a single site of activity, and there are already concerns that resistance may develop. If strong reliance is placed on this type of chemistry then it is likely that effective control will break down.

7. Economic impact of changes in pesticide availability

Gross margins were calculated using figures taken from the 2009 edition of Nix. These included the cost of seed, pesticides, and cultivations. The values for each of the crops were taken from Nix as well, as prices are very changeable this can have an influence on the gross margin. Nix has been taken as a standard reference source, although the values for pesticides, fertiliser and crops may well have increased or decreased in the time since publication see Appendix 4 – Business as usual gross margins for details of the standard gross margins used to compare against.

7.1. Summary matrix

7.1.1. Wheat

Under business as usual spray applications the weeds, pests or diseases that have the biggest potential impact on the wheat gross margin are take-all, followed by black-grass, cleavers and autumn aphids carrying BYDV (Table 71, last column). From this it can be seen that about £58 million are lost to take-all, despite current spray applications, £35 million are lost to black-grass, £20 million to cleavers and £19 million to autumn aphids. If current chemistry and control could be improved in these areas, this could lead to increased yields and improved gross margins

Table 71 – Effect of scenarios on wheat gross margin (Million £) and the losses to potential gross margin despite BAU treatments

	Wheat gross margin (Million £)							
	Baseline	Untreated	2a	2b	2c	3	WFD	Potential increase in GM from BAU
Weed								
Black-grass	872	473	720	720	720	720	519	35.1
Cleavers	872	759	848	848	848	848	872	20.1
Annual Meadow Grass	872	809	846	846	846	846	823	18.2
Rye-grass	872	724	853	853	853	853	743	14.2
BLW - not cleavers	872	680	830	830	830	771	872	40.9
Pest								
Aphids autumn BYDV	872	846	872	872	872	815	853	18.9
Slugs	872	850	872	872	872	859	841	2.5
Orange Wheat Blossom Midge	872	866	872	872	872	870	866	2.1
Wheat Bulb Fly	872	870	872	872	872	871	871	0.7
Disease								
S. tritici	872	772	682	856	856	682	814	6.9
Take all	872	864	791	872	872	791	872	57.7
Yellow rust	872	887	797	844	844	797	867	6.9
Eyespot	872	933	849	865	865	849	872	11.5

5-10% reduction in GM   >10% reduction in GM

It can be seen that the biggest impacts on gross margin generally occur on crops that are left untreated for each of the weeds black-grass, cleavers and rye-grass if left untreated will all cause more than a 10% reduction in gross margin. In the case of black-grass the reduction in gross margin is close to 50%. In some situations, such as yellow rust and eyespot control, the gross margin has actually improved in untreated situations. This is because the entire cost of fungicides was removed from the gross margin, but only a small proportion would have been targeted at these diseases specifically. Most fungicides are targeted at a range of diseases rather than a single specific disease.

Of the five scenarios where different pesticides are lost it can bee seen that the biggest impacts are likely to occur from the water frame work directive reducing the level of control that can be achieved on grass weeds. The impact in wheat is predominantly as a result of the reduced levels of control achievable in the oilseed rape break crops, leading to increasing populations. The reduction in the active ingredients available will also cause reliance on fewer actives, used in greater quantities. This is likely to cause an increase in the level of resistance seen in black-grass and rye-grass populations, making them even more difficult to control.

Scenario 2a and 3 are likely to cause impacts on the levels of disease control achievable with a reduction in the gross margin from septoria of over 10%, yellow rust and take all are likely to cause reductions in the gross margin of between 5 and 10%. These reductions are due to reduced availability of azole fungicides in these scenarios. Under the 2b and 2c scenarios a reasonable variety of azoles remain including prothioconazole, so the level of control should remain reasonable, with just a slight increase in costs from additional spray applications and increased costs of fungicides causing slight reductions in margin. If Chlorothalonil is lost to the WFD then it could cause yield losses of 2-2.5% from septoria and about 0.5% from other diseases. If this occurred on top of one of the other scenarios it would be additional to the losses already calculated for each of the scenarios, decreasing the gross margins still further.

As far as pests are concerned the only scenarios that have a major impact on the gross margins are scenario 3 and WFD, where a whole swath of insecticides is lost. This is likely to have an impact on the level of control achieved on aphids, leading to a reduction in gross margin between 5% and 10%. Under annex 3 methiocarb could potentially be lost for the control of slugs, leaving metaldehyde as the mainstay of slug control, however under the water framework directive metaldehyde is under threat. If metaldehyde were lost to the water framework directive, that would leave methiocarb as the mainstay for slug control. This would lead to an increase in the area that might be treated with methiocarb which could potentially make it more susceptible to the water framework directive. If both of these molluscicides were lost the control of slugs would become much more difficult with high yield losses on affected fields, causing the gross margin to fall as a result to close to that seen for untreated fields

7.1.2. Winter barley

Under current practice the weeds, pests or diseases that cause the greatest potential loss of gross margin in winter barley are take-all and black-grass. If 100 percent control of these could be achieved there is the potential to increase gross margins by £11 million and £5 million respectively (Table 72). In the absence of any control it is the weeds that cause the biggest reductions in gross margins with black-grass, rye-grass and cleavers all causing more than 10% reduction in the gross margin if left untreated. Uncontrolled aphid populations also cause more than a 10% reduction in gross margin.

The loss of pendimethalin in all of the scenarios will increase the difficulties faced in controlling grass weed populations, especially black-grass (10%+ reduction in gross margin). There will be increased requirements to plough to bury seed, reducing the gross margin. Where there are fewer active ingredients available for use on black-grass there will be increasing dependence upon fewer actives, leading to increased resistance within these populations.

As with wheat the effect of the water framework directive losses is generally indirect, with a loss of grass weed control on oilseed rape leading to increased resistance and higher populations in the following crop. This leads to an increase in the amount of ploughing required and a reduction in yields, resulting in a reduction in the gross margin. The loss of chlorotoluron to WFD will make the control of annual meadow grass in winter barley more difficult leading to losses in gross margin of between 5-10%.

The loss of virtually all insecticides in scenario 3 leads to a reduction in the gross margin as a result of aphid attack. This leads to a greater than 10% reduction in gross margin.

Of the barley diseases net blotch is causes the greatest reduction as a result of the scenarios, with a 5-10% reduction in gross margin seen in scenarios 2a and 3.

Table 72 – Effect of scenarios on winter barley gross margin (Million £) and the losses to potential gross margin despite BAU treatments

	Winter Barley gross margin (Million £)							
	Baseline	Untreated	2a	2b	2c	3	WFD	Potential increase in GM from BAU
Weed								
Black-grass	128	67	95	95	95	95	52	5.3
Cleavers	128	110	123	123	123	115	128	3.1
Annual Meadow Grass	128	118	123	123	123	123	118	2.8
Rye-grass	128	106	124	124	124	124	100	2.2
BLW - not cleavers	128	98	120	120	120	107	128	6.2
Pest								
Aphids	128	124	128	128	128	115	124	2.8
Slugs	128	127	128	128	128	126	124	0.4
Leather jackets	128	128	128	128	128	128	128	0.0
Frit Fly	128	128	128	128	128	128	128	0.0
Disease								
Take all	128	126	128	128	128	128	128	10.5
Fusarium	128	138	124	127	127	124	128	3.2
Eyespot	128	137	125	127	127	125	128	2.8
Net Blotch	128	133	122	128	128	122	128	1.5
5-10% reduction in GM	>10% reduction in GM							

7.1.3. Spring barley

The main impacts on gross margin in spring barley come from weeds. If left untreated black-grass, rye-grass, cleavers and annual meadow grass all cause more than a 10% reduction in gross margin (Table 73).

It is the water framework directive scenario that has the biggest effects upon the gross margin, with grass weeds becoming very difficult to control. Increases in ploughing and rolling will increase costs, whilst reducing yields as a result of competition will reduce yields. The loss of chlorotoluron makes annual meadow grass control more difficult, whilst losses of rape herbicides increase resistance and plant populations of black-grass and rye-grass.

The losses of herbicides in scenario 3 also cause large reductions in the gross margin from weeds.

Table 73 – Effect of scenarios on spring barley gross margin (Million £) and the losses to potential gross margin despite BAU treatments

	Spring Barley gross margin (Million £)							
	Baseline	Untreated	2a	2b	2c	3	WFD	Potential increase in GM from BAU
Weed								
Black-grass	202	191	202	202	202	198	192	1.0
Cleavers	202	197	198	198	198	192	202	1.4
Annual Meadow Grass	202	197	182	194	194	191	173	3.8
Rye-grass	202	197	202	202	202	202	198	0.4
BLW - not cleavers	202	129	193	193	193	180	202	8.5
Pest								
Aphids	202	202	202	202	202	201	201	0.1
Leather jackets	202	202	202	202	202	202	202	0.0
Slugs	202	202	202	202	202	202	202	0.0
Gout Fly	202	202	202	202	202	202	202	0.0
Disease								
Mildew	202	206	197	202	202	197	202	2.9
Rhynchosporium	202	205	197	201	201	197	201	2.4
Brown Rust	202	209	198	202	202	198	202	1.4
BYDV	202	208	200	202	202	200	202	1.7

5-10% reduction in GM | >10% reduction in GM

7.1.4. Oats

As with the other cereal crops the predominant impact on gross margins in oats is caused by weeds. Under the current situation the level of control that is achieved could still be improved to give £1.6 million a year extra on the gross margin if black-grass was controlled (Table 74). One hundred percent control of cleavers, annual meadow grass and rye-grass could lead to £0.9, £0.8 and £0.7 million increases, respectively.

Water framework directive and scenario 3 have the greatest effects on the gross margin. Water framework directive makes the control of black-grass more difficult, with an increasing reliance on ploughing and rolling to control black-grass and rye-grass and to improve the establishment of the crop. The increased cost, coupled with reduced yields results in large reductions in the gross margin.

Table 74 – Effect of scenarios on oat gross margin (Million £) and the losses to potential gross margin despite BAU treatments

	Oats gross margin (Million £)							
	Baseline	Untreated	2a	2b	2c	3	WFD	Potential increase in GM from BAU
Weed								
Black-grass	42	40	42	42	42	41	40	0.2
Cleavers	42	41	41	41	41	40	42	0.3
Annual Meadow Grass	42	38	39	39	39	38	41	0.8
Rye-grass	42	41	42	42	42	42	41	0.1
BLW - not cleavers	42	25	39	39	39	36	42	2.0
Pest								
Aphids	42	42	42	42	42	41	41	0.3
Slugs	42	42	42	42	42	42	42	0.0
Frit Fly	42	42	42	42	42	42	42	0.0
Leather jackets	42	42	42	42	42	42	42	0.0
Disease								
Crown Rust	42	40	42	42	42	41	42	0.6
Mildew	42	43	40	42	42	40	42	0.2
BYDV	42	43	42	42	42	42	42	0.1
Take all	42	43	42	42	42	42	42	0.3

5-10% reduction in GM | >10% reduction in GM

7.1.5. Oilseed Rape

Unlike the cereal crops the biggest influence on the current gross margin of oilseed rape come from diseases (Table 75). If complete control of phoma was possible it could increase the current gross margin by £26.3 million, full control of light leaf spot and turnip yellows could each increase gross margins by £17.5 million.

The loss of the majority of azole fungicides in scenarios 2a and 3 lead to more than a 10% reduction in gross margin from phoma and light leaf spot.

The majority of herbicides for use on rape remain with the 91/414/EEC revisions, however under the water framework directive the key black-grass herbicides carbetamide and propyzamide are under threat. The loss of these actives could make the control of weeds on affected crops almost impossible. It would also have knock on effects into wheat rotations as oilseed rape is often used as a cleaning crop to reduce black-grass pressure before planting a cereal crop. If this was not possible it would increase the pressure on the few actives available for use on black-grass in cereals, greatly increasing the risk of resistance developing.

Table 75 – Effect of scenarios on oilseed rape gross margin (Million £) and the losses to potential gross margin despite BAU treatments

	OSR gross margin (Million £)							
	Baseline	Untreated	2a	2b	2c	3	WFD	Potential increase in GM from BAU
Weed								
Volunteer cereals	203	18	203	203	203	203	203	1.3
Black-grass	203	162	203	203	203	203	115	2.9
Rye-grass	203	207	203	203	203	203	161	1.8
Cleavers	203	236	203	203	203	203	203	1.3
BLW - not cleavers	203	185	203	203	203	203	203	8.1
Pest								
Slugs	203	194	203	203	203	195	190	1.7
Aphids & turnip yellows	203	199	203	203	203	197	197	1.3
Cabbage stem flea beetle	203	204	203	203	203	197	201	2.0
pollen beetle	203	205	203	203	203	203	202	0.2
Disease								
Phoma (L. maculans)	203	167	180	203	203	180	203	26.3
Light Leaf spot	203	173	180	203	203	180	203	17.5
Turnip yellows	203	188	195	203	203	195	203	17.5
Sclerotinia	203	195	197	203	203	197	203	8.4

5-10% reduction in GM | >10% reduction in GM

8. Research priorities

8.1. General issues

- One of the most noticeable problems with doing a report like this is the lack of survey data available to produce the figures required in the analysis. In order to validate some of these results improved and recent survey data would be needed. This would help in areas such as the typical weed populations in treated and untreated situations. It would also help to link pest populations to yield losses. Consideration should be given to working with other interest parties to improve the data on weed incidence.
- It is worth noting that there are some areas where current levels of control are causing losses, even with the current pesticides available. In particular this is for crop lodging, oilseed rape disease, take all, autumn aphid control and weed control in general.
- Maintaining the diversity of chemistry is important to protect each active from being affected by the water framework directive. The greater the use of one active, over a large area, the more likely it is to appear in water.
- A key conclusion of this report is the potential impact losses in herbicides and weed control will cause. The greatest yield and gross margin reductions in cereal crops arise from weed populations, especially black-grass and to a slightly lesser extent rye-grass, cleavers and annual meadow grass. The scenario that has the biggest potential impact is the Water Framework

Directive, with the potential to cause more than a 10% loss of production. This is in part a direct effect of the lack of ability to retain the current levels of control in oilseed rape. A loss of chlorothalonil to meet requirements of the Water Framework Directive could lead to increased problems with controlling septoria on wheat – this could increase losses from diseases to 2.5% if it occurred in combination with the losses of some triazoles from the revision of 91/414/EEC.

- Protecting important active substances and pro-actively finding ways of ensuring their continued availability should be a priority. There are many ways in which pesticides can reach water, and all could be important. It is very important that routes to water and their relative importance for different groups of pesticides is better understood. This should aim to determine how pesticide use - from storage, filling, field application, sprayer cleaning - all contributes to losses. Alternative approaches which provide tools to voluntarily reduce the amount of specific actives, or target applications to higher risk situations.
- Anything that reduces overall amounts of pesticides, especially herbicides, used will help reduce risks of water contamination. In order to protect some of the active substances at risk from restrictions due to the WFD further research could be done to increase the precision of locating problem areas within fields and targeting the plant protection products to the area of the problem, rather than the whole field. Alternatively, for pests and diseases, opportunities to develop and to exploit varieties with resistance should be considered. This is unlikely to have significant impact in management of grass weeds, although competitive varieties can help reduce seed return and tillering. Obviously the timescale of genetic improvement will require several years to see any benefit.
- A key reason for applying pesticides is because of the significant risk of not applying them and the weed, pest or disease developing. Priority should be given to research which allows better prediction of future risks. For example there are models available which can be used as a basis to predict the numbers of weed seed surviving and their likely impact in future crops. Similarly better prediction of slug impacts could be used to reduce applications of metaldehyde.
- Formulation of pesticide products is normally aimed at maximising efficacy, operator and environmental safety. Often compromises have to be made to simply produce a product which is 'usable' and meets user needs. It may be necessary to reconsider the balance between different objectives and see if improvements in formulation might significantly reduce the likelihood of active substances reaching water. HGCA could consider working with the crop protection industry to see what new opportunities could be developed and there is scope to co-fund a generic piece of research which investigated the potential opportunities. Particular targets for investigation would be residual herbicides and slug pellets.
- Currently pesticide approvals are based typically on worst case scenarios. Despite this some active substances appear in water. There is a need to develop a 'pesticide management policy' which allow pesticide use to be managed in such a way as to allow effect crop protection whilst minimising the amount reaching water. This might result in lower rates, buffers areas, different

timings or setting priorities and restricted amounts for treatment within a catchment. It would be possible to develop decision models which can be locally based and use localised risk assessments to improve the higher scale models used. Consideration of how this could be achieved, with other stakeholder partners should be a priority, with a view to developing solutions to management of pesticide use within defined catchments.

	Wheat				Winter Barley				Spring Barley				Oats				OSR			
	Scenario 2c	Scenario 2a	WFD	Potential	Scenario 2c	Scenario 2a	WFD	Potential	Scenario 2c	Scenario 2a	WFD	Potential	Scenario 2c	Scenario 2a	WFD	Potential	Scenario 2c	Scenario 2a	WFD	Potential
Weed																				
Black-grass	**	**	***	*	**	**	***	*			*				*				***	*
Cleavers													*	*						
Annual Meadow Grass									*	*	*		*	*					*	
Rye-grass			**				**												**	
BLW - not cleavers				*				*	*	*		*	*	*		*				*
Pest																				
Aphids autumn			**				**												*	
Slugs																			*	
OWBM																				
Wheat Bulb Fly																				
CSFB																				
Pollen beetle																				
Disease																				
S. tritici		**																		
Take all		*		*																
Yellow rust	*	*																		
Eyespot		*																		
Fusarium		*				*														
Net blotch																				
Mildew														*						
Rhynchosporium																				
BYDV																				
Phoma (L. maculans)																		*		*
Light Leaf spot																		*		*
Turnip yellows																		*		*
Sclerotinia																				*
* - 1-5%	** - 5-10%				*** - >10%															

Figure 2- Interaction between scenarios and weeds, pests and diseases on production.

8.2. Weed control

- Weeds are a problem of a farming system and their impact though a rotation is an essential management issue. HGCA should actively consider working with other Sectors, and non-levy boards, to facilitate weed biology understanding and the role of cultural control through a rotation. Consideration should be given to providing information based on current knowledge to help improve weed management in a crop rotation, especially those in winter dominated wheat and oilseed rape cropping with serious grass-weed problems. This should aim to allow farmers and agronomists to balance efficacy, protecting water quality and managing herbicide resistance.

- The number of herbicides is already limited because of the challenge to be specific to a weed and not harm the crop. The likelihood of a new herbicide coming to the market is even more difficult with current requirements for meeting efficacy, including resistance risk, and fate assessments of the regulatory system. In global terms UK crops are relatively minor. Wheat is very likely to have new products, although few will be screened for specifically in this crop. Other cereals and oilseed are secondary objectives. Consideration should be given to assisting crop protection manufacturers to get herbicide recommendations into as many cereal crops as possible. Developing new options in oilseed rape could be considered in conjunction with HDC programmes for brassica field vegetables.
- Although a competitive crop is a very effective means of minimising amount of weed and seed return, it is seldom enough to remove the need for a herbicide. It would however be very helpful to have more data on the competitive ability of varieties and including some data to quantify this in RL would be a helpful management aid. A method of assessing and reporting competitiveness would need to be developed.

8.3. Pest control

- Only under the most severe restrictions would there be major pest issues. The major threats come from insecticides and molluscicides being found in water and exceeding WFD chemical or ecological standards. There is a further risk if metaldehyde and tefluthrin do not achieve Annex 1 listing. This needs careful monitoring. If they do not slug control and wheat bulb fly control will become much more important issues. There should be a positive approach to interacting with water companies and the EA to identify emerging issues early and develop positive solutions if/as they arise.
- There are several potential new insecticides from different modes of action in development. As a result there should be several options for the future, however, ensuring these are protected against the development of resistance would be a priority. Resistance risks can be further minimised by ensuring plant based resistance is made available and protected as much as possible.
- Formulation of slug pellets could be important in determining how much reaches water. This is worthy of further investigation, as is the wider dimension of how formulation may help minimise non-target impacts.

8.4. Disease control

- There is scope to improve the level of disease control achieved in oilseed rape and from the control of take all and septoria in wheat over and above what is currently achieved.
- Chlorothalonil will be a key fungicide in resistance management and used several times at many points in a crop rotation. It is very important that this active substance is kept out of water and therefore it will be important to understand the priorities uses of it within a rotation. The concerns of overuse of

chlorothalonil also need to be communicated within the industry to encourage responsible use.

8.5. Plant growth regulator use

- The WFD and review of 91/414/EEC are not predicted to have significant impacts on crop lodging. The major potential risk comes from any restrictions on use of chlormequat that may arise from market requirements or the need to reduce residue levels even more. However, there is a significant yield loss due to lodging from current practice. It would be appropriate to address this existing loss through new research and knowledge transfer.
- Previous projects have already identified the key traits which help reduce lodging risk. Ensuring that these are exploited and included into new varieties should be a priority. It would also be important to improve risk management of plant growth regulator use by matching assessments of crop state and variety to risk. It is important to ensure that current knowledge is transferred and new knowledge include as relevant to reduce unnecessary use of PGRs.

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10. References for yield losses to pests

10.1. Wheat

Pest	Treatment	% crop area currently treated	Marketable yield losses after treatment	Marketable yield loss without treatment	Comments	References
Autumn aphids	Seed treatment/ foliar spray	82	1%	2%	Some aphids will escape by being below soil level	
Summer aphids	Foliar spray	1	<1%	2%	Can lose up to 20% yield	Gratwick M (1992). Crop Pests in the UK. Collected Edition of MAFF leaflets. Chapman & Hall. London
Slugs	Pellets	22	<1%	5%	Could lose whole crop but heavy land most susceptible	
Cereal cyst nematode	None	0	N/A	<1%	Reports of cereal cyst nematode are very rare	Empson DW, Gair R (1982). Cereal Pests. MAFF Reference Book 186 HMSO London
Frit Fly	Foliar spray	<1%	<1%	<1%	Can prevent yield loss of 10% by treatment	French N, Nichols D, Wright AJ, Green DI, Green DBI, Fenlon JS (1988). Chemical control of frit fly on winter cereals sown after grass. *Annals of Applied Biology* **113** 245-257
Gout fly	Foliar spray	<1%	<1%	1%	Can lose up to 50% of yield but unlikely in all crops	Oakley JN (2003). Pest management in cereals and oilseed rape – a guide. HGCA 23pp
Orange wheat blossom midge	Foliar spray	18	<1%	2%	Attacks are very sporadic	Oakley JN (2003). Pest management in cereals and oilseed rape – a guide. HGCA 23pp
Wheat bulb fly	Seed treatment/ egg hatchspray/deadheart spray	3%	<1%	2%	Will only affect crops in east approx 1/4 of wheat area?	Young JEB, Ellis SA. (1995). Impact of changes in arable agriculture on the biology and control of wheat bulb fly. HGCA Research Review No 33
Leatherjackets	Foliar spray	<1%	<1%	<1%		

10.2. Winter barley

Pest	Treatment	% crop area currently treated	Marketable yield losses after treatment	Marketable yield loss without treatment	Comments	References
Autumn aphids	Seed treatment/ foliar spray	81	1%	2%		Plumb R T, Lennon E A, Gutteridge RA (19??). Forecasting barley yellow dwarf virus by monitoring vector populations and infectivity. Internal rothamsted publication
Frit Fly	Foliar spray	<1%	<1%	<1%	Attack on barley less common than in wheat	French N, Nichols D, Wright AJ, Green DI, Green DBI, Fenlon JS (1988). Chemical control of frit fly on winter cereals sown after grass. *Annals of Applied Biology* **113** 245-257
Gout fly	Foliar spray	<1%	<1%	<1%	Can lose up to 50% of yield but unlikely in all crops	Oakley JN (2003). Pest management in cereals and oilseed rape – a guide. HGCA 23pp
Slugs	Pellets	22	<1%	2%	Much less susceptible than wheat	
Leatherj ackets	Foliar spray	<1%	<1%	<1%		

10.3. Spring barley

Pest	Treatment	% crop area currently treated	Marketable yield losses after treatment	Marketable yield loss without treatment	Comments	References
Aphids and BYDV	Rarely any treatment	11%	<1%	<1%		To prevent any BYDV transmission would require frequent & regular sprays which would be uneconomic and environmentally damaging
Frit fly	Foliar spray	<1%	<1%	<1%	Rarely a problem	
Gout fly					Could lose up to 50% yield	Oakley JN (2003). Pest management in cereals and oilseed rape – a guide. HGCA 23pp
Leather jackets	Foliar spray	2%	<1%	<1%		
Slugs	Pellets	2%	<1%	<1%	Risk much reduced from autumn	

10.4. Oats

Pest	Treatment	% crop area currently treated	Marketable yield losses after treatment	Marketable yield loss without treatment	Comments	References
Aphids	Foliar spray	54%	<1%	2%		
Frit fly	Foliar spray	<1%	<1%	<1%		
Stem nematode	None	0	<1%	<1%	Incidence of damage declined with resistant varieties	
Wireworms	Seed treatment	<1%	<1%	<1%	Can lose about 9% of yield in heavy attack	
Slugs	Pellets	2%	<1%	<1%		
Leather-jackets	Foliar spray	<1%	<1%	<1%		

10.5. Winter oilseed rape

Pest	Treatment	% crop area currently treated	Marketable yield losses after treatment	Marketable yield loss without treatment	Comments	References
Aphids (virus)	Foliar spray	45% Probably most for virus control	<1%	3%	Will be more interest now in Turnip Yellows. Yields can be decreased by 26%	Stevens M, McGrann G, Clark B. (2008). Turnip yellows virus (syn Beet western yellows virus): an emerging threat to European oilseed rape production? HGCA Research Review 69.
Aphids (direct feeding)	Foliar spray	45%	<1%	<1%	Spring crop 3-46% yield loss. Winter crops 0.3-11% yield loss	Ellis S A, Oakley J N, Parker W E, Raw K (1999). The development of an action threshold for cabbage aphid (*Brevicoryne brassicae*) in oilseed rape. *Annals of Applied Biology* **134** 153-162.
Flea beetles inc. cabbage stem flea beetle	Seed treatment/foliar spray	67%	<1%	1%		
Pollen beetle	Foliar spray	40%	<1%	<1%		
Seed weevil	Foliar spray	20%	<1%	<1%		
Slugs	Pellets	59%	<1%	4%		

Appendix 1 – Glossary of Latin names and abbreviations

Common Name	Scientific Name	Crop Affected
Weeds		
Annual meadow grass	*Poa. Annua*	
Barley	*Hordeum vulgare*	
Barren brome	*Anisantha sterilis*	
Black-grass	*Alopecurus myosuroides*	
Charlock	*Sinapis arvensis*	
Chickweed	*Stellaria media*	
Cleavers	*Galium aparine*	
Couch	*Elytrigia repens*	
Creeping thistle	*Cirsium arvense*	
Cut-leaved crane's-bill	*Geranium dissectum*	
Fat hen	*Chenopodium album*	
Field pansy	*Viola arvensis*	
Field-speedwell	*Veronica persica*	
Fumitory	*Fumaria officinalis*	
Rye-grass (Italian)	*Lolium multiflorum*	
Ivy-leaved speedwell	*Veronica hederifolia*	
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*	
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*	
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)*	
Wheat	*Triticum aestivum*	
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*	

Common Name	Scientific Name	Crop Affected
Pests		
Bird-cherry aphid (autumn BYDV)	*Rhopalosiphum padi*	Wheat, Barley, Oats
Brassica pod midge	*Dasineura brassicae Winn.*	OSR
Cabbage aphid	*Brevicoryne brassicae L.*	OSR
Cabbage leaf miner	*Phytomyza rufipes Meig.*	OSR
Cabbage seed weevil	*Ceutorhynchus assimilis Payk.*	OSR
Cabbage stem flea beetle	*Psylliodes chrysocephala L.*	OSR
Cabbage stem weevil	*Ceutorhynchus quadridens Panz.* ,	OSR
Cereal cyst eelworms	*Heterodera major*	Wheat
Field slug	*Deroceras reticulatum*	Wheat, Barley, Oats
Frit fly	*Oscinella frit*	Wheat, Barley, Oats
Gout fly	*Chlorops pumilionis*	Wheat, Barley
Grain aphid (autumn BYDV & summer feeding)	*Sitobion avenae*	Wheat, Barley, Oats
Keeled slug	*Tandonia budapestensis*	Wheat, Barley, Oats
Leatherjackets	*Tipula paludosa*	Wheat, Barley, Oats
Nematodes - stem	*Ditylenchus dipsaci*	Oats
Orange wheat blossom midge	*Sitodiplosis mosellana*	Wheat
Pollen beetle	*Meligethes spp.*	OSR
Rape winter stem weevil	*Ceutorhynchus picitarsis Gyll.*	OSR
Wheat bulb fly	*Delia coarctata*	Wheat, Barley
White and yellow-soled slugs	*Arion spp*	Wheat, Barley, Oats
Disease		
Barley yellow dwarf virus	Barley yellow dwarf virus (BYDV)	Wheat, Barley, Oats
Brown rust	*Puccinia triticina*	Wheat
Brown rust	*Puccinia hordei*	Barley
Clubroot	Plasmodiophora brassicae	OSR
Crown rust	*Puccinia coronata*	Oats
Dark leaf and pod spot	*Alternaria brassicae* and *Alternaria brassicIcola*	OSR
Downy Mildew	*Hyaloperonospora parasitica* (previously *Peronospora parasitica*)	OSR
Ergot	*Claviceps purpurea*	Wheat
Eyespot	*Pseudocercosporella herpotrichoides (Tapesia yallundae)*	Wheat
Fusarium diseases	*Fusarium spp*	Wheat, Barley, Oats
Fusarium foot rot	*Fusarium spp*	Wheat
Grey mould	*Botryotinia fuckeliana* (asexual stage *Botrytis cinerea*)	OSR
Halo spot	*Selenophoma donacis*	Barley
Light leaf spot	*Pyrenopeziza brassicae* (asexual stage *Cylindrosporium concentricum)*	OSR

Common Name	*Scientific Name*	Crop Affected
Loose smut	*Ustilago nuda f. sp. tritici (U. tritici)*	Wheat
Loose smut	*Ustilago nuda f. sp. Hordei*	Barley
Loose smut	*Ustilago avenae*	Oats
Mosaic viruses	*Barley yellow mosaic virus (BaYMV)*	
Mosaic viruses	*Barley mild mosaic virus (BaMMV)*	
Mosaic viruses	*Oat mosaic virus (OMV)*	
Mosaic viruses	*Oat golden stripe virus (OGSV)*	
Mosaic viruses	*Soil-borne cereal mosaic virus (SBCMV)*	
Mosaic viruses	*Soil-borne wheat mosaic virus (SBWMV)*	
Net blotch	*Pyrenophora teres f. teres (Drechslera teres)*	Barley
Phoma B	*Leptosphaeria biglobosa* (asexual stage Phoma B - *Phoma lingam*)	OSR
Phoma Leaf Spot and Stem Canker	*Leptosphaeria maculans* (asexual stage Phoma A - *Phoma lingam*)	OSR
Powdery mildew	*Blumeria graminis f. sp. tritici*	Wheat
Powdery mildew	*Blumeria graminis f. sp. Hordei*	Barley
Powdery mildew	*Blumeria graminis f. sp. Avenae*	Oats
Powdery mildew	*Erysiphe cruciferarum*	OSR
Ramularia leaf spot	*Ramularia collo-cygni*	Barley
Rhynchosporium	*Rhynchosporium secalis*	Barley
Sclerotinia stem rot	*Sclerotinia sclerotiorum*	OSR
Septoria nodorum	*Septoria nodorum (Stagonospora nodorum)*	Wheat
Septoria tritici	*Septoria tritici (Mycosphaerella graminicola)*	Wheat
Sharp eyespot	*Rhizoctonia cerealis*	Wheat
Snow rot	*Typhula incarnata*	Wheat, Barley
Take-all	*Gaeumannomyces graminis*	Wheat, Barley, Oats
Turnip yellows	*Turnip yellows virus* (TuYV)	OSR
Verticillium wilt	*Verticillium longisporum*	OSR
Yellow rust	*Puccinia striiformis*	Wheat, Barley

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
CSFB	Cabbage Stem Flea Beetle
MRL	Maximum Residue Level
OSR	Oilseed rape
OWBM	Orange Wheat Blossom Midge
PSD	Pesticides Safety Directorate
WFD	Water Framework Directive

Appendix 2 – Loss of Active Substances

Table 76 Availability of herbicide active ingredients for combinable crops in the different scenarios

Substance	Status	Date of expiry of Annex 1	Approved in UK	Scenario					Approved for use on				
				2a	2b	2c	3	WFD	W	WB	O	SB	OSR
2,4-D	A1	2011	Y	d			x		Y	y	y	y	
2,4-DB	A1		Y				x		Y	y	y	y	
amidosulfuron	A1		Y						y	y	y	y	
bentazone	A1		Y					x				y	
bifenox	A1		Y						Y	y			y
bromoxynil	A1		Y	–					Y	y	y	y	
carbetamide	list 3 VW		Y					x					y
carboxin	list 3 VW		Y						Y				
carfentrazone ethyl	A1		Y						Y	y	y	y	
chlorotoluron	A1		Y					x	Y	y		y	
clodinafop	A1		Y					x	Y				
clomazone	A1		Y										y
clopyralid	A1		Y					x	Y	y	y	y	y
cycloxydim	list 3 VW		Y										y
desmedipham	A1		Y									y	
dicamba	A1		Y						Y	y	y	y	
dichlorprop p	A1	2017	Y				x		Y	y	y	y	
diflufenican	A1		Y						Y	y		y	
dimethanamid -p	A1		Y										y
diquat	A1		Y						?	y	y	y	y
ethofumesate	A1		Y							y		y	
fenoxaprop p	A1		Y						y	y		y	
florasulam	A1		Y						Y	y	y	y	
fluazifop-p	list 3 VW		Y										y
flufenacet	A1		Y						Y	y			
flumioxazin	A1	2012	Y	d	d	d			Y				
flupyrsulfuron methyl	A1		Y						y	y	y	y	
fluroxypyr	A1		Y						Y	y	y	y	
flurtamone	A1		Y						Y	y			y
glufosinate	A1	2017	Y	d	d	d							y
glyphosate	A1		Y					x	Y	y	y	y	y
iodosulfuron	A1		Y						Y	y		y	
ioxynil	A1	2014	Y	d	d	d			Y	y	y	y	
isoproturon	A1	gone	Y					x	Y	y		y	
linuron	A1	2013	Y	d	d	d			Y	y	y	y	
MCPA	A1	2016	Y				x		Y	y	y	y	

Substance	Status	Date of expiry of Annex 1	Approved in UK	Scenario					Approved for use on				
				2a	2b	2c	3	WFD	W	WB	O	SB	OSR
MCPB	A1	2016	Y				x		Y	y	y	y	
mecoprop-p	A1	2014	Y				x	x	y	y	y	y	
mepiquat	A1		Y						Y	y		y	
mesosulfuron	A1		Y						Y	?	y		
metamitron	A1		Y									y	
metazachlor	A1		Y					x					y
metsulfuron methyl	A1		Y						Y	y	y	y	
napropamide	list 3		Y										y
pendimethalin	A1	2013	Y	x	x	x			Y	y	y	y	
phenmedipham	A1		Y									y	
picloram	A1	2018	Y	d									y
picolinafen	A1		Y						Y	y			
propachlor	list 3		Y										y
propaquizafop	list 3		Y										y
propoxycarbazone	A1		Y						Y				
propyzamide	A1		Y					x					y
prosulfocarb	A1		Y					x	Y	y			
quinmerac	list 3 VW		Y										y
quizalofop-p-ethyl	list 3		Y										y
quizalofop-p-tefuryl	list 3		Y										y
sulfosulfuron	A1		Y						Y				
tepraloxydim	A1		Y										y
terbuthylazine	list 3 VW		Y						y	y		y	
thifensulfuron methyl	A1		Y						Y	y	y	y	
tralkoxydim	A1		Y						Y	y		y	
triallate	list 3		Y						Y	y		y	
tribenuron	A1		Y						Y	y	y	y	
triflusulfuron	list 3	2018	Y	d								y	

x – lost
d – chance of getting 5 year derogation

Table 77 - Availability of insecticide active ingredients for combinable crops in the different scenarios

Substance	Status	Date of expiry of Annex 1	Approved in UK	Scenario					Approved for use on				
				2a	2b	2c	3	WFD	W	WB	O	SB	OSR
alpha cypermethrin	A1	2015	Y	-			x		y	y		y	y
beta-cyfluthrin	A1	2013	Y				x		Y				y
bifenthrin	list 3	2018	Y	x	x	x			Y	y		y	
chlorpyrifos	A1	2016	Y				x	x	Y	y	y	y	
clothianidin	A1		Y						Y	y	y		
cyfluthrin	A1	2013	Y				x		Y	y			y
cypermethrin	A1	2016	Y				x		Y	y	y	y	y
deltamethrin	A1	2013	Y	d	d				y	y	y	y	y
dimethoate	A1	2016	Y	d			x		Y				
esfenvalerate	A1	2011	Y	x	x	x			Y	y		y	
imidacloprid	A1		Y						Y	y	y		y
lambda cyhalothrin	A1	2011	Y				x		Y	y	y	y	y
methiocarb	A1	2017	Y				x		Y				y
pirimicarb	A1	2017	Y				x		Y	y	y	y	y
tau fluvalinate	list 3 VW	2020	Y				x		Y	y		y	y
tefluthrin	list 3	2020	Y				x		Y	y	y	y	
thiacloprid	A1		Y						Y				y
zeta-cypermethrin	list 3	2018	Y				x		Y	y	y	y	y
ferric phosphate	A1		Y						y	y	y	y	y
metaldehyde	list 3 VW		Y					x	Y	y	y	y	y

Table 78 – Availability of fungicide active ingredients for cereal crops in the different scenarios

Substance	Status	Date of expiry of Annex 1	Approved in UK	Scenario 2a	2b	2c	3	WFD	Approved for use on W	WB	O	SB	OSR
azoxystrobin	A1		Y						y	y	y	y	y
bromuconazole	list 3		Y						Y	y			
carbendazim	A1	2009	Y	x	x	x		x	Y	y		y	y
chlorothalonil	A1		Y					x	Y	y	y	y	y
cyproconazole	list 3 VW	2020	Y	d	d	d			y	y	y	y	y
cyprodinil	A1		Y						Y	y		y	
difenoconazole	A1	2018	Y	d					Y				y
dimoxystrobin	A1		Y						Y				
epoxiconazole	A1	2018	Y	d	d	d			Y	y	y	y	
famoxadone	A1		Y						Y	y		y	y
fenpropidin	A1		Y	–					Y	y		y	
fenpropimorph	A1		Y						y	y	y	y	
fludioxonil	A1		Y						Y	y	y	y	
fluquinconazole	list 3 VW	2020	Y	d					y	y			
flusilazole	A1	suspended	Y	d	d	d			y	y		y	y
fuberidazole	A1		Y						Y	y	y		
guazatine	list 3 VW		Y						Y	y	y	y	
imazalil	A1		Y							y	y	y	
iprodione	A1	2013	Y	d					Y	y		y	y
kresoxim methyl	A1		Y						Y	y	y	y	
mancozeb	A1	2015	Y	d	d	d			Y	y		y	y
metconazole	A1	2017	Y	d	d	d			Y	y		y	y
metrafenone	A1		Y						Y	y	y	y	
picoxystrobin	A1		Y						Y	y	y	y	
prochloraz	list 3 VW	2020	Y	d					Y	y		y	y
propiconazole	A1	2013	Y	d					Y	y	y	y	y
pyraclostrobin	A1		Y						Y	y	y	y	
quinoxyfen	A1	2014	Y	x	x	x		x	Y	y	y	y	
silthiofam	A1		Y						Y	y			
spiroxamine	A1		Y						Y	y	y	y	
tebuconazole	A1	2018	Y	d	d	d			Y	y	y	y	y
tetraconazole	list 3	2018	Y	d					Y	y	y	y	
thiophanate methyl	A1		Y						Y				y
thiram	A1	2013	Y	d			x		Y	y	y	y	y
triadimenol	A1		Y	–					Y	y	y	y	
trifloxystrobin	A1		Y						Y	y	y	y	
triticonazole	A1	2017	Y	d					Y	y	y		

x – lost

d – chance of getting 5 year derogation

Table 79 Availability of PGR active ingredients for combinable crops in the different scenarios

Substance	Status	Date of expiry of Annex 1	Approved in UK	2a	2b	2c	3	WFD	Approved for use on W	WB	O	SB	OSR
chlormequat	list 3		Y						Y	y	y	y	
imazaquin	A1		Y						Y				
prohexadione calcium	A1		Y						y	y			
trinexapac	A1		Y						Y	y	y	y	
metconazole	A1	2017	Y	d	d	d			Y	y		y	y
tebuconazole	A1	2018	Y	d	d	d			Y	y	y	y	y

x – lost

d – chance of getting 5 year derogation

Appendix 3 – Fungicide information

Table 80 - Summary of benefits and consequences in relation to individual fungicide active ingredients for wheat.

Fungicide	Key benefits	Consequences	Alternatives
Azole products (generic)	Broad-spectrum systemic fungicides offering better curative activity than other fungicide groups	This is the most important group of fungicides for control of wheat - effective alternatives are not available so consequences are increased numbers of sprays of weaker products and higher losses from diseases	Use varieties with high disease resistance. Modify crop agronomy (eg sow date, seed rate, nitrogen fertiliser) and use less intensive rotations. Reduce wheat production and adjust regional distributions
bromuconazole	Broad-spectrum activity, including eyespot and fusarium ear blight diseases	Limited – may be more widely used and at higher rates	Remains under all situations
cyproconazole	Broad-spectrum activity, strong against rust diseases	Still an important product in mixtures - replace with strobilurin products which may be affected by the selection of fungicide resistant strains and weaker azoles	Lost after 5 years in 2a, 2b and 2c See generic azole options
difenoconazole	Broad-spectrum activity, strong against septoria diseases and brown rust	Limited - may be more widely used and at higher rates	Remains in 2b&c but lost in 2a and 3
epoxiconazole	The most widely used azole fungicide – very strong activity against septoria and rust diseases	A key product for wheat – large areas would require treatment with other azole fungicides and other chemical groups eg chlorothalonil, morpholines, strobilurins and more frequent applications. Increase in breakdown of resistant varieties. Efficiency of production likely to be reduced	Worse scenario for 2a than 2b and 2c. Some adjustment to crop agronomy will be possible eg delayed sowing and reduced nitrogen fertiliser. Use a higher proportion of resistant varieties. Use GM crops

Fungicide	Key benefits	Consequences	Alternatives
fluquinconazole	Used in mixture with prochloraz as broad spectrum product against septoria and rust diseases. Used as a seed treatment for take-all and early foliar disease control	Silthiofam could be used for take-all control. Limited impact on foliar disease management	Lost after 5 years in 2a and withdrawn in 2b, 2c and 3. See generic azole options with more specific attention to managing take-all
flusilazole	Established product with eyespot activity as well as moderate foliar disease activity	Limited impact – substituted by remaining azoles	Lost after 5years See generic azole options
metconazole	Established product with good activity against fusarium ear blight as well as good foliar disease activity	Still important – substitute strobiluirin mixtures for fusarium ear blight control	Lost See generic azole options; reduce maize/ wheat rotations
prochloraz	Established product with eyespot activity as well as foliar disease activity. Potential to contribute to fungicide resistance management in S. tritici.	Use metrafenone or cyprodinil for eyespot control. Less effective seed treatments	Remains in 2a for 5 years but lost in 2b&c and 3 Delay sowing especially in more intensive wheat rotations
propiconazole	Established product with some foliar disease activity	Limited - substituted by remaining azoles	Remains in 2b&c but lost in 2a and 3 See generic azole options

Fungicide	Key benefits	Consequences	Alternatives
prothioconazole	The most recent azole with very strong broad-spectrum activity, strong against septoria diseases and eyespot, plus fusarium ear blight and rust diseases. Used in various seed treatments	A key product for wheat – large areas would require treatment with other fungicides and more frequent applications (in 2a and 3). Increase in breakdown of resistant varieties. Fewer options for fusarium and mycotoxin management and for seed treatments. Use more metrafenone or cyprodinil for eyespot control Efficiency of production likely to be reduced Under 2b and 2c increased use of this product to repoace epoxiconazole	Lost under 2a and 3 only so large impact on these scearios. Conversely in 2b and 2c production little impact if this product replaces other strong azoles. Some adjustment to crop agronomy will be possible eg delayed sowing and reduced nitrogen fertiliser. Less intensive production. Use a higher proportion of resistant varieties. Use GM crops
tebuconazole	Broad-spectrum activity, strong against rust diseases and fusarium ear blight; moderate septoria activity	Increase use of strobilurin and morpholine products for rust control. Increased risk of fusarium ear blight and mycotoxins Sulphur for powdery mildew	Lost See generic azole options; concern about mycotoxins may reduce wheat/maize rotations
tetraconazole	Product with moderate foliar disease activity	Limited - may be more widely used and at higher rates	Remains in 2b&c and 3, but lost in 2a See generic azole options
triadimenol	Long established product with some foliar disease activity	Limited – alternative seed treatments required	Remains available in all situations
triticonazole	Used as seed treatment.	Less effective seed treatment	Remains in 2b&c but lost in 2a Develop non chemical seed treatments

Fungicide	Key benefits	Consequences	Alternatives
boscalid	Recent introduction used in mixture with epoxiconazole to strengthen eyespot activity, has broad-spectrum activity against foliar diseases	Use with other azoles where epoxiconazole is lost. Metrafenone or cyprodinil for eyespot; increased risk of fungicide resistance in septoria species	Retained See generic azole options
carbendazim	Long established product, activity diminished by fungicide resistance but still used against fusarium ear diseases.	Increase use of strobilurin or thiophanate methyl products for ear disease control, though their effectiveness may be reduced by fungicide resistance problems.	Lost Substitute thiophanate methyl in short term but use more resistant varieties for fusarium control.
cyflufenamid	Recent introduction with very strong powdery mildew activity	Some increase in use with loss of other chemistry which could increase risk of fungicide resistance problems. Sulphur. Lower yield on fertile sites	Retained Use resistant varieties.
mancozeb	Broad-spectrum protectant fungicide useful activity against brown rust, glume blotch and sooty moulds	Increase strobilurin use though their activity may soon be reduced by fungicide resistance	Lost Maintain high diversity of fungicides in programmes
proquinazid – not assessed by PSD	Recent introduction with very strong powdery mildew activity	Metrafenone a possible alternative but loss of chemistry could increase risk of fungicide resistance problems. Sulphur Use resistant varieties, lower yield on fertile sites	Use resistant varieties, lower yield on fertile sites

Fungicide	Key benefits	Consequences	Alternatives
quinoxyfen	Established product with good powdery mildew activity	Little as Metrafenone a possible alternative but loss of chemistry could increase risk of fungicide resistance problems Sulphur Use resistant varieties, lower yield on fertile sites	Lost Use resistant varieties, lower yield on fertile sites
thiram	Only seed treatment approval on wheat	Some increased damage from seed-borne diseases	Remains in 2b&c but lost in 2a Develop non- chemical seed treatments
chlorothalonil	Broad-spectrum protectant fungicide with low risk of resistance	Vital product for septoria control – control is likely to less efficient, requiring more frequent applications of weaker products and greater risk of fungicide resistance	Remains in all scenarios Grow highly resistant varieties, reduce production in disease prone areas, reduce intensity of production and accept lower yields. Use GM crops
Azole products (generic)	Broad-spectrum systemic fungicides offering better curative activity than other fungicide groups	This is the most important group of fungicides for control of wheat - effective alternatives are not available so consequences are increased numbers of sprays of weaker products and higher losses from diseases	Use varieties with high disease resistance. Modify crop agronomy (eg sow date, seed rate, nitrogen fertiliser) and use less intensive rotations. Reduce wheat production and adjust regional distributions
Morpholine products (generic)	Broad-spectrum systemic fungicides offering some rapid knock-down activity	This is important group of fungicides for use in mixtures for foliar disease control – could be affectd by fungicide resistance if are increased numbers of sprays of weaker products are used.	Use varieties with high disease resistance. Modify crop agronomy (eg sow date, seed rate, nitrogen fertiliser) and use less intensive rotations. Reduce wheat production and adjust regional distributions

Fungicide	Key benefits	Consequences	Alternatives
Strobilurin products Generic)	Broad-spectrum systemic fungicides offering some curative activity and physiological benefits	Fungicide resistance is a threat to this group, but rust diseases may still be well controlled.	Some adjustment to crop agronomy will be possible eg delayed sowing and reduced nitrogen fertiliser. Less intensive production. Use a higher proportion of resistant varieties.

Appendix 4 – Business as usual gross margins

Table 81 – Wheat gross margin

Business as normal wheat - with standard spray applications (2008)		
Total UK Wheat area (from DEFRA Stats)	2,072,900	
UK average wheat yield	8.25	t/ha
Price	135	£/t
Total UK wheat production	17,101,425	t
Total value UK wheat	**2,308,692,375**	**£**
Seed	49	£/ha
Fertiliser	323	£/ha
Herbicides	60	£/ha
Insecticides	7	£/ha
Fungicides	63	£/ha
Cultivation costs	113	£/ha
Other	78	£/ha
Total cost of inputs	**1,435,421,063**	**£**
UK Wheat Gross Margin	**873,271,312**	**£**
Gross margin / ha	421	£/ha

Table 82 – Winter barley gross margin

Business as normal winter barley - with standard spray applications (2008)		
UK winter barley area	421,000	ha
UK average winter barley yield	5.75	%
Price	145	£/t
Total UK winter barley production	2,420,750	t
Total value UK winter barley	**351,008,750**	**£**
Seed	56	£/ha
Fertiliser	206	£/ha
Herbicides	51	£/ha
Insecticides	3	£/ha
Fungicides	47	£/ha
Cultivation costs	113	£/ha
Other	52	£/ha
Total cost of inputs	**222,737,067**	**£**
UK winter barley gross margin	**128,271,683**	**£**
Gross margin / ha	305	£

Table 83 – Spring barley gross margin

Business as normal spring barley - with standard spray applications (2008)		
UK spring barley area	609,000	ha
UK average spring barley yield	5.25	%
Price	150	£/t
Total UK spring barley production	3,197,250	t
Total value UK spring barley	**479,587,500**	**£**
Seed	59	£/ha
Fertiliser	176	£/ha
Herbicides	37	£/ha
Insecticides	2	£/ha
Fungicides	35	£/ha
Cultivation costs	113	£/ha
Other	34	£/ha
Total cost of inputs	**277,616,710**	**£**
UK spring barley gross margin	**201,970,790**	**£**
Gross margin / ha	332	£/ha

Table 84 – Oat gross margin

Business as normal oats - with standard spray applications (2008)		
UK oats area	130,200	ha
UK average oats yield	6.50	%
Price	125	£/t
Total UK oats production	846,300	t
Total value UK oats	**105,787,500**	**£**
Seed	52	£/ha
Fertiliser	218	£/ha
Herbicides	40	£/ha
Insecticides	10	£/ha
Fungicides	20	£/ha
Cultivation costs	113	£/ha
Other	34	£/ha
Total cost of inputs	**63,494,200**	**£**
UK oats gross margin	**42,293,300**	**£**
Gross margin / ha	325	£/ha

Table 85 – OSR gross margin

Business as normal OSR - with standard spray applications (2008)		
UK OSR area	599,100	ha
UK average OSR yield	3.25	%
Price	300	£/t
Total UK OSR production	1,947,075	t
Total value UK OSR	**584,122,500**	**£**
Seed	41	£/ha
Fertiliser	306	£/ha
Herbicides	77	£/ha
Insecticides	12	£/ha
Fungicides	30	£/ha
Cultivation costs	113	£/ha
Other	57	£/ha
Total cost of inputs	**380,708,080**	**£**
UK OSR gross margin	**203,414,420**	**£**
Gross margin / ha	340	£/ha