Research Report

Pesticide availability for potatoes following revision of Directive 91/414/EEC: Impact assessments and identification of research priorities

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Foreword

The Potato Council is concerned about the future sustainability of the potato industry in Great Britain because of the potential impact of the EU review that will result in a loss of a range of crop protection products over the next 15 years.

Two specific Case Studies looking at the control of Potato Cyst Nematodes and Weeds have been researched and were published by the Potato Council in 2008. The information from these Case Studies contributed significantly to the discussions in the UK and Europe -during the latter half of 2008.

This Report on Pesticide Availability builds on previous case studies and uses the most recently available information It provides the most comprehensive assessment of the potential impact of the revision of the pesticide legislation and the implementation of the Water Framework Directive. This has been used to identify research and knowledge transfer priorities for the potato industry.

A common framework, applicable to other agricultural sectors, has been adopted by ADAS in the preparation of the Potato Council Report. This structure provides the base for cross-sector analysis and for development of shared activities under the umbrella of the Agriculture and Horticulture Development Board.

Executive Summary

Pesticides are fundamental to the way potatoes are currently grown in the UK. They provide very cost-effective options for controlling the major weeds, pests and diseases. The availability of pesticides is currently under pressure due to changes in European legislation (revision of 91/414/EEC), the implementation of the Water Framework Directive along with other non-legislative reasons such as increasing resistance of target organisms and market acceptability driven by residues in food products. The availability of pesticides for controlling weeds, pests and diseases in other parts of the rotation can also affect potato production. These pressures are all leading to potential reductions in the availability of pesticides which may affect potato production.

The objective of this study was to evaluate the current status of control of weeds, pests and disease in potato production, how this might be affected by changes in pesticide availability, and to identify the priority areas for research in order to plan for and mitigate the impacts.

The key weeds, pests and diseases that affect each of the potato market sectors (processing, fresh market and seed) were identified along with the area affected. Estimates of harvest yield and market yield impacts on an area weighted basis were made for the business as usual scenario, untreated scenario and different pesticide availability scenarios. These were based on research, surveys and expert opinion. The same analysis methodology was also used to evaluate weed, pest and disease impacts in cereals, oilseeds, forage crops and grassland through other AHDB sectors.

Under current production methods and available treatments, late blight causes the largest loss in potential yield and quality with an industry value of about £55 million per year. Potato cyst nematodes are the second greatest cause of losses, worth nearly £26 million, mainly affecting the processing and fresh market sectors. Slugs are also a problem, causing over £15 million worth of losses across all sectors. In the untreated situations, late blight would dominate the losses with a value of £363 million, almost half the production. PCN, slugs and the most competitive weeds would all cause a similar level of losses in output, in the region of £55 million each. If no weed control was practiced, losses could be in the region of £228 million, however this is negated by the use of mechanical weeding. In the seed sector, where PCN issues are avoided through use of clean land, blight is still the most important problem, but aphid control for reducing virus infections is second and slugs third.

Future pesticide availability will be affected by legislative changes, environmental factors and market requirements. Most of these changes will result in reduced availability, however the agrochemical industry is developing new actives that may replace or improve current pesticides.

There is still some uncertainty over impacts of revisions of 91/414/EEC 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. A number of scenarios, based on a PSD report released in December 2008, were assessed to determine the effect on potatoes. After the vote in the European Parliament (13th January 2009), it is likely that the least severe of the four PSD scenarios (scenario 2c) will be close to the final outcome, but much will depend on final implementation. If this is the case it would result in the loss of about 23 active substances, of which only 20 are approved for use in the UK. Of these 20 active substances, 5 are used in the production of

potatoes - 2 are fungicides (mancozeb and maneb) and 3 are herbicides (linuron, pendimethalin and glufosinate ammonium).

Under scenario 2c the greatest economic losses to potatoes are due to poorer blight control due to the loss of mancozeb and maneb. Disease control may be affected by an increase in resistance, and costs of blight control programmes will increase. The losses of the herbicides linuron and pendimethalin, which are likely, as well as metribuzin (which depends on definitions of endocrine disruption), will not necessarily cause large yield effects but herbicide costs will increase, with more emphasis on one or two post-emergence products, both of which have limited weed control spectrum, and some increased mechanical weed control. With no change to insecticide availability there is no impact on pest control.

Grass weed control in potatoes may also be affected by actives failing to achieve Annex 1 listing before end December 2009. 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 including cycloxydim, quizafop-P-tefuryl and propaquizafop used for grass weed control on a small area of potatoes. 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. However, tepraloxydim is on Annex 1 and although not currently approved for use on potatoes, is likely to be able to gain an approval if the need arose. Another notable active substances affected is metaldehyde, which, is widely used for the control of slugs in combinable crops and already under pressure from the Water Framework Directive (WFD).

The implementation of the WFD and the Drinking Water Directive, 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, in potatoes or other crops. Many of the at-risk products are used in combinable crops with few impacts direct impacts on weed or disease control in potatoes, although the loss of bentazone would reduce the post-emergence weed control options in ware potatoes to two active substance (rimsulfuron and metribuzin), and in seed potatoes to one (metribuzin), or none on certain varieties where metribuzin is not tolerated. If this is in combination with the changes to 91/414/EEC, that weaken the pre-emergence options, then this could lead to weedier crops and some yield loss.

More serious, is the threat to insecticides with many potentially at risk under the WFD. As a result there could be very limited options for the control of some pest species. At present, slugs and potato cyst nematodes are two key pests of ware potatoes, and aphids in seed production. Other pests tend to cause minimal damage at an industry scale, although can cause localised problems. Slugs in particular could be difficult to control. Metaldehyde is used widely in many crops in the rotation, and is already under scrutiny due to water contamination. Any restrictions on use of metaldehyde could result in an increase in use of methiocarb, the only other slug control option in potatoes, which may in turn become a problem in water. Loss or limitations in use, of methiocarb would have very serious implications for potato production, and other crops.

Potato cyst nematodes cause serious yield losses in processing and fresh market potatoes, even with current control option. The loss of nematicides would mean much higher losses, and would need a change in rotation planning in order to minimise the impacts. Other alternative control methods such as trap cropping or soil sterilisation are expensive and still largely unproven commercially.

In the seed sector, loss of aphicides could be serious, however it is unlikely that all actives would be withdrawn.

The loss of active substances as a result of needing to meet WFD requirements would be additional to any losses from the revision of 91/414/EEC, so blight, weeds, slugs and PCN control could all be affected.

Residues and market acceptability may also limit usage of pesticides. Of the actives being found as residues on raw product or in food products, chlorpropham (CIPC), sprout suppressant is the most critical for potato production and there is already a stewardship programme in place. Loss of CIPC would have significant impacts on the storage of potatoes. Glyphosate residues are found in cereals, and any restriction on use pre-harvest could impact on control of potato volunteers and couch control, with consequences for PCN build up and weed control respectively.

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. Of these, the insecticides are of most interest in potato production. 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 to produce non-genetically modified blight resistant crop plants.

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 metribuzin	Weed control	2011-2020
	mancozeb maneb	Blight	2011-2020
Failure to achieve Annex 1 listing	metaldehyde (with potential consequences for methiocarb)	Slugs	By December 2010
	Cycloxydim propaquizafop quizalofop-P-tefuryl	Grass weeds Grass weeds Grass weeds	
WFD	metaldehyde (with potential consequences for methiocarb)	Slugs	2009 onwards
	Chlorothalonil	Blight	2009 onwards
	Insecticides	All pests	2009 onwards
Market acceptability	Chlorpropham	Sprout control	Now
	glyphosate (in rotation)	Couch and volunteer cereal	Now

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

Losses to industry £M		Weeds	Disease			Pests					
Crop	Scenario	All weeds	Blight	Dry rot	Stem Canker, Black scurf, Silver scurf, Skin spot, Black dot (Combined skin diseases)	Potato cyst nematodes	Slugs	Peach potato aphid	Potato aphid	Free living nematode	Wireworm
Processing	Revision 91/414/EEC (2c)	4.8	7.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	WFD	4.8	0.0	0.0	0.0	16.4	13.6	0.0	0.0	1.0	0.7
	Untreated	55.0	83.6	3.0	0.0	16.4	13.6	3.2	0.0	0.8	0.7
	Business as usual	1.9	14.2	1.7	0.0	7.5	3.9	1.9	0.0	3.0	0.4
Fresh	Revision 91/414/EEC (2c)	6.8	17.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	WFD	6.8	0.0	0.0	0.0	38.9	33.7	0.0	0.0	2.2	1.8
	Untreated	135.0	207.8	13.1	7.3	38.9	33.7	7.9	0.0	2.2	1.8
	Business as usual	4.8	35.1	4.1	2.4	18.5	9.8	4.8	0.1	7.2	1.0
Seed	Revision 91/414/EEC (2c)	1.9	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	WFD	1.9	0.0	0.0	0.0	0.0	5.5	0.9	0.0	0.0	0.3
	Untreated	25.0	38.1	1.3	2.3	0.0	5.5	16.6	0.0	0.0	0.3
	Business as usual	0.8	6.3	0.7	0.4	0.0	1.7	5.2	0.0	0.0	0.2
Total	Revision 91/414/EEC (2c)	13.5	27.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	WFD	13.5	0.0	0.0	0.0	55.3	52.8	0.9	0.0	3.2	2.8
	Untreated	215.0	329.5	17.4	9.7	55.3	52.8	27.6	0.0	3.0	2.8
	Business as usual	7.5	55.6	6.5	2.8	25.9	15.4	11.9	0.1	10.2	1.5
	Significant losses of	>30% from standard GM 20-30% from standard GM 10-20% from standard GM									

The economic impacts on gross margin (£ million per year):

- Improvements over Business as Usual – assuming no current options are lost
    - Improving blight control could increase output by up to £56 million.
    - Slugs currently cost the industry £15.4 million.
    - In processing and fresh market potatoes, PCN causes £26 million in losses
    - In the seed sector gross margin losses due to virus is estimated at £26 million, the largest impact after blight in the sector.
- Losses due to revision on 91/414/EEC
    - The impact of changes in blight programmes is a loss of £28 million
    - There would be minimal impact from changes to weed control by using alternative actives or mechanical weeding, but increased costs would reduce gross margin by £13 million.
    - There is potentially greater impact in seed crops due to lack of post-emergence options.
- Water Framework Directive – could potentially have the most significant impact:
    - Losses from PCN could cost the ware sector up to £55 million (with no mitigating action)
    - Loss of slug control could cost the industry £53 million

Table ES3 summarises in a matrix, the major areas of loss and priority. 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 ES3 Summary matrix of research priorities

Crop protection priorities - potatoes	Weeds	Pests						Diseases			Store	Issue	Research activities	Knowledge transfer
	Weeds	Potato cyst nematode	Slugs	Peach Potato Aphid	Potato aphid	Free living nematode	Wireworm	Blight	Dry Rot	Skin diseases	Sprout control			
Breeding and genetics		1		1				1				Longer term option for reducing reliance on pesticides	Improve genetic resistance/tolerance to pests & disease	Highlight priorities to plant breeding companies
Disease management								1	3	?		Blight is the largest cause of yield loss in current production	Improvements required in current levels of blight control	
												Blight control costs will increase, and risk of resistance will increase with loss of mancozeb under 91/414/EEC 2c	Loss of mancozeb under 91/414/EEC will need revised blight programmes to increase effectiveness, minimise resistance and costs.	Advice on avoiding resistance
												Dry rot is not a major cause of production loss but increased resistance could increase storage losses	Alternative to thiabendazole	
Pest management		1	1	2								Slugs greatest pest threat under BAU and potentially under WFD	Improve ability to target and maximise effectiveness of slug control	Communicate existing best practice and interact with metaldehyde stewardship group in order to protect active. Liaise with other sectors to maximise impact throughout rotation.
												PCN is one of greatest pest threats to ware production with high individual crop losses.	Review efficacy and economics of alternative control measures, also minimising resistance risks	
												Virus transfer by aphids is particular concern in seed industry with some current losses, which could increase if actives lost under WFD, and greater risk of increased resistance		Communicate current resistance management strategies
Weed management	2											Weed control options will be limited by 91/414/EEC and water framework directive, including rotational control of weeds such as couch and volunteer potatoes	Understand weed distribution and competitivity to identify key weeds in potatoes	
													Review efficacy and economics of alternative control measures	Monitor Annex listings and ensure alternative active substances are approved for potatoes to fill gaps
												Cultivation for weed control will become more important	Improve prediction of weed emergence patterns and improve predictions of need and timing	
												Seed sector is particularly at risk, loosing all post-emeregence actives	Identify new post-emergence products for key weed control	
Store management and sprouting control											1	Continued pressure on sprout suppressants from residue levels and market acceptability		Continue stewardship support and maximise uptake
Pesticide application & formulation	2		1										Develop opportunities for improved formulation and application to minimise risk of water contamination	
													Understand major routes by which pesticides reach water	
Precision farming	2		1					2					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
Pesticide risk management	1	1	1	1	1			1			2		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	Promote existing knowledge on the need for responsible pesticide applications

KEY

based on economic impact and likelihood of loss of active

1	High	3	Low
2	Medium	?	For discussion

Contents

1.0 Introduction

The availability, efficacy and suitability of pesticides (Plant Protection Products – PPPS) for the control of weeds, pests and disease in UK potatoes 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. Alongside this is the development of resistance in target organisms, such as late blight, 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). This is affecting some actives, particularly those such as chlorpropham in potatoes which can be found at detectable levels in tuber samples post-harvest. These changes will affect UK potato production and economics and it is vital to understand the impacts in order to prioritise levy investment to address threats.

2.0 Objectives

The overall aim of the project was to identify, the most economically significant threats to production, in processing, fresh and seed potatoes, due to the reduced availability of pesticides in the next 5-10 years, in order to inform priorities for levy investment. Specific objectives include:

1. Estimation of 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.

3.0 Methodology

3.1 Overview

The recent report by ADAS for European Crop Protection Association (ECPA)[1] provided a methodology and a framework for evaluating the yields and quality implications and subsequent impacts on gross margin, of reduced availability of pesticides. The report included an assessment of potatoes based on the limited availability of pesticides determined by the 91/414/EC proposals. The ECPA report has provided a good basis for extending the work to cover other actives and more detail on potato market sectors. The market sectors covered in this report are processing, fresh market and seed potatoes. This report reviews the economic impacts of weeds, pests and disease under current conditions, untreated and reduced pesticide scenarios.

[1] Clarke et al (2008)

3.2 Analysis framework

The analysis framework was developed to allows figures to be added or updated as information becomes available or to try 'what if' scenarios. The potato analysis framework was developed alongside other sectors – cereals, oilseeds, protein crops, forage crops and grassland – to ensure a common platform. An adaptation was required for potatoes in order to differentiate between impacts on harvested yield and impacts on marketable yield.

The analysis framework has separate assessments for the three main potato market sectors – processing, fresh market (including chip shop trade) and seed. For each market sector there is an analysis for individual 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.
- Area affected by each weed, pest or disease, expressed as % area.
- Yield impact for each weed, pest or disease, expressed as % loss in harvested yield.
- Impact on quality or storage losses expressed as % loss in marketable yield.
- 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.

The framework is structured so that the yield and quality impacts of individual weeds, pests and diseases can be assessed and compared under different scenarios.

- 'business as usual'
- Untreated
- 91/414/EEC revised proposals (December 2008) – 4 scenarios
- Water Framework Directive impacts

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

- Resistance impacts
- Reduced availability through market acceptability
- Other specific issues

Information from the individual weed, pest or disease effects were collated into a summary sheet for each of the market sectors and comparisons made in terms of impact on industry level production and economic impact of individual weeds, pests and diseases in each sector.

A consultation was held with representatives from PCL, HGCA, HDC, EBLEX and DairyCo, to discuss preliminary results and ensure cross-sector factors were fully understood.

3.3 Identifying area affected, harvest yield impacts and market yield impacts

Specialists identified the key weeds, pests and diseases with chemical control that affect potatoes in the 3 main market sectors – processing, fresh market and seed – and made estimates of area affected, harvest yield impacts and market yield impacts.

The area of potatoes affected by weeds, pests and disease will vary each year depending on a range of factors including rotation and weather, so a typical average was taken. There can be reductions in yields and/or quality depending on the final market.

The impact of weeds, pests and diseases on the weight of crop harvested is expressed as a % reduction in harvested yield.

Where there was an impact on the saleability of the potatoes due to quality aspects or losses in store, this is expressed as a % reduction in marketable yield.

In establishing the area, yield and 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)
- Other specific research
- Expert opinion

Initial assessments of areas affected by each of the weeds, pests and diseases were discussed with specialist potato agronomists for validation.

The area affected and yield impacts for each market sector were initially identified for 2 scenarios:

- Business as usual with currently available treatments
- Untreated

Following the assessment of future pesticide availability further scenarios were added:

- 91/414/EC (3 separate scenarios depending on final outcome)
- Water Framework Directive
- Others

3.4 Economic impacts of key weeds, pests and diseases

For each sector (processing, fresh market and seed) a 'business as usual' gross margin was developed based on costs from John Nix Farm Management Pocketbook[2] for maincrop processing and fresh market potatoes, and from SAC Farm Management Handbook[3] for seed crops (Table 1).

Table 1 Business as usual gross margin

		Sector		
	Unit	Processing	Fresh Market	Seed
Total area	Ha	36,000	86,000	17,000
Average yield	t/ha	49	43	25
Average price	£/t	110	130	200
UK production	Tonnes	1,746,000	3,698,000	432,000
UK value	**£ million**	**192**	**462**	**86**
Inputs				
Seed	£/ha		690	1,200
Fertiliser	£/ha		661	586
Herbicides	£/ha		100	70
Insecticides	£/ha		125	50
Fungicides	£/ha		275	215
Cultivation costs	£/ha		270	-
Other	£/ha		1,158	871
Total UK inputs	**£ million**	**118**	**282**	**51**
UK gross margin	**£ million**	**76**	**199**	**35**
Gross margin/ha	£/ha	2,100	2,300	2,040

2 Nix, J. (2009) The John Nix Farm Management Pocketbook
3 SAC (2009) Farm Management Handbook

For each scenario (business as usual, untreated, different pesticide availability) the net impact on harvest yield and market yield was calculated for each weed, pest or disease, along with any changes in input costs (mitigating measures), to achieve the new sector gross margin. This was then compared with the standard figure to establish the change in margin. In this way the weeds, pests and diseases can be ranked in order of economic impact.

3.5 Assessment of future status of pesticide availability

A review of actives currently used in potato crop was undertaken to identify if and when they will be affected and the reasons for, and likelihood of reduced availability. The ECPA report included a review of actives likely to become unavailable for potato production due to 91/414/EEC, and this has been updated and refined for each of the crops, and other reasons examined, such as resistance, Water Framework Directive and market requirements, to provide a full picture of availability and timescale. Changes to pesticide availability in the future falls into a number of categories:

- Reform of 91/414/EEC
- Annex 1 listing deadline of December 2010
- Water quality
- Market acceptability
- Resistance
- Withdrawal of active/products by manufacturers for commercial reasons
- New actives/products under development

The availability of active substances under each of these scenarios was assessed to identify the key impacts, and the timescale.

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.

3.6 Evaluation of alternative control methods

In the absence of current chemical control, there may be other options available such as alternative plant protection products, 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 was evaluated where information was available. This was based on current research, to identify actions that may be used to mitigate the impacts of changes in pesticide availability, and their associated costs. The costs of likely mitigating measures were taken into account in the analysis of the gross margins.

3.7 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.

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

4.1 Background Statistics

4.1.1 Area yield and production

The area of potatoes grown in the UK has remained fairly static over the past 5 years at around 140,000ha, although there was a small increase in 2008 to 145,000ha[4]. Potato Council statistics for Great Britain show that in 2007 there were 2871 registered growers, growing 124,000ha or an average of 43ha each. Average maincrop yields were 42.2t/ha with total UK production of 5.45 million tonnes[5].

When measuring the relative impacts of different weeds, pests and diseases it is important to distinguish between the three broad markets – seed, fresh market and processing - as impacts vary depending on the particular market specifications. It is acknowledged that there are further specialisations, particularly within the fresh market, with earlies, salad crops, bagged chip market and pre-pack, however the general market requirements are similar so are viewed as one market.

Around 26% of the potato area is grown for processing including crisps and frozen chips. The yields in this sector are higher at around 49t/ha.

The fresh market accounts for 62% of the potato production grown on 86,000ha. This includes pre-pack and potatoes for the chip shop and bag market. Average yields are around 43t/ha.

The remaining 12% of the area of potatoes is grown for seed. Of the 17,000ha seed area, almost 11,000ha are grown in Scotland, making up around 50% of the Scottish potato area. Yields are generally lower than ware production at around 25t/ha harvested yield.

Area, production and yield figures are summarised in Table 2.

Table 2 Potato market by sector

	HG area		HG supply		Average harvested yield
	Ha	%*	Tonnes	%	t/ha
Total	140,000**		5,880,000		42**
Seed	17,000	12%	432,000	7%	25***
Fresh market	86,000	62%	3,698,000	63%	43*
Processing	36,000	26%	1,764,000	30%	49*

*Potato Council
**Defra 2008
***SASA

[4] Defra (2008) June Census Survey
[5] Potato Council (2008) Consumption and processing in GB

4.1.2 Prices

Prices for potatoes vary significantly between years and market segment, and within market segment depending on quality. For the purposes of this study an average price for sold potatoes for each sector is used. These figures take into account the range of prices within a season including any wastage or stockfeed (Table 3).

Table 3 Typical potato prices by sector

	Average
	£/t
Seed	200
Fresh Market	130
Processing	110

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:

- 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

Weeds can cause yield losses at high populations, while some such as cleavers can interfere with harvest and others such as high populations of couch can cause quality problems or encourage pest attacks. Weeds in themselves rarely directly cause losses of quality.

Yield losses in potatoes in the absence of any weed control varies enormously between studies, ranging from 14% to 80%, with an average of around 30%[6], and the same will be true in the field depending on which weeds are present, planting date, variety and weather, all of which impact on the early growth of the potato and its ability to out-compete the weeds.

For this analysis, the impact of a particular weed on potato production was determined by the competitiveness of the weed, the weed population density and the area affected by the weed. There is little research on yield effect of individual weeds on potatoes. The competitiveness of weeds in potatoes was therefore based on research by Blair *et al*[7] on relative weed competitiveness in cereal, and was used along with an estimate of the typical weed population densities[8] to estimate the total yield effect. The area affected by individual weeds was determined from a survey of

[6] Various sources
[7] Blair AM, Cussans JW, & Lutman PJW (1999) A biological framework for developing a weed management support system for winter wheat: weed competition and time of weed control. *Proceedings 1999 Brighton Conference – Weeds,* Brighton, UK, 753-760.
[8] Expert opinion and validation comments from agronomists

weeds by Whitehead and Wright[9]. This survey was conducted in winter cereals and gave an indication of typical areas affected by common weeds. There are limitations in the work as it is likely that it will over-estimate the area of predominantly heavy land weeds such as black-grass, and may under-estimate the area affected by lighter land weeds in predominantly spring rotations such as sugar beet and spring barley. In particular, common weeds of potatoes such as bindweed, redshank and knotgrass were not included in the survey so there is limited information on the effect of these weeds.

- The weeds with the highest competitive index (relative to cereals but assumed similar for potatoes) are cleavers, oilseed rape, rye-grass and black-grass.
- The most common weeds in an arable rotation (and assumed for potatoes) are chickweed, annual meadow grass, field speedwells, mayweed, found in 94%, 74%, 72% and 67% of fields respectively. Cleavers are also an important weed, present in 58% of fields.
- It is assumed that common weeds of potatoes, bindweed, redshank, fat hen and knotgrass will have a competitive index of no more than cleavers, and a similar area affected.

There is significant variation in weed distribution depending on soil type, rotation and previous management but for this analysis there is assumed to be no difference between the sectors for weed incidence and competitive effects and control levels, so production impacts will be pro rata on production for the sectors.

The impact of weeds on harvest and market yield was evaluated under two scenarios:

1. Business as usual where herbicides are applied under conventional management
2. Untreated

Business as usual
In the business as usual scenario (Table 4) the impact on potential production, (calculated from the area affected, the competitive index and the weed density) from most individual weeds was very low with less than 0.5% of production potential lost due to weed competition for most weeds. The biggest impact came from cleavers (0.87% loss in production) due to their competitive nature and wide spread across the country. Annual meadow grass was second in terms of loss of production potential, despite its low competitive index, it can result in low level losses over a large area. The incidence of poor control of annual meadow grass is likely to increase with the loss of paraquat in 2008.

Bindweed and redshank could have a similar impact to cleavers.

Untreated
In the untreated situation, losses from individual weeds were higher, with up to almost 8% of production lost from cleavers, and 7% for annual meadow grass and rye-grass.

Bindweed and redshank could have a similar impact to cleavers.

[9] Whitehead,R and Wright, H.C. (1989) The incidence of weeds in winter cereals in Great Britain. Brighton Crop Protection Conference-weeds-1989. Volume 1 pages 107-118.

Losses to couch were low based on these incidence levels, even in the untreated scenario, but ensuring that levels do not build up to high populations is dependent on good control in other parts of the rotation using products such as pre-harvest glyphosate.

Weeds are seldom treated individually, and average yield losses would lead to a reduction in production of 30% in the untreated situation.

Table 4 Summary of production losses due to weeds in business as usual and untreated scenarios

			Business as usual Loss of production potential			Untreated Loss of production		
Weed	**Competitive index**	**Area affected**	**% yield loss**	**Loss of yield potential**	**Loss of yield potential**	**% yield loss**	**Loss of production**	**Loss of production**
	%	%	**%**	**Tonnes**	**%**	**%**	**Tonnes**	**%**
Cleavers	3.00%	58%	1.50%	51,000	0.87%	13.50%	461,000	7.8%
Rye-grass	0.55%	14%	4.40%	37,000	0.63%	50.60%	417,000	7.1%
Annual Meadow Grass	0.10%	79%	1.00%	46,000	0.78%	9.00%	418,000	7.1%
Wild Oilseed Rape	1.00%	42%	1.00%	25,000	0.42%	9.00%	223,000	3.8%
Mayweed	0.40%	67%	0.80%	31,000	0.53%	5.20%	205,000	3.5%
Chickweed	0.20%	94%	0.60%	33,000	0.56%	3.40%	188,000	3.2%
Poppy	0.30%	18%	0.60%	6,460	0.11%	8.40%	89,400	1.5%
Shepherd Purse	0.30%	23%	0.60%	8,000	0.14%	5.40%	73,300	1.2%
Charlock	0.40%	36%	0.40%	9,000	0.15%	2.80%	59,300	1.0%
Barren Brome	0.13%	13%	0.13%	1,070	0.02%	6.37%	49,500	0.8%
Field Speedwell	0.08%	72%	0.08%	3,240	0.06%	1.12%	47,400	0.8%
Black-grass	0.40%	5%	4.00%	12,000	0.20%	16.00%	47,000	0.80%
Volunteer Rape	0.40%	23%	0.40%	5,390	0.09%	2.80%	37,700	0.6%
Couch	0.33%	21%	0.33%	4,290	0.07%	2.97%	36,700	0.6%
Rough Meadow Grass	0.33%	7%	0.66%	3,200	0.05%	7.59%	33,300	0.6%
Red Dead Nettle	0.08%	47%	0.08%	2,160	0.04%	1.12%	32,200	0.5%
Parsley-Piert	0.20%	12%	0.40%	3,200	0.05%	3.60%	26,800	0.5%
Fumitory	0.08%	17%	0.16%	1,120	0.02%	2.24%	24,600	0.4%
Ivy-leaved Speedwell	0.08%	30%	0.08%	1,100	0.02%	1.12%	21,400	0.4%
Field Pansy	0.02%	45%	0.08%	2,150	0.04%	0.42%	10,800	0.2%
Fat Hen	0.20%	13%	0.20%	1,110	0.02%	1.40%	10,800	0.2%
Geranium sp.	0.08%	11%	0.40%	3,190	0.05%	1.20%	7,600	0.1%
Volunteer cereals	0.30%	7%	3.00%	12,890	0.22%	6.00%	24,800	0.42%
Thistles	0.30%	4%	0.90%	2,890	0.05%	2.10%	6,500	0.11%
Volunteer potatoes	0.30%	4%	1.50%	3,150	0.05%	3.00%	10,800	0.18%

Value of losses

The value of these losses from individual weeds in each of the sectors is shown in Table 5. In the business as usual situation, the loss of potential value is low for most weeds with cleavers, rye-grass and annual meadow grass causing £4-7 million of losses.

In the untreated scenario, the highest losses for individual weeds could cause £45-60 million in lost output. This is equivalent to 6-8% of current output.

Losses without any form of weed control could cause yield losses of around 30% which would lead to loss in output of £228 million, if no other measures were taken, however mechanical weeding would reduce these losses.

Table 5 Output losses in each sector under business and usual and untreated scenarios

	Business as usual Loss of potential output				Untreated Loss of output			
Weed	**Processing**	**Fresh**	**Seed**	**Total**	**Processing**	**Fresh**	**Seed**	**Total**
	£ million	£ million	£ million	£ million	£ million	£ million	£ million	£ million
Cleavers	1.5	3.6	1.4	6.5	13.2	32.9	12.7	58.8
Rye-grass	1.1	2.6	1.0	4.7	11.9	29.7	11.5	53.2
Annual Meadow Grass	1.3	3.3	1.3	5.9	12.0	29.8	11.5	53.3
Wild Oilseed Rape	0.7	1.8	0.7	3.2	6.4	15.9	6.2	28.4
Mayweed	0.9	2.2	0.9	4.0	5.9	14.6	5.7	26.1
Chickweed	0.9	2.4	0.9	4.2	5.4	13.4	5.2	24.0
Poppy	0.2	0.5	0.2	0.8	2.6	6.4	2.5	11.4
Shepherd Purse	0.2	0.6	0.2	1.0	2.1	5.2	2.0	9.3
Charlock	0.3	0.6	0.2	1.1	1.7	4.2	1.6	7.6
Barren Brome	0.0	0.1	0.0	0.1	1.4	3.5	1.4	6.3
Field Speedwell	0.1	0.2	0.1	0.4	1.4	3.4	1.3	6.0
Black-grass	0.3	0.9	0.3	1.5	1.3	3.4	1.3	6.0
Volunteer Rape	0.2	0.4	0.1	0.7	1.1	2.7	1.0	4.8
Couch	0.1	0.3	0.1	0.5	1.0	2.6	1.0	4.7
Rough Meadow Grass	0.1	0.2	0.1	0.4	1.0	2.4	0.9	4.2
Red Dead Nettle	0.1	0.2	0.1	0.3	0.9	2.3	0.9	4.1
Parsley-Piert	0.1	0.2	0.1	0.4	0.8	1.9	0.7	3.4
Fumitory	0.0	0.1	0.0	0.1	0.7	1.8	0.7	3.1
Ivy-leaved Speedwell	0.0	0.1	0.0	0.1	0.6	1.5	0.6	2.7
Field Pansy	0.1	0.2	0.1	0.3	0.3	0.8	0.3	1.4
Fat Hen	0.0	0.1	0.0	0.1	0.3	0.8	0.3	1.4
Geranium sp.	0.1	0.2	0.1	0.4	0.2	0.5	0.2	1.0
Volunteer cereals	0.4	0.9	0.4	1.6	0.7	1.8	0.7	3.2
Thistles	0.1	0.2	0.1	0.4	0.2	0.5	0.2	0.8
Volunteer potatoes	0.1	0.2	0.1	0.4	0.3	0.8	0.3	1.4
Total losses*	1.9	4.8	0.9	7.6	58	144.	25.9	228

*Based on 30% overall yield loss

Conclusions

- There is a need for more reliable information on weed distribution in potato crops and yield impacts of individual weeds to validate or improve the reliability of these findings

- Weeds that are widespread and have a higher competitive index pose the greatest threat to yield – cleavers, rye-grass, annual meadow grass and possibly bindweed, redshank and fat hen.
- With currently available pesticides loss of potential production due to the most competitive weeds is low (<1%), with a value of £5-7 million.
- In the absence of any treatment for weed control yield losses from the most competitive weeds could reduce production by 6-8%, with a value of £45-60 million.
- Weeds are seldom treated individually, and average yield losses would lead to a reduction in production of 30% in the untreated situation, worth £228 million over the sectors.

4.3 Diseases

There are over 30 fungal, bacterial and viral diseases which could have an economic impact on the potato crop in the UK. The potato crop is vulnerable to fungal diseases at every stage of the growing season, with the haulm, roots, stolons and tubers targeted by various pathogens.

The main entry routes for diseases into potato crops are through infected seed and air borne on the foliage, along with some soil borne pathogens, all of which can lead to tuber infection in progeny crops and quality losses, depending on the market.

Pesticide treatments for disease fall into three main categories – pre-panting seed treatment (rhizoctonia, silver scurf, black dot), foliage sprays (blight) and post-harvest storage treatments (silver scurf, dry rot) – along with some pre-planting soil fungicides.

The majority of fungicides applied to potatoes are to control late blight. Over 18 active ingredients are available individually or in co-formulations for the control of foliar late blight in the UK. The most recent survey of potato diseases in the UK was done in 2000, when it was estimated that bacterial, fungal and viral diseases may account for up to 15% of the losses in ware and seed crops annually[10]. Over 2 M ha of fungicides were applied to potato crops in 2006[11]. The most frequently applied active ingredients were mancozeb to 0.8 M ha, cymoxanil to 0.6 M ha, fluazinam to 0.4 M ha, and cyazofamid to 0.3 M ha. Mancozeb is applied frequently in co-formulations and only 8% of the 0.8 M ha treated with mancozeb alone.

Seed-borne diseases that can affect yield and quality include rhizoctonia (causing stem canker and black scurf), silver scurf and black dot. Post-harvest diseases that develop in store include silver scurf, fusarium dry rots. These diseases can be minimise by the use of fungicides such as azoxystrobin, flutolanil, imazalil and thiabendazole. Powdery and common scab are also important diseases, particularly for the fresh market, and are controlled through cultural practices as there are no chemical control measures currently available.

The impact of each main disease on potato production was estimated from the area affected by the disease, using the Pesticide Usage Survey[12] as a guide, and the

[10] CSL (2001) Potatoes: a survey of diseases 2000/01
[11] CSL (2006) Pesticide Usage Survey - potatoes
[12] CSL (2006) Pesticide usage survey

impact on harvested and marketable yield sourced from research studies where available and expert opinion where no yield figures were available.

The impact of disease on harvested and market yield were evaluated under two scenarios:

1. Business as usual where fungicides are applied under conventional management
2. Untreated

Each scenario was examined for each of the 3 potato sectors – processing, fresh market and seed.

Business as usual

Under current treatment, (Table 6), late blight is the most serious disease for potatoes in the UK, with the risk affecting the majority of crops, requiring preventative programmes even in the absence of disease. In years of moderate blight pressure and with applications of blight programmes it is estimated that harvest yield losses are still in the region of 7% and marketable yield by a further 0.3%[13] due to problems in store, with a lost yield potential of 430,000 tonnes.

Diseases such as stem canker, black scurf, silver scurf, black dot and skin spot are less widespread and affect quality rather than yield. These diseases have a bigger impact on the seed market where seed health is paramount, and the fresh market where skin appearance is important in accessing the top pre-pack markets. Around 43% of the area is treated for these diseases each year. Harvest yield losses are generally quite low at less than 1% of yield[14] in both the business as usual and untreated scenarios. There are higher losses of market yield[15], with some differences between the sectors but the total losses are small compared to the impact of blight. Stem canker causes the greatest losses.

Storage diseases such as dry rot have relatively small impact with current treatment at only 2% of total yield[16], and is more significant in terms of production than the skin diseases, with lost yield potential of 41,000 tonnes.

Table 6 Estimates of impacts on harvested and market yields from disease – business as usual with currently available treatments

	All sectors			Processing	Fresh	Seed
Disease	**% area affected***	**Lost yield potential – harvest yield**	**Lost yield potential – market yield**	**Lost yield potential**	**Lost yield potential**	**Lost yield potential**
	%	**%**	**%**			
Late blight	100%	7.0%	0.3%	128,000	270,000	31,000
Dry rot	43%	0.0%	2%	15,000	32,000	4,000
Stem canker	49%	0.5%	1%	8,000	18,000	2,100
Black scurf	49%					
Silver scurf	43%					
Skin spot	43%					
Black dot	15%					
Powdery scab	10%	0.0%	1%	1,000	2,000	<1000

Untreated

In the untreated situation (Table 7) harvest yield losses from late blight can be in excess of 40%[17] with up to a further 15% of losses in market yield in store[18]. In store,

[13] ADAS (2002) Testing the sustainability of stockless arable organic farming on a fertile soil. Defra OF0301

[14] Various references and expert opinion (see full references section)

[15] Various references and expert opinion (see full references section)

[16] British Potato Coucil (2006) Managing the risk of dry rot – Growers guide

late blight lesions also make potatoes more susceptible to dry and soft rots. All crops are at risk of blight although seed crops and earlier harvested crops are less at risk. In total over 2.8 million tonnes could be lost.

Stem canker, black scurf, black dot and skin spot in the untreated situation, have a bigger impact reducing yield by up to 7% combined, with the largest impact in the fresh market sector. One of the key mitigating measures against these diseases in ware is use of high quality seed, however seed availability may be an issue if similarly affected.

The losses due to dry rot in store is expected to more than double in the absence of any treatment. Much will depend on the type and management of the stores.

Table 7 Estimates of impacts on harvest and market yields from disease – untreated

	Processing				
Disease	**% area affected**	**Lost yield – harvest yield**	**Lost yield – market yield**	**Lost production**	**Lost production**
	%	**%**	**%**	t	%
Late blight	100%	40.0%	15.0%	841,000	47.7%
Dry rot	43%	0.0%	4.0%	30,000	1.7%
Stem canker	49%	2.0%	5.0%	52,000	2.9%
Black scurf	49%				
Silver scurf	43%				
Skin spot	43%				
Black dot	15%				
Powdery scab	10%	0.0%	1.0%	2,000	0.1%
	Fresh				
Disease	**% area affected**	**Lost yield – harvest yield**	**Lost yield – market yield**	**Lost production**	**Lost production**
	%	**%**	**%**	t	%
Late blight	100%	40.0%	15.0%	1,764,000	47.7%
Dry rot	43%	0.0%	4.0%	64,000	1.7%
Stem canker	49%	2.0%	5.0%	109,000	2.9%
Black scurf	49%				
Silver scurf	43%				
Skin spot	43%				
Black dot	15%				
Powdery scab	10%	0.0%	2.0%	7,000	0.2%
	Seed				
	% area affected	**Lost yield – harvest yield**	**Lost yield – market yield**	**Lost production**	**Lost production**
	%	**%**	**%**	t	%
Late blight	100%	40.0%	15.0%	207,000	47.9%
Dry rot	43%	0.0%	4.0%	7,000	1.6%
Stem canker	49%	2.0%	5.0%	13,000	3.1%
Black scurf	49%				
Silver scurf	43%				
Skin spot	43%				
Black dot	15%				
Powdery scab	10%	0.0%	2.0%	<1000	<0.5%

[17] Zarb, J., Ghorbani, R., Juntharathep, P., Shotton, P., Santos, J., Wilcockson, S., Leifert, C., Litterrick, A.M., Bain, R.A., Wolfe, M. (2002) Control strategies for late blight in organic potato production. From Powell et al (eds) UK Organic Research 2002:Porcessding of the COR Conference, 26-28th March 2002, Aberystwyth, pp.221-222.
[18] ADAS (2002) Testing the sustainability of stockless arable organic farming on a fertile soil. Defra OFO301

Value of losses

The value of these losses in potential yield in the business as usual scenario and the actual losses from the untreated, are dominated by losses due to late blight, which are in the region of £55 million in the current treated situation, and could be as high as £363 million in the untreated situation (Table 8). Other diseases are of relative low importance with currently available treatments, although dry rot still costs the industry around £7 million, and skin diseases £4 million. In the untreated situation losses from skin diseases could reach £23 million and dry rot £13 million.

Table 8 Loss in value of production in different market sectors

Disease	Processing		Fresh		Seed		Total	
	£ million		£ million		£ million		£ million	
	BAU	Untreated	BAU	Untreated	BAU	Untreated	BAU	Untreated
Late blight	14	93	35	229	6	41	55	363
Dry rot	2	3	4	8	1	1	7	13
Stem canker	1	6	2	14	0	3	4	23
Black scurf								
Silver scurf								
Skin spot								
Black dot								
Powdery scab	<1	<1	<1	1	<1	<1	<1	1

Conclusions

- Late blight is the most important disease with the potential to cause severe harvest and market yield losses if untreated.
- Even with current treatments, losses to late blight are significant and common.
- Predominantly seed borne diseases such as stem canker, black scurf, silver scurf, black dot and skin spot have only a small impact on harvest yield, but can have a larger impact on market yield particularly in the fresh market sector.
- After harvest, dry rot is an important disease and without treatment, likely to at least double the level of market yield loss.

4.4 Pests

Pests in potatoes fall into two main groups – those that have little effect on harvest yield, but can affect quality and the marketable yield, and those that have an impact on harvested yield, but without much impact on marketable yield.

The first group contains the soil pests such as slugs and wireworms, where the damage caused to tubers has little effect on the harvested yield but can have major effects on the marketable yield. Of the two, slugs are more serious concern as they are more widespread across all crop situations, while wireworms tend to be more of a risk after grassland or arable crops with grass weeds. Aphids also fall into this category, the impact of direct feeding is very low. Their greatest impact is as virus vectors which can impact quality in seed crops and yields in ware crops. Free living nematodes in the soil rarely cause large yield losses but they can transfer tobacco rattle virus which causes spraing, with major impacts on quality.

In the second group the main pest is potato cyst nematode. This is rarely a problem in seed potatoes as soil has to be shown to be free of the pest in order to grow seed potatoes. In fresh and processing potatoes it is one of the most expensive pests to control, with the biggest potential yield losses.

The impact of pests on harvested and market yield were evaluated under two scenarios:

1. Business as usual where fungicides are applied under conventional management
2. Untreated

Each scenario was examined for each of the 3 potato sectors – processing, fresh market and seed.

Business as usual
Under the business as usual scenario (Table 9) the most important pests in processing and fresh market is potato cyst nematodes. PCN is an important pest of processing and fresh market potatoes, where despite testing and treatment, harvest yields can be reduced by 16%[19]. Given that 24% of fields are treated annually, the impact on overall production is lower at just under 4%. There are no direct market yield effects, although a higher number of smaller tubers may cause a reduction in marketable yield. The situation is different in the seed sector (Table 10), where soils are routinely tested and potatoes are not grown if PCN is found so there is only a small effect from PCN (from where potatoes are rejected if PCN is found at testing).

Slugs are also an important pest, causing over 2% reduction in potential production overall, although individual crops losses can be much higher. A large proportion of the ware crops are treated for slugs, although this does vary year to year depending on the season, but with greater use of irrigation the risk often remains high.

Free living nematodes (causing spraing) reduce production by less than 2% overall, but losses in marketable yield of 30% are common despite treatment, but these only affect a small area.

Aphids cause some losses due to direct feeding damage and transmission of viruses.

Wireworm has a small effect on overall production (<1%), as it only affects a small area each year. The yield effects are mainly on the marketability of the crop, and can be severe in individual cases.

Table 9 Estimates of impacts on harvested and market yields from pests – business as usual with currently available treatments – processing and fresh

	Ware			Processing	Fresh	Ware total
	% area affected*	**Lost yield potential – harvest yield**	**Lost yield potential – market yield**	**Lost yield potential**	**Lost yield potential**	**Lost yield potential**
	%	**%**	**%**	t	t	%
Potato cyst nematode	24%	16.00%	0%	68,000	142,000	3.85%
Slugs	37%	0.50%	5%	36,000	75,000	2.08%
Peach-Potato aphid	100%	1.00%	0%	18,000	37,000	1.02%
Potato aphid	5%	0.50%	0%	<1000	<1000	<0.5%
Free living nematodes	3%	0.05%	30%	26,000	55,550	1.47%
Wireworm	2%	0.10%	10%	4,000	7,000	<0.5%

[19] Potato Council (2008) Impact of reduced pesticide availability on control of potato cyst nematodes

In the seed sector (Table 10), the impacts of pests is different, with the main pest being the peach potato aphid and the transfer of virus leading to downgrading or failure of the crop for the seed market. The combined downgrading and failure rate in England and Wales was 25% in 2007, which was a large increase on the 9% in 2006[20], but indicative of the problem. The impacts on the marketable yield have been scaled back from these figures to reflect that most were downgrades so potatoes could still be sold as seed, and few were actual crop failures. Slugs have a similar impact as in the ware sectors, with just under 2% reduction in yield potential, although given the earlier lifting date this may be over estimated.

Table 10 Estimates of impacts on harvested and market yields from pests – business as usual with currently available treatments - seed

	Seed			Seed	
	% area affected	**Lost yield potential – harvest yield**	**Lost yield potential – market yield**	**Lost yield potential**	
	%	**%**	**%**	T	%
Potato cyst nematode	0%	0.00%	1%	0	0.00%
Slugs	40%	2.70%	5%	8,500	1.97%
Peach-Potato aphid	100%	0.00%	5%	26,320	6.09%
Potato aphid	3%	0.45%	0%	10	0.00%
Free living nematodes	1%	0.70%	0%	10	0.00%
Wireworm	2%	0.1%	10%	1,000	0.23%

Untreated

In the untreated ware situation (Table 11), PCN continues to have the biggest net impact on production, but slugs are an increased threat, likely to cause a further 7% drop in production.

Table 11 Estimates of impacts on harvested and market yields from pests – untreated – processing and fresh

	Ware			Processing	Fresh	Ware
	% area affected*	**Lost yield – harvest yield**	**Lost yield – market yield**	**Lost yield**	**Lost yield**	**Lost yield**
	%	**%**	**%**	t	T	%
Potato cyst nematode	24%	37.00%	0%	157,000	315,000	8.64%
Slugs	37%	4.50%	15%	127,000	267,000	7.21%
Peach-Potato aphid	100%	2.00%	0%	35,000	74,000	1.98%
Potato aphid	5%	0.45%	0%	0	0	0.00%
Free living nematodes	3%	0.50%	10%	9,000	19,760	0.51%
Wireworm	2%	0.4%	20%	7,000	15,000	0.40%

In the seed sector (Table 12) aphids and virus transfer, have the largest net impact on production with reduction in the region of 10%. Slugs may also be a problem with up to 6% of production lost due to slugs.

[20] Potato Council (2009) A review of aphids and virus transmission in seed potato crops

Table 12 Estimates of impacts on harvested and market yields from pests - untreated - seed

	Seed			Seed	
	% area affected*	**Lost yield – harvest yield**	**Lost yield – market yield**	**Lost yield**	
	%	**%**	**%**	T	%
Potato cyst nematode	0%	0.00%	0%	0	0.00%
Slugs	37%	2.70%	15%	28,000	6.55%
Peach-Potato aphid	100%	0.00%	20%	43,000	9.95%
Potato aphid	3%	0.45%	0%	60	0.01%
Free living nematodes	1%	0.70%	0%	30	0.01%
Wireworm	2%	0.40%	20%	2,000	0.47%

Value of losses

The value of losses to pests (Table 13) highlights that in the business as usual scenario, PCN are the dominant pest, causing losses of £26 million between the processing and fresh market sector. Slugs are an important pest across all sectors, causing losses of over £15 million. In the seed sector the dominant pest is aphids, which cause £5.3 million of loss in value with current treatments, due to failures in achieving target seed grades.

In the untreated scenario, total losses due to PCN remains the highest at over £58 million affecting the ware sectors. Slugs increase in importance if not treatment is available with losses of over £54 million likely across all sectors. .

Aphid transfer of virus causes around £12 million of lost value under business as usual, of which, almost half is in the seed sector. In the untreated situation losses increase to over £22 million.

Table 13 Value of losses to pests

Disease	Processing		Fresh		Seed		Total	
	£ million		£ million		£ million		£ million	
	BAU	Untreated	BAU	Untreated	BAU	Untreated	BAU	Untreated
Potato cyst nematode	7.5	17.3	18.5	41.0	0.0	0.0	25.9	58.2
Slugs	4.0	14.1	9.8	34.7	1.7	5.7	15.4	54.3
Peach-Potato aphid	2.0	3.9	4.8	9.6	5.3	8.6	12.1	22.1
Potato aphid	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Free living nematodes	2.9	1.0	7.2	2.6	0.0	0.0	10.1	3.6
Wireworm	0.4	0.8	0.9	2.0	0.2	0.4	1.6	3.2

Conclusions

- PCN is the most significant pest, causing high losses even with treatment.
- Slugs cause significant losses across all sectors, and without treatment losses are on a par with those of PCN.
- PCN is a significant pest threat in the processing and fresh market sectors, causing high losses even with treatment.
- Aphid transfer of virus is most significant in the seed sector, where they are the pest causing the most significant losses.
- FLN (causing spraing) and wireworms are significant pests where they occur, but are only found of a small area, limiting their impact overall.

4.5 Priority weeds, pests and diseases

The comparison of economic impact of weeds pests and diseases across the industry (Table 14) shows that in the business as usual scenario late blight is the top cause of loss in output, causing losses of £55 million on average. PCN is also an important problem, with all losses coming in the processing and fresh market sector at £26 million. Losses to slugs are also significant at £15 million across all sectors. Dry rot, weeds and skin diseases also feature but have much lower impact than the top three.

It is important to note in the seed sector the ranking is different. Blight remains the top cause of losses at £6 million, but virus transfer of aphids is a close second at £5.3 million of losses. Slugs are third, causing £1.7 million losses.

Table 14 Business as usual rank of top losses – all sectors

Rank	Weed, pest or disease	Loss in output
		£ million
1	Blight	55
2	Potato cyst nematode	26
3	Slugs	15
4	Dry rot	7
5	Most competitive individual weeds	7
6	Skin diseases	3

In the untreated scenario, (Table 15) blight is the main cause of loss of ouput, with losses in the region of £363 million, almost 50% of the original value and dwarfing the losses of other problems. PCN and slugs are also a serious problem causing loss in output of £54-58 million each. Individual weeds can cause similar levels of losses. If weed control was taken as a whole, rather than individual weeds, losses in the untreated without any control measures would be in the region of £228 million which would raise it to second place above PCN.

Table 15 Untreated rank of top losses – all sectors

Rank	Weed, pest or disease	Loss in output
		£ million
1	Blight	363
2	PCN	58
4	Most competitive individual weeds	58
3	Slugs	54
5	Skin diseases	23
6	Dry rot	13

In the seed sector alone, where PCN is excluded due to soil testing, the ranking is different. Blight still ranks as number 1, but virus caused by aphids is second and slugs third.

5.0 Assessment of future status of pesticide availability

5.1 Current pesticides approved for use in potato crops

There are currently 56 active substances that are approved for use in potatoes in the UK, including weeds (14), pests (16), disease (24) and sprout control (2) and 448 products registered with PSD[21].

Table 16 Actives currently approved on potatoes

Pesticides currently approved on potatoes		
Herbicides		
Bentazone	Basagran	Residual
Carfentrazone ethyl	Aurora	Grass weeds
Clomazone	Centium	Cleaver
Cycloxydim	Laser	Grass weed
Diquat	Retro	Non-selective
Glufosinate ammonium	Harvest	Desiccant
Glyphosate	Roundup	Non-selective
Linuron	Linuron	Residual
Metribuzin	Sencorex Artist (+flufenacet)	Residual
Pendimethalin	Pendimethalin	Residual
Propaquizafop	Falcon	Grass weeds
Prosulfocarb	Defy	Grass weeds
Quizalofop-p-tefuryl	Panarex	Grass weeds
Rimsulfuron	Titus	Cleavers
Fungicides		
Azoxystrobin	Amistar	Black dot, rhizoctonia
Benalaxyl	Intro Plus (+mancozeb)	Blight
Benthiavalicarb-isopropyl*	Valbon (+mancozeb)	Blight
Chlorothalonil	Bravo	Blight
Copper compounds	Bordeaux mixture	Blight
Copper oxychloride	Cuprokylt	Blight
Cyazofamid	Ranman twinpak	Blight
Cymoxanil	Sipman Curzate (+mancozeb) Tanos (+famoxadone)	Blight
Dimethomorph	Invader (+mancozeb)	Blight
Famoxadone	Tanos (+cymoxanil)	Blight
Fenamidone	Consento (+ propamocarb hydrochloride)	Blight
Fluazinam	Shirlan Epok (+metalaxyl-M)	Blight
Fluopicolide *	Infinito (+propamocarb hydrochloride)	Blight
Flutolanil	Rhino	Rhizoctonia
Imazalil	Fungazil	Dry rot Black scurf Stem canker Silver scurf Skin spot Gangrene

[21] PSD Pesticide database

Pesticides currently approved on potatoes (cont)		
Iprodione	Rovral	Rhizoctonia
Mancozeb	Dithane	Blight
Mandipropamid*	Revus	Blight
Maneb	Trimangol	Blight
Metalaxyl-M	Epok (+fluazanim)	Blight
Pencycuron	Monceren	Rhizoctonia Silver scurf
Propamocarb hydrochloride	Merlin (+chlorothalonil) Consento (+fenamidone) Infinito (+fluopicolide)	Blight
Tolclofos methyl	Rizolex	Rhizoctonia
Zoxamide	Electis/Roxam (+mancozeb)	Blight
Thiabendazole*	Hykeep Storite (+imazalil)	Dry rot Gangrene Silver scurf Skin spot
Insecticides	**Product name**	**Main target**
Acetamiprid	Insyst	
Chlorpyrifos	Dursban	Leather jackets Cutworms
Cypermethrin	Toppel	Aphids Caterpillars Cutworms
Ethprophos	Mocap 10G	Wireworm PCN
Flonicamid	Teppeki	Aphids
Fosthiazate	Nemathorin 10G	PCN (Wireworms)
Lambda cyhalothrin	Hallmark Dovetail (+pirimicarb)	Aphids Apids Cutworms
Oxamyl	Vydate 10G	FLN PCN
Pirimicarb	Aphox	Aphids
Pymetrozine	Plenum	Aphids
Thiacloprid	Biscaya	Aphids
Thiamethoxam*	Actara	
Zeta-cypermethrin	Fury	Aphids Cutworms
Nicotine*	No-Fid	Aphids Leaf miner
Methiocarb	Various	Slugs
Ferric phosphate*	Sluggo	Slugs
Sprout Suppressants		
Chlorpropham	CIPC	Sprout suppressant
Maleic hydrazide	Fazor	Sprout suppressant

*Not evaluated by PSD for 91/414/EEC

Current potato plant protection products offer a reasonable range of actives for the control of most problems in UK potato production. The weakest areas are in the control of potato blight, where resistance to some actives is increasing and resistance management strategies using multi-site products such as mancozeb are important. Other weaknesses are in some weed control where there are few post-emergence options for some varieties of potatoes. Difficulties, and expense, in controlling potato cyst nematodes is also considered a problem.

5.2 Drivers for change in pesticide availability

There are several drivers for change in future pesticide status within potato production:

- Changes to EC directive 91/414/EEC
- Annex 1 review programme
- Water Framework Directive
- Changes in marketing of products
- Market acceptability
- Resistance
- Cost

5.2.1 91/414/EEC

The positive vote in the European Parliament on 13 January 2009 on proposals to change the authorisation process for active substances and products, will change the availability of current pesticides. The main impact comes from the changes to the approval system, moving from a risk based system to a hazard based system in order to reinforce human health and environmental protection, which will result in the withdrawal of pesticides that are categorised as carcinogenic, genotoxic, reprotoxic or neurotoxic. In addition some or all active substances that affect hormones, endocrine disruptors, may also be included depending on the adopted cut-off criteria.

The new regulations will allow comparative assessment, and substitution of certain plant protection products with other less hazardous alternatives and this will be carried out at Member State level. It is important to note that these changes will come into effect as the current product approvals come to an end so there will be a phased approach.

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. It is still unclear how this will apply. |t is most likely to help minor uses, but may be beneficial for some specific issues.

The legislation will come into force in 2010 at the earliest. The exact timing depend 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[22] 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 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.

1. Annex 2a – Substances that may not be approved according to the Council common position (CPP) with the endocrine disruptor definition based on the previous UK assessment in May 2008 assuming ‘ may cause effect’ is interpreted in a broad way.
2. Annex 2b – Substances that may not be approved according to the CCP assuming assessment using the ENVI committee proposal to define potential endocrine disruptors as substances which are for example R3 (toxic to reproduction)
3. Annex 2c – Substances that may not be approved according to the CCP assuming assessment using the Swedish assessment that potential endocrine disruptors are R2, R3 or 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 to 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 can not 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).

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

It is important to note that these are best assessments based on interpretation of the information available at the time and the lists are not definitive. Similarly, the assessments have not included actives that are on list 4 of the review programme, or those that are not yet on Annex 1.

Based on the analysis by PSD, the main actives used in potato production likely to be affected by the changes to 91/414/EEC are:

Table 17 Actives affected by changes to 91/414/EEC

	2a	2b	2c	ENVI
Herbicides	glufosinate ammonium linuron metribuzin pendimethalin	glufosinate ammonium linuron metribuzin pendimethalin	glufosinate ammonium linuron pendimethalin	glufosinate ammonium linuron metribuzin pendimethalin
Fungicides	iprodione mancozeb maneb	mancozeb maneb	mancozeb maneb	iprodione mancozeb maneb
Insecticides	None	None	None	All except pymetrozine, thiacloprid and thiamethoxam

The most likely scenario is 2c. Glufosinate ammonium, linuron, mancozeb and maneb may be allowed a derogation under Article 4(7).

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 (Table 18).

Table 18 Timetable of withdrawal under 91/414/EEC

	Herbicides	Fungicides	Insecticides
2011			Lambda cyhalothrin
2012			
2013	Linuron Metribuzin Pendimethalin	Iprodione Maneb	Fosthiazate Nicotine
2014		Mancozeb	Thiacloprid
2015			
2016			Chlorpyrifos Cypermethrin Oxamyl
2017	Glufosinate ammonium		Ethroprophos Pirimicarb Methiocarb
2018			Zeta-cypermethrin

5.2.2 Annex 1 review programme

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.

Under the review programme the key actives used on potatoes are:

Table 19 Key actives used on potatoes under the Annex 1 review programme

	Annex 1	Main use
Herbicides	cycloxydim propaquizafop quizalofop-P-tefuryl	Grass weed control
Fungicides	None	-
Insecticides	zeta-cypermethrin	Aphids, cutworms

5.2.3 Water Framework Directive and Drinking Water 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 impacts on water quality through use of nitrates, phosphates, pesticides and slurries and manures. Pesticides are a concern due to the impact on chemical status, although they can also have an ecological impact through changes in flora and fauna. Under the Water Framework Directive (WFD) the EU have identified a Priority List of 33 substances with a high risk to aquatic life.

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 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 will be 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[23]. The Voluntary Initiative aims to reduce environmental impact of pesticides through education and awareness of farmers and spray operators[24].

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

[23] http://www.defra.gov.uk/farm/environment/water/csf/delivery-initiative.htm
[24] http://www.voluntaryinitiative.org.uk/Content/Water_WP.asp

above the 0.1µg/l concentration[25]. 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 EU Priority list of 33 substances includes IPU, trifluralin, simazine, and atrazine, all of which were used in UK agriculture but have, or are in the process of being withdrawn. The active substance, chlorpyrifos, is also on the list and remains at high risk of withdrawal.

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 (weed control in oilseed rape), chlorotoluron (grass weed control in cereals), mecoprop (widely used herbicide in cereals and grassland), isoproturon (weed control in cereals) – and more recently, since a test was developed, metaldehyde (slug control in all crops). 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. An industry led metaldehyde stewardship programme is underway[26] to promote best practice when using slug pellets on farm, and consider other ways of minimising entry into water, such as limits on total application rates and buffer zones.

Based on findings from EA indicator testing and Drinking Water Inspectorate reports from water companies[27] the only active used in potatoes that are at high risk from limits due to chemical quality is metaldehyde (having recently been reregistered with lower application rates), although some might affect the control of potato volunteers in the rotation such as loss of clopyralid, often used where sugar beet is in the rotation, and glyphosate, used late in cereals and gives control of tubers.

There may be bigger impacts due to ecological quality requirements with all insecticides at risk, along with bentazone and chlorothalonil (due in part to the high usage in other crops).

Many other insecticides are at medium risk, and it is a possibility that these will be limited in use.

It should be noted that EQS are not yet agreed or determined and this list is the project opinion of likely at risk substances.

Table 20 Actives at risk under WFD

	High risk	Medium risk
Herbicides	Bentazone clopyralid (in rotation) glyphosate (in rotation)	
Fungicides	Chlorothalonil	
Insecticides	Chlorpyrifos Metaldehyde	Other insecticides

[25] Defra (2008)Observatory monitoring framework – indicator data sheet DA4 pesticides in water. https://statistics.defra.gov.uk/esg/ace/da4_data.htm
[26] http://www.pelletsarepesticides.co.uk/
[27] http://www.dwi.gov.uk/pubs/annrep07/contents.shtm

The actives that are most at risk of withdrawal due to chemical or ecological quality are often those that are widely used across a number of crops. Chlorothalonil is used in potatoes for blight control, but is most widely used in cereals for protectant disease control. Glyphosate is used widely in combinable crops for stale seedbed preparation, desiccation and pre-harvest weed control. Metaldehyde slug pellets are used in a wide range of crops. Slug control is vital for good crop establishment in combinable crops and in potatoes and vegetables vital for quality output. Given their use and value in many crops, preservation of slug pellets is of great importance across all cropping sectors, and product stewardship will be a vital component. Any restrictions on use of metaldehyde could result in an increase in use of methiocarb, the only other slug control option in potatoes, which may in turn become a problem in water. Loss or limitations in use, of methiocarb would have very serious implications for potato production, and other crops.

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.

5.2.4 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.

From these discussions a number of potential new products have been identified as likely to come to market soon, subject to meeting regulatory requirements. It is notable that there are no new potato products weed or fungicide products near to market. 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 potatoes. There are also three new carboximide fungicides that are being tested for use in cereals. 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. At the time of writing (January 2009) none of these are yet available in UK.

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.

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.

New insecticides

Dupont - Indoxacarb:[28]

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.

Dupont - Rynaxypyr:[29]

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).

[28] http://www2.dupont.com/Professional_Products/en_US/Science_Of/indoxacarb.html

[29] http://www2.dupont.com/Production_Agriculture/en_US/products_services/insecticides/Rynaxypyr_insecticide.html

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.

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.

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.

Specifically considering potatoes, finding alternative multi-site fungicides, as replacements for mancozeb and maneb will provide a significant challenge. There are no imminent options available. There is some prospect of options eventually being found because blight fungicides are found because of the importance worldwide of downy mildew on grape vines.

5.2.5 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 (not human health). There is a testing regime organised and reported on by the Pesticides Residue Committee[30].

Results from PRC testing of potatoes in recent years have found residues of chlorpropham, fosthiazate and oxamyl, along with some residues from previous applications of tecnazene and aldicarb, both now withdrawn from use[31] (Table 21).

[30] Pesticide Residue Committee information http://www.pesticides.gov.uk/prc_home.asp
[31] Pesticide Residue Committee Annual Reports 2000-2008 http://www.pesticides.gov.uk/prc.asp?id=959

Table 21 Results from PRC testing of potatoes

Year	No.samples*	Residue<MRL	Residues>MRL	Multiple residues
2008	150	88	2 (oxamyl)	21
2007	144	54	3 (fosthiazate)	15
2006	139	53	0	7
2005	143	46	2 (tecnazene**, imazalil)	10
2004	143	58	0	18
2003	144	44	1 (tecnazene**)	13
2002	241	92	3 (imazalil, dithiocarbamate**)	18
2001	239	80	3 (aldicarb**, maleic hydrazide)	18
2000	144	69	0	30

Notes:*The samples contain some non-UK grown potatoes
**Tecnazene, dithiocarbamate and aldicarb are no longer approved on potatoes in the UK
Source:PRC reports 2000-2008

Monitoring data from the UK food industry is also published by the PRC and gives further information on residues found in food stuff. In most years residues have been below the MRL, but chlorpropham and maleic hydrazide both products used to control sprouting in store, have regularly featured, along with other actives such as oxadyxil, diquat and thiabendazole[32]

Chlopropham has come under a great deal of scrutiny since 2002, in anticipation of the reregistering of the active in Annex 1 and the requirement for an MRL, which was set at 10mg/kg and came into effect in 2007. An industry stewardship programme was established, in order to ensure that the MRL could be consistently met, including limits on the maximum amount that could be used and a training and awareness programme.

Metaldehyde slug pellets have just been reregistered with lower applications rates and new harvest intervals intended to ensure that potatoes will meet new residue requirements. It will be important for growers to use this active correctly, as it is already under pressure due to water quality issues.

The loss of sulphuric acid (withdrawn in February 2009)[33] for use as a potato desiccant may also have implications for residue management. Sulphuric acid was used on 12% of the GB potato area in 2006[34], and has a very fast haulm knockdown compared to other desiccants. Blight protection is required as long as there is green material and additional blight sprays are often required post-desiccation with other desiccants and care will be required to ensure that total product dose rates and harvest intervals are adhered to in order to reduce the risk of further product restrictions. Tesco have recently set maximum limits for propamocarb in potatoes destined for their Natures Choice brand.

[32] Monitoring data from UK food industry (2000-2008) http://www.pesticides.gov.uk/prc.asp?id=959
[33] http://www.pesticides.gov.uk/approvals.asp?id=2628
[34] PSD (2006) Pesticide usage survey

Meeting MRL standards is one measure which will help ensure that actives do not come under greater scrutiny from approvals authorities and market outlets. Increasingly, any detectable residue is becoming and issue requiring increased awareness and vigilance of pesticide users and advisors to ensure proper use and to avoid limitations on usage. 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 chemicals. Growing to soil association organic standards is one example, as is the supply of Conservation Grade oats to Jordans, and Tesco Natures Choice. These standards are a marketing decision by the grower, however if consumer requirements for these products becomes widespread, this may limit the pesticides available.

5.2.6 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.

Fungicides

In the UK at present, fungicide resistance has only been reported for phenylamides for late blight control and thiabendazole (TBZ) for dry rot caused by Fusarium spp.[35] The phenylamides[36] include metalaxyl, and resistance to this active ingredient has been widespread in the late blight population since the 1980s. The proportion of metalaxyl resistant strains in the population has remained relatively constant, between 40 and 50% with the predominant strain the A1 genotype. A Potato Council survey of the blight populations from 2003 to 2007, however, found a shift in genotype from A1 to A2 over this period, with a new isolate, A2_13 accounting for over 70 % of isolates recovered in 2007[37]. Tests have found that, so far, all isolates belonging to this strain in GB were phenylamide resistant.

An anti-resistance strategy for blight control is in place to prevent any further risks from resistance. As part of this, many fungicides at risk from resistance development have application restrictions limiting number of applications per season or time of application during the season. This involves the alternation of products with different modes of action, as well as applying at risk products in conjunction or co-formulation

[35] Peters, J.C., Lees,A.K., Cullen, D.W., Sullivan, L., Stroud G.P., Cunnington A.C. (2008) Characterization of Fusarium spp. responsible for causing fry rot of potatoes in Great Bridtain. Plant Pathology. 57 262-271.

[36] Phenylamide blight resistance increases in potatoes: http://www.fwi.co.uk/Articles/2008/02/14/109370/phenylamide-blight-resistance-increases-in-potatoes.html

[37] Cooke, DEL, Lees, AK., Shaw, DS., Taylor, MC., Prentice, MWC., Bradshaw, NJ., Bain, RA. (2008) The status of GB blight populations and the threat of oospores. Proceedings Crop Protection in Northern Britain 2008.

with others where the mode of action differs. Therefore full use of fungicides targeting a range of metabolic pathways at appropriate times in the spray programme will avoiding reliance on a single group and form an effective part of the anti-resistance strategy. Fungicide resistance has been reported for several products currently used against blight in other plant pathogens including copper-based products, QoI fungicides and the cyanoacetamide-oximes (cymoxanil), however, no resistance has been reported for blight[38].

Mancozeb is a dithiocarbamate fungicide with multi-site action, and is used widely commercially. Products containing this active ingredient alone or in co-formulation with other active ingredients were applied to over 38 % of the total area planted in 2007. No resistance to this fungicide has been reported and it has been used worldwide since the 1960s[3]. It is currently used as a partner product for many products. Loss of mancozeb through changes to 91/414/EC (see section 5.2.1) will add to resistance pressures and may ultimately reduce control.

Loss of sulphuric acid as a desiccant may place additional pressure on blight resistance, as other desiccation options usually have slower haulm knockdown and require additional blight sprays.

A late blight epidemic can be initiated from discard piles, volunteers and infected seed. The loss of blight fungicides, and any herbicides commonly used to control volunteer potatoes and those on discard piles, will increase the risk of inoculum developing during the growing season on unprotected foliage. Harvested tubers will also have greater risk of being infected, and perpetuate a more severe epidemic in years to come. This would also have significance for the prevalence of tuber rots in store, as tubers with blight lesions would be more susceptible to bacterial soft rots and fungal dry rots in the field and during storage.

The use of cultivars to substitute for late blight control is under investigation but not currently in widespread use. Lady Balfour (NIAB foliar blight rating 8 and tuber blight rating 7) and Sarpo Mira (NIAB foliar blight rating 9 and tuber blight rating 9) have been used in organic farming, but varieties favoured for processing and ware production are generally blight susceptible e.g. Russett Burbank (NIAB foliar blight rating 3 and tuber blight rating 1) and King Edward (NIAB foliar blight rating 3 and tuber blight rating 4). Varietal choices tend to be made based on the market the crop is destined for, and chosen for characteristics such as fry colour. Using provisional planting data from 2008 where actual varieties are known, the percentage of crops grown with a variety resistance rating for foliar blight of between 3 and 4 (blight susceptible) accounted for 80% of total plantings[39]. Other surveys have found a decline in the percentage of resistant varieties being grown, with reductions of 44% and 77% in total area planted with more resistant varieties for foliar and tuber blight respectively between 1996 and 2004[40].

Insecticides
There is well established insecticide resistance in peach-potato aphid due either to metabolic resistance or target site resistance. Monitoring has shown variable levels but a general decline in aphid numbers with metabolic resistance, but an increase in those with target site resistance. There is currently no evidence of resistance to

[38] FRAG-UK and British Potato Council (2004 nd amended 2007) Potato late blight: Guidelines for managing fungicide resistance. Growers' advice.
[39] BPC (2007) Production and price trends 1960-2007
[40] Wale, S. (2007) The use of plant resistance to reduce potato pests and diseases. Research Review British Potato Council

neonicotinoids (acetabmiprid or thiacloprid), nicotine, flomacid, pymetrozine or pirimicarb. However, there is resistance to pyrethroids (cypermethrin, zeta-cypermethrin and lambda-cyhalothrin) and the organo-phosphate, chlorpyrifos[41].

5.2.7 Cost

The cost of products for use in potatoes, for what are, on a world scale, minor crop or pest, is an issue for many growers, which may in the future affect investment, development of actives and costs. This is particularly relevant for herbicides which need to be crop specific, and for other pests and disease that are crop specific.

[41] Potato Council (2008) Guidelines for preventing and managing insecticide resistance in aphids on potatoes

6.0 Evaluation of alternative control measures

6.1 Mitigating 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.

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 and rotation

- 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. 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.
- Greater level of testing
- Control of weeds in other parts of the rotation is vital

Mechanical measures

- Ridging up – Ridging up as potatoes germinate is a common practice in organic systems for weed control and can be very successful given a competitive crop. It can lead to loss of moisture and greater level of greens depending on the shape of the ridge achieved. It would mean that tied ridges for reduction in erosion would not be possible.
- Gas burner for weed control
- Soil sterilisation for the control of pests such as PCN/FLN

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 or tolerance to certain pests or diseases, such as potato cyst nematodes and some viruses. 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.

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 potato 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.

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.

6.2 Weeds

Current conventional weed control relies on a fast growing competitive crop to suppress weeds. There are many strategies depending on the weed spectrum, but most use a non-selective product such as diquat just prior to crop emergence, mixed with a residual component. Post-emergence products are limited to metribuzin on selected varieties, bentazone and rimsulfuron.

A Potato Council project looking at the impact of loss of actives for weed control[42] suggested that alternative chemical control options to the loss of linuron and pendimethalin would cost the growers up to £26/ha more than current programmes. These replacement programmes still used metribuzin, which may also be affected by the legislation. In this case the chemical control options are more limited and will require greater use of rimsulfuron, adding further to the costs.

In the same study, inter-row cultivations were reviewed, at an additional cost of £117/ha for two passes. Inter-row cultivations can be very successful, but there are cases where yields have been reduced due to damage to stolons.

Another non-chemical alternative is a gas burner, but is likely to be too expensive for all but small areas of high value crop. There are also environmental implications from use of propane adding to CO2 emissions.

Control of weeds that are difficult to control in potatoes, such as couch, is important in order to avoid yield losses.

6.3 Diseases

Mitigation measures against blight are generally already practiced in order to reduce the risk of blight under current product availability. This includes controlling growth on outgrade piles and volunteers in other crops in the rotation with pesticides. There are no specific alternative control measures available in the short term, however breeding programmes for blight resistance are being developed but these are still some way from market.

[42] Ballingall, M and Davies, K (2008), Weed and herbicide case study on potatoes

The main mitigation measure against many of the skin diseases is to use disease free seed. This may encourage more farmers to use higher quality seed, with implications for costs and availability. Storage conditions and hygiene are also important actions, but generally already implemented. Some skin diseases also have a soil borne element and planting on disease free fields (soil tests are available for Rhizoctonia and black dot) will be a strategy which might limit the land availability or require longer rotations with similar implications. There is current research on the use of *Verticillium biguttatum* as a biological control agent for Rhizoctonia but there is nothing available commercially.

In store, diseases such as dry rot can be managed through using disease free seed, good store hygiene and use of more resistant varieties, all of which are currently practiced.

6.4 Pests

The control of PCN without nematicides is possible but no individual method is likely to used a direct replacement, and would be used as an integrated pest management programme. These methods were detailed in the Potato Council report on impacts of 91/414 on PCN control[43] and include using clean land, longer rotations on infested land, use of resistant varieties and GM crop breeding, and trap cropping using *Solanum sisymbriifolium* (sticky nightshade). The cost of trap cropping is around £355-385/ha for seed and establishment, without including any costs for missed cropping opportunities.

Steam sterilisation using equipment currently under development is an option for PCN and FLN control, but it is unlikely to be practical for large areas.

The control of potato volunteers in other parts of the rotation is an important part of minimising the build up of PCN.

Using clean land for potato productions would reduce the problem of PCN and FLN, but there are limitations of suitable soil types and irrigation.

Alternative measures for slug control are limited, and are often used alongside molluscides in any case. These include seedbed cultivations to reduce slug numbers. Lifting potatoes early can reduce slug damage, but this has implications for harvest and market yields.

Alternative measures for aphid control for virus control, important in seed production, is through growing potatoes at altitude or on exposed, windy sites where there are fewer aphid vectors. Hand rouging of infected plants, which is currently practiced, is required also an option, along with early haulm destruction.

There are few options for the control of wireworms, other than testing and avoiding fields with infestation, and ensuring that grass weeds are controlled in the rotation to reduce the risk of build up of the pest. Lifting early, as soon as feeding damage is spotted will minimise the level of damage, but will also limit yield.

[43] Potato Council (2008) The impact of current proposals for replacing Directive 91/414/EEC on control of potato cyst nematodes and free-living nematodes

7.0 Economic evaluation of loss of actives

7.1 Weeds

7.1.1 Scenario 2a, 2b and 2c CCP impacts

Table 22 Active substances affected by 91/414/EEC

Active substances affected	Main targets
Pendimethalin	Annual meadow grass and broadleaved weeds
Linuron	Annual meadow grass and broadleaved weeds
Metribuzin*	Broadleaved weeds
Glufosinate ammonium	Broadspectrum pre-em

*2a and b only, not 2c

- Linuron, metribuzin and pendimethalin are 3 of the main BLW herbicides used in potato crops in the UK giving residual control of weeds. In the 2006 Pesticide Usage survey 66% of potatoes were treated with linuron, 5.9% with pendimethalin and 26% with metribuzin.
- The remaining alternatives pre-emergence actives are clomazone which is good on cleavers and chickweed but has an otherwise limited spectrum, and prosulfocarb which has a broader spectrum but is week on bindweed and spring polygonums, particularly redshank (Table 23).
- The contact actives for use pre-emergence diquat (Retro) and carfentrazone-ethyl (Shark) will still be available. Carfentrazone-ethyl has good activity on fat-hen but poor activity on mayweeds.
- There is no change to the availability of post emergence products which are bentazone (but this is under threat from WFD) and rimsulfuron, and given potentially poorer early control there may be more emphasis on these products. Bentazone has is not effective on many of the common spring polygonums including redshank, knotgrass and pale persicaria. Rimsulfuron has a wider spectrum and can give control of bindweed, cleavers and spring polygonums, but is weak on fat hen, a common late season weed.
- Rimsulfuron cannot be used on seed crops leaving these crops open to late season weed competition.
- Reliance on the remaining products will mean poorer weed control, particularly of polygonums, higher costs and some potential yield effects.
- It is most likely that scenario 2c will be adopted under the legislation, in which case metribuzin will remain available. This will retain some flexibility in pre-emergence sprays, and for certain varieties, allow post-emergence applications.
- Under the changes to 91/414/EEC there is no change to the actives for grass weed control.

Weeds controlled by remaining products

Table 23 Weeds control by remaining herbicides

	clomazone	prosulfocarb	bentazone	rimsulfuron Cot-2 lvs	rimsulfuron 2-6 lvs
AMG	MS	S pre-em			
Black bindweed			MS	MS	MR
Black nightshade		S pre-em		MS	R
Charlock			S	S	S
Chickweed, Common	S	S up to 3 shoots	S	S	S
Cleavers	S	S up to 3 leaves	S	S	S
Crane's bill		S pre-em	S		
Dead nettle, Henbit			MS		
Dead nettle, Red	S	S pre-em	MS	S	S
Fat hen	MS		MS	MR	MR
Fool's Parsley	S		S		
Forget me not, Field		S pre-em	S		
Fumitory, Common			MS		
Groundsel, common					
Hempnettle				S	S
Knotgrass				MS	R
Mayweed, scentless				S	S
nettle, small				S	S
Pale persicaria**				MS	MR
Pansy, Field		MS at emergence			
Pansy, field					
Perennial sowthistle					
Redshank				S	MS
Shepherd purse	S				
Speedwell, common field		S up to 5 leaves			
Speedwell, green field		S up to 6 leaves			
Speedwell, Ivy-leaved		S up to 3 leaves			
Speedwell, wall		S pre-em			
Volunteer oilseed rape				S	S

S=susceptible, MS=moderately susceptible, MR=moderately resistant, no information=not on label

7.1.2 Scenario 3 ENVI impacts

Table 24 Active substances affected by scenario 3

Active substances affected
None

7.1.3 WFD impacts

Table 25 Active substances affected by WFD

Active substances affected	Main target
Bentazone	Post-emergence broadleaved weeds
Glyphosate (rotational use)	Couch and volunteer potatoes

- The loss of bentazone under the Water Framework Directive would mean rimsulfuron was the only post-emergence product available for broadleaved weed control in ware potatoes, and no products for use post-emergence in seed crops.

- On its own this would not necessarily be serious, but in combination with the likely loss of linuron and pendimethalin and possible loss of metribuzin, it leaves few options for residual or post-emergence weed control.
- The loss of glyphosate, or even restrictions on use in other parts of the rotation, may have impacts on the potato crop, particularly with respect to couch control. The other products recommended for couch in potatoes (cycloxydim, propaquizafop and rimsulfuron) only suppress the growth, and high populations would mean changing rotations or potential yield loss and quality implications.
- Cycloxydim, quizalafop-p-tefuryl and propaquizafop are also at risk under the Annex 1 review programme (see below), which would leave only rimsulfuron with only moderate activity on couch, and cannot be used in seed crops.

7.1.4 Annex 1 listing

Table 26 Active substances affected by Annex 1 listing

Active substances affected	Main target
Cycloxydim	Grass weed control
Propaquizafop	Grass weed control
Quizalofop-p-tefuryl	Grass weed control

- Less than 1% of the potato area was treated with cycloxydim, quizalofop-p-tefuryl or propaquizafop in 2007[44]
- Loss of these actives would put more reliance on control in other parts of the rotation (such as pre-harvest glyphosate) and avoiding heavily infested fields which could limit the land availability for potatoes.
- The only remaining post-emergence option would be rimsulfuron which has only moderate activity on couch, and cannot be used in seed crops.
- An alternative, already on Annex 1 but not currently approved on potatoes could be tepraloxydim (Aramo) if approval were to be given.

7.1.5 Effect on gross margin

Each of black-grass, ryegrass, cleavers and annual meadow grass are likely to cause up to 8% loss in production where present, if untreated. Others such as redshank and bindweed may cause similar levels of losses. These will be the priority weeds for control. In combination, total yield losses from weeds can range from 14-80%[45] in the absence of any control measures.

The withdrawal of certain herbicides will increase the pesticide costs by up to £26/ha[44] (based on the withdrawal of linuron and pendimethalin). Costs of ridging are around £117/ha for two passes[44]. Yield impacts from weeds is very variable depending on soils and weather so gross margins based on a range of yield losses, including no yield loss, were calculated.

[44] Potato Council (2008) Impact of reduced pesticide availability on control weeds in potato crops
[45] Bond W. & Turner R (2005) Weed Management Outline for Potatoes

The effect on the gross margin is therefore the additional costs of pesticides used on 75% of the area and the use of mechanical ridging on 25% of the area. This action is likely to be the same under changes due to 91/414/EC and the Water Framework Directive, but will not be additive if both groups are affected .

If the weed control was successful, and resulted in no yield loss, the gross margin would reduced by 4%, while a 10% loss in yield would incur between 28% and 35% reduction in gross margin and costing the industry a total of £100 million (Table 24). It is therefore essential that the cost-effectiveness of weed control options are examined in detail.

Table 27 Effect of herbicide withdrawal on gross margin

Gross margin	Processing	Fresh	Seed
Gross margin	£ million	£ million	£ million
Business as usual	76	199	35
0% yield loss	73 (-4%)	196 (-2%)	34 (-2%)
5% yield loss	63 (-17%)	172 (-14%)	30 (-14%)
10% yield loss	54 (-29%)	148 (-26%)	25 (- 27%)
20% yield loss	35 (-46%)	83 (-58%)	16 (-54%)

7.2 Diseases

Table 28 Impact of diseases on yield loss and production under different scenarios

Processing Potatoes (yield loss on affected area & total loss of production)

Disease	2a % yield loss	2a Production loss	2b % yield loss	2b Production loss	2c % yield loss	2c Production loss	3 % yield loss	3 Production loss	WFD % yield loss	WFD Production loss
	%	t	%	t	%	t	%	t	%	t
Blight	3.2%	56,000	3.2%	56,000	3.2%	56,000	0.0%	0	0.00%	0
Dry rot	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.00%	0
Stem canker	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.00%	0
Black scurf	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.00%	0
Silver scurf	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.00%	0
Skin spot	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.00%	0
Black dot	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.00%	0
Powdery scab	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.00%	0

Fresh Potatoes (yield loss on affected area & total loss of production)

Disease	2a % yield loss	2a Production loss	2b % yield loss	2b Production loss	2c % yield loss	2c Production loss	3 % yield loss	3 Production loss	WFD % yield loss	WFD Production loss
	%	t	%	t	%	t	%	t	%	t
Blight	3.2%	118,000	3.2%	118,000	3.2%	118,000	0.0%	0	0.00%	0
Dry rot	0.00%	0	0.0%	0	0.0%	0	0.0%	0	0.00%	0
Stem canker	0.00%	0	0.0%	0	0.0%	0	0.0%	0	0.00%	0
Black scurf	0.00%	0	0.0%	0	0.0%	0	0.0%	0	0.00%	0
Silver scurf	0.00%	0	0.0%	0	0.0%	0	0.0%	0	0.00%	0
Skin spot	0.00%	0	0.0%	0	0.0%	0	0.0%	0	0.00%	0
Black dot	0.00%	0	0.0%	0	0.0%	0	0.0%	0	0.00%	0
Powdery scab	0.00%	0	0.0%	0	0.0%	0	0.0%	0	0.00%	0

Seed Potatoes (yield loss on affected area & total loss of production)

Disease	2a % yield loss	2a Production loss	2b % yield loss	2b Production loss	2c % yield loss	2c Production loss	3 % yield loss	3 Production loss	WFD % yield loss	WFD Production loss
	%	t	%	t	%	t	%	t	%	t
Blight	3.2%	14,000	3.2%	14,000	3.2%	14,000	0.0%	0	0.00%	0
dry rot	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.00%	0
Stem Canker	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.00%	0
Black Scurf	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.00%	0
Silver scurf	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.00%	0
Skin spot	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.00%	0
Black dot	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.00%	0
Powdery scab	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.00%	0

>10% impact

5-10% impact

7.2.1 Scenario 2a, 2b and 2c

Table 29 Active substances affected by 91/414/EEC scenario 2a, 2b and 2c

Active substances affected	Main target
Iprodione*	Black scurf
Mancozeb	Blight
Maneb	Blight

*2a and b only, not 2c

- Removal of mancozeb would remove over half of the currently available products for late blight control and a key active in anti-resistance management.
- This will increase the usage of other actives, and use of shorter intervals, resulting in increased spraying in a season and higher costs.
- Yield impacts are only slightly greater than current programmes, but costs are likely to be higher.
- Removal of iprodione, used in seed treatments for black scurf and stem canker, will have limited impacts as flutolanil and pencycuron woud still be available. A widening of rotation between potato crops would reduce the disease from soil sources.

7.2.2 Scenario 3 ENVI

Table 30 Active substances affected by 91/414/EEC scenario 3

Active substances affected
None

7.2.3 Water Framework Directive

Table 31 Active substances affected by WFD

Active substances affected	Main target
Chlorothalonil	Blight

- Chlorothalonil is a contact fungicide, and is often applied in conjunction with other actives as part of an anti-resistance strategy.
- Loss of chlorothalonil will not have a serious impact on blight control or costs, as there are alternative products.
- It may lead to increased risk of resistance in the blight population.

7.2.4 Effect on gross margin

The loss of mancozeb under scenario 2a-c, is serious for resistance management, but the use of other products will still allow reasonable control. This is likely to cost more for products and in number of products applied which reduces the gross margin by 5%-10% compared to business as usual in all sectors (Table 32), although the impacts are small compared to the untreated scenarios where losses would be made. Dry rot and stem canker also cause small losses of less than 5%.

Table 32 Impact on gross margin

	Top diseases by sector - gross margin £ million						
	Baseline	Untreated	2a	2b	2c	3.0	WFD
Processing							
Blight	76	-8	69	69	69	76	76
Stem canker	76	71	76	76	76	76	76
Dry rot	76	74	76	76	76	76	76
Black scurf	76	75	76	76	76	76	76
Fresh							
Blight	199	-9	181	181	181	199	199
Dry rot	199	186	199	199	199	199	199
Stem canker	199	193	199	199	199	199	199
Silver scurf	199	195	199	199	199	199	199
Seed							
Blight	35	-3	32	32	32	35	35
Stem Canker	35	32	35	35	35	35	35
dry rot	35	34	35	35	35	35	35
Black Scurf	35	34	35	35	35	35	35

0-5% reduction in GM
5-10% reduction in GM
>10% reduction in GM

7.3 Pests

Table 33 Impact of pests on yield loss and production under different scenarios

Processing Potatoes (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)
Potato cyst nematode	0.0%	0	0.0%	0	0.0%	0	37.0%	157,000	37.0%	157,000
Slugs	0.0%	0	0.0%	0	0.0%	0	19.5%	127,000	19.5%	127,000
Peach-Potato aphid	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0
Potato aphid	0.0%	0	0.0%	0	0.0%	0	0.5%	0	0.5%	11,000
free living nematodes	0.0%	0	0.0%	0	0.0%	0	12.5%	11,000	12.5%	0
Wireworm	0.0%	0	0.0%	0	0.0%	0	20.9%	7,000	20.4%	7,000

Fresh Potatoes (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)
Potato cyst nematode	0.0%	0	0.0%	0	0.0%	0	37.0%	315,000	37.0%	315,000
Slugs	0.0%	0	0.0%	0	0.0%	0	19.5%	267,000	19.5%	267,000
Peach-Potato aphid	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0
Potato aphid	0.0%	0	0.0%	0	0.0%	0	0.5%	1,000	0.5%	1,000
free living nematodes	0.0%	0	0.0%	0	0.0%	0	11.0%	20,000	11.0%	20,000
Wireworm	0.0%	0	0.0%	0	0.0%	0	20.4%	15,090	20.4%	15,000

Seed Potatoes (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)
Potatoe cyst nematode	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0
Slugs	0.0%	0	0.0%	0	0.0%	0	17.7%	28,300	17.7%	28,300
Peach-Potato aphid	0.0%	0	0.0%	0	0.0%	0	1.0%	4,320	1.0%	4,320
Potato aphid	0.0%	0	0.0%	0	0.0%	0	0.5%	60	0.5%	0
FLN	0.0%	0	0.0%	0	0.0%	0	10.7%	460	10.7%	460
Wireworm	0.0%	0	0.0%	0	0.0%	0	0.4%	1,760	20.4%	1,760

5-10% reduction in production

>10% reduction in production

7.3.1 Scenario 2a, 2b and 2c

Table 34 Active substances affected by 91/414/EEC scenario 2a, 2b and 2c

Active substances affected
None

7.3.2 Scenario 3 ENVI

Table 35 Active substances affected by 91/414/EEC scenario 3

Active substances affected	Main target
Chlorpyrifos	Leatherjackets, cutworms
Cypermethrin	Aphids, caterpillars,
Ethrophos	Wireworms, PCN
Fosthiazate	PCN
Lambda cyhalothrin	Aphids
Oxamyl	PCN, FLN
Pirimicarb	Aphids
Zeta-cypermethrin	Aphids, cutworms
Methiocarb	Slugs

- The loss of actives under Annex 3 is significant for pest control. The losses would mean no chemical control measures for PCN, FLN or wireworm.
- Slug control will be affected by the loss of methiocarb, leaving possibly only ferric phosphate available (not assessed by PSD), and its activity on slugs in potatoes is not well understood.
- Aphid control may not be so severely affected with acetamiprid and pymetrozine still available and possibly thiamethoxam and nicotine (neither were assessed by PSD), although loss of actives will increase the risk of resistance.
- The main pest threat to production on potatoes is slugs, causing losses in all sectors of around 7% production (excluding control from ferric phosphate).
- Without adequate control from methiocarb control levels are similar to untreated levels, with few options for alternative control methods. This could lead to a reduction in marketable yields of up to 25% on the areas affected.
- Ferric phosphate is an option for control, and is used in organic potato production but there is little information on activity.
- The other main problem is PCN control in ware potatoes, where individual yield losses can be as high as 37% (over current losses of 16%), which would reduce overall production by 5%-10%, but much higher impacts in the individual crops affected.
- Mitigating measures are currently available that could minimise these losses. The economics of using trap cropping at a minimum of £355/ha[46], or steam sterilisation which is still under development needs further evaluation. Others involve longer term changes such as changes to rotation or use of resistant varieties with implications for marketing.
- Losses from aphids are likely to be limited as some actives are still available for control, although there could be an increased risk of resistance given the reduced range.

7.3.3 Water Framework Directive

Table 36 Active substances affected by WFD

Active substances affected
Most insecticides at risk

As for Annex 3 ENVI

7.3.4 Effect on gross margins

The impact on the gross margin reflects the production issues (Table 37). There is no impact from the Annex 2a-c, but large changes from Annex 3 and WFD. The lack of slug control options have a large impact on the gross margin of over 40% in all sectors. Lack of chemical control options for PCN in the processing and fresh markets results in a 22% drop in gross margin. Gross margins would be reduced further if combinations of pests occurred.

The impact from no control of FLN is lower due to the smaller area affected, but it is still at the level of untreated.

[46] Potato Council (2008) Impact of reduced pesticide availability on control of potato cyst nematode

Some products left for controlling aphids means that there are limited impacts, although some effect is seen in the seed sector due to the raised risk of resistance developing.

Table 37 Effect on gross margins

	Top pests by sector - gross margin £ million						
	Baseline	Untreated	2a	2b	2c	3.0	WFD
Processing							
Potato cyst nematode	76	60	76	76	76	60	60
Slugs	76	62	76	76	76	62	62
Peach-Potato aphid	76	73	76	76	76	76	76
free living nematodes	76	75	76	76	76	75	75
Fresh							
Potato cyst nematode	199	160	194	199	199	160	160
Slugs	199	165	199	199	199	165	165
Peach-Potato aphid	199	191	199	199	199	199	199
free living nematodes	199	197	199	199	199	197	197
Seed							
Slugs	35	29	35	35	35	29	29
Peach-Potato aphid	35	18	35	35	35	34	34
FLN	35	35	35	35	35	35	35
Potato aphid	35	35	35	35	35	35	35

0-5% reduction in GM
5-10% reduction in GM
>10% reduction in GM

If costs of trap cropping are included for PCN, and similar levels of control are achieved to nematicide use, the baseline gross margins are reduced by 3%, to £73.8 million for processing and £193.7 million for fresh market.

7.4 Sprout suppressants

The use of chlorpropham (CIPC) for the control of sprouting in store has come under scrutiny in recent years, following the setting of maximum residue levels in 2007. It is also one of the pesticides regularly found in residue testing by the food industry.

In response to this there is a CIPC stewardship programme to highlight good management of the pesticide in order to avoid potential loss of the active.

The use of maleic hydrazide in crop, is an option in some cases, but only gives short term control of sprouting. There are potential alternative actives, such as carvone in the Netherlands and 1,4-dimethylmaphthalene in USA, but none are yet approved in the UK.

Loss of CIPC would cause serious difficulties in storing potatoes, particularly for the processing market, which requires storage at higher temperatures.

8.0 Summary matrix

The impact on industry gross margins under current pesticide measures still leaves some room for improvement (Table 38). The biggest impact on the potato production comes from late blight with losses of £55 million, followed by PCN in ware crops with losses of almost £26 million. Slugs are an important problem in all sectors, costing the industry losses of over £15 million. In the seed sector, losses due to virus transfer from aphids is important causing losses of more than £5 million or over 10% of gross margin. If current chemistry and control could be improved in these areas, this could lead to increased yields and improved gross margins.

The impact on industry gross margins due to changes in PPP availability, taking into account alternative control measures (except PCN), show that the largest impacts come from loss of insecticides and molluscicides under the WFD (Table 38). It should be noted that complete loss of actives under the WFD is by no means certain, and that there could be restrictions in use in certain areas, buffer zones or other measures to still allow some usage. Impacts from changes to 91/414/EEC however are more certain.

Table 38 Summary matrix of losses (£ million)

Losses to industry £M		Weeds	Disease			Pests					
Crop	Scenario	All weeds	Blight	Dry rot	Stem Canker, Black scurf, Silver scurf, Skin spot, Black dot (Combined skin diseases)	Potato cyst nematodes	Slugs	Peach potato aphid	Potato aphid	Free living nematode	Wireworm
Processing	Revision 91/414/EEC (2c)	4.8	7.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	WFD	4.8	0.0	0.0	0.0	16.4	13.6	0.0	0.0	1.0	0.7
	Untreated	55.0	83.6	3.0	0.0	16.4	13.6	3.2	0.0	0.8	0.7
	Business as usual	1.9	14.2	1.7	0.0	7.5	3.9	1.9	0.0	3.0	0.4
Fresh	Revision 91/414/EEC (2c)	6.8	17.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	WFD	6.8	0.0	0.0	0.0	38.9	33.7	0.0	0.0	2.2	1.8
	Untreated	135.0	207.8	13.1	7.3	38.9	33.7	7.9	0.0	2.2	1.8
	Business as usual	4.8	35.1	4.1	2.4	18.5	9.8	4.8	0.1	7.2	1.0
Seed	Revision 91/414/EEC (2c)	1.9	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	WFD	1.9	0.0	0.0	0.0	0.0	5.5	0.9	0.0	0.0	0.3
	Untreated	25.0	38.1	1.3	2.3	0.0	5.5	16.6	0.0	0.0	0.3
	Business as usual	0.8	6.3	0.7	0.4	0.0	1.7	5.2	0.0	0.0	0.2
Total	Revision 91/414/EEC (2c)	13.5	27.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	WFD	13.5	0.0	0.0	0.0	55.3	52.8	0.9	0.0	3.2	2.8
	Untreated	215.0	329.5	17.4	9.7	55.3	52.8	27.6	0.0	3.0	2.8
	Business as usual	7.5	55.6	6.5	2.8	25.9	15.4	11.9	0.1	10.2	1.5
	Significant losses of	>30% from standard GM									
		20-30% from standard GM									
		10-20% from standard GM									

Under the revisions of 91/414/EEC there are changes to current performance in blight control (£27.8 million reduction across all sectors) and in weed control (£13.5 million reduction across all sectors). These losses are predominantly from the additional costs of control, rather than loss in yield due to reduced control.

Under the Water Framework Directive, the greatest change comes from the potential loss of insecticides. This could reduce levels of control of PCN and slugs to untreated levels in the worst case, reducing gross margin by £55 million and £53 million respectively. This does not take into account any mitigation measures by using resistant or tolerant varieties, or the cost or benefit of alternative control measures).

Virus transfer of aphids would also impact on seed production, despite some actives likely still to remain available.

Weed control is also affected by the Water Framework Directive, primarily through loss of post-emergence options, with a similar impact to the changes from 91/414/EeC of reducing gross margin by £13.5 million.

The mitigating actions and yield losses from weeds are similar for changes in 91/414/EEC and the Water Framework Directive, therefore the losses are not additive if all affected active substances are lost. Losses in gross margin are estimated at £13.5 million for changes is either or both scenarios.

At these impact levels it is likely that changes in the structure of the potato industry would take place. However, there is a degree of uncertainty over what actives will be affected and these are the worst case situations, where actives are completely withdrawn with no economic alternative. It is possible that changes in approval may still allow some usage, such as catchment based limits, or buffer strips. In these situations the overall effect will be lower, but may mean withdrawal of potato production from certain areas.

The seed sector could be at greater risk from virus transfer by aphids due to insecticide withdrawal under the WFD, particularly if selective withdrawal results in increased pressure on aphid resistance.

The changes to 91/414/EEC Annex 2c are more certain, although the final implementation is still to be agreed. There is likely to be reduction in gross margin of 9% due to the withdrawal of mancozeb for late blight control, due mainly from the additional costs of alternative actives, but there is also an increased risk of resistance developing.

The combined impact of 91/414/EEC and WFD show that PCN and slugs are the priority, followed by blight control.

Overall ranking of losses (Table 39) demonstrate that reduction in potential yield under the business as usual (BAU) scenario are often higher than the losses due to reduced pesticide availability, and puts blight, PCN and slugs as priorities.

Table 39 Top ranking losses

Rank	Problem	Losses (£ million)
1	BAU Blight	£55 million
2	WFD PCN WFD Slugs	£54 £53
3	2c Blight	£28
4	BAU PCN	£26
5	BAU Slugs	£15
6	2c/WFD Weeds	£13
7	BAU Aphids	£12
8	BAU FLN	£11

Market acceptability is an issue for chlorpropham and there is a stewardship programme in place. Another impact might be on glyphosate which is regularly found in cereals (and is also threatened under WFD). Limitations on the use of glyphosate could result in greater levels of couch in potatoes.

The economic impact and likelihood of change is taken into account in the matrix of research priorities (Table 40).

Table 40 Matrix of research priorities

Crop protection priorities - potatoes	Weeds	Pests						Diseases			Store
	Weeds	Potato cyst nematod	Slugs	Peach Potato Aphid	Potato aphid	Free living nematode	Wireworm	Blight	Dry Rot	Skin diseases	Sprout control
Breeding and genetics		1		1				1			
Disease management								1	3	?	
Pest management		1	1	2							
Weed management	2										
Store management and											2
Pesticide application &	2		1								
Precision farming	2		1					2			
Pesticide risk management	1	1	1	1	1			1			2

KEY

based on economic impact and likelihood of loss of active

1	High
2	Medium
3	Low
?	For discussion

9.0 Research priorities

General issues

- One of the most noticeable problems in compiling the baseline data was 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 the case for late blight and PCN control.
- 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. This may be a result of usage in other sectors and cross-sector co-operation on product stewardship will be necessary.
- 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 contribute 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 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. 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 slug pellets.
- 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. PCL, and other AHDB sectors 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 allows pesticide use to be managed in such a way as to allow effective 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.

Weed control

- Weeds are a problem of a farming system and their impact though a rotation is an essential management issue. PCL 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.
- The number of herbicides in potatoes is already limited because of the challenge to be specific to a weed and not harming 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. Potatoes are a high value, but small crop and may not attract investment. Consideration should be given to evaluating non-chemical weed control options and assisting crop protection manufacturers to look to other crops for potato opportunities.
- There is little information on the impact of individual weeds on yields of potatoes, or the incidence of weeds. Greater knowledge would allow potato growers to make judgements on the weed control measures best suited to the situation.
- Mechanical weed control can be very effective but is a significant economic and environmental cost. Improving the timing and reducing the need for mechanical weed would be possible if more was known about weed emergence patterns and their competitivity in relation to potato growth and possible damage. This could avoid unnecessary passes. This would be an area of work relevant to several other sectors, such as horticulture and sugar beet.
- Seed potatoes are at greater risk of poor weed control due to the lack of post-emergence options. This should be a priority for investigating alternatives.

Pest control

- There is scope for improvement in PCN and slug control over performance of currently available chemicals, through better identification or targeting of the pests and practical and reliable methods need to be identified.

- Pest control in potatoes only becomes an issue under the WFD, and it is as yet unclear the extent of the restrictions and whether that will impact on availability of actives, or restrictions on their usage, or a combination of the two. 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 does not achieve Annex 1 listing. This needs careful monitoring. If metaldehyde use is affected, there will be greater emphasis on methiocarb, which in turn may limit options in potato production. Action with other AHDB sectors and industry stakeholders should reinforce messages from product stewardship campaigns. There should be a cross sector interaction with water companies and the EA to identify emerging issues early and develop positive solutions if/as they arise.
- 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. The efficacy of ferric phosphate in potatoes should also be established.
- 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 aphid 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.

Disease control

- There is scope to improve the level of late blight control achieved in potatoes over and above what is currently achieved.
- The loss of mancozeb will affect resistance management and potential consequence and actions are a priority for detailed investigation.
- Dry rot may be at risk from developing resistance to thiabendazole, and resistance management should be promoted in the industry, and alternatives evaluated.

Sprout control

- The WFD and review of 91/414/EEC are not predicted to have significant impacts actives used for sprout control. The major potential risk comes from any restrictions on use of chlorpropham that may arise from market requirements or the need to reduce residue levels even more. This is currently being addressed through a stewardship programme, but investigation of alternatives may be necessary.

Appendix 1 – Glossary of Latin names

Common Name	*Scientific Name*
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*
Pests	
Potato cyst nematode	*Globodera pallida, Globodera rostochiensis*
Free living nematodes	*species including Longidorus spp.,*

Common Name	Scientific Name
	Trichodorus spp.
Peach potato aphid	*Myzus persicae*
Potato aphid	*Macrosiphum euphorbiae*
Field slug	*Deroceras reticulatum*
Keeled slug	*Tandonia budapestensis*
White and yellow-soled slugs	*Arion spp*
Leatherjackets	*Tipula paludosa*
Wireworm	*Agriotes lineatus*, *Agriotes obscurus*, *Agriotes sputator*
Diseases	
Late Blight	*Phytophthora infestans*
Rhizoctonia	*Rhizoctonia solani*
Black dot	*Colletotrichum coccodes*
Silver Scurf	*Helmithosporium solani*
Skin spot	*Polyscytalum pustulans*
Powdery scab	*Spongospora subterranean*
Common scab	
Dry Rot	*Fusarium spp.*
Gangrene	
Ring rot	*Clavibacter michaginensis*
Brown rot	*Ralstonia solanacearum*