Agronomic and economic impact assessment for possible human health and ecotoxicology criteria for endocrine disrupting substances

Report to Chemicals Regulation Directorate

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This report considers the short term impact of the withdrawal of 40 potentially endocrine disrupting substances classed either as of more likely or less likely to pose a risk to human health. The more/less status was initially known for 14 actives identified as endocrine disruptors, 5 deemed more likely and 9 less likely (Group 1)[2]. This status was defined for the remaining actives (Group 2 – the 'possible' endocrine disruptors) later in the project with 4 defined as of more likely to pose a risk and 22 less likely. The actives under consideration in this report are the result of an assessment of around 25% of those active substances currently available, and impacts are based on the assumption that **all** non assessed active substances remain available. Thus the impacts are likely to be much greater than those estimated here. Additionally this assessment does not take account of the impact of the other cut-off criteria in Regulation 1107/2009 and the recent EU decision to withdraw 3 neonicitinoid insecticides.

The **Group 1** actives were assessed by ADAS experts against a selected number of active: crop combinations to consider marketable yield impacts as well as any additional costs required to maintain production after the possible withdrawal of the active substance. These assessments were reviewed and commented upon by two external experts and their industry contacts. The effects were then translated into economic impacts using a number of national datasets. The impacts were considered step wise: first with the withdrawal of the active in question only; then assuming all those actives categorised "more likely" were withdrawn together; then withdrawal of both more/less actives, and finally with withdrawal of the actives in the second group of actives, Group 2 (since their status was unknown at that stage).

For **Group 2** the approach was broader. Another crop:active selection process was undertaken with yield impacts considered in the light of withdrawal of all potentially endocrine disrupting substances. Expert judgement was then used to identify whether there would be a yield impact (either with a non ED alternative if available, or in the absence of alternatives). This yield impact was classified as small (modest decline in yield, but production still possible) or large (significant reduction in yield, production seriously challenged). Whilst the output from this part of the exercise is qualitative some quantitative impacts were estimated from the assessment of the Group 1 actives.

Results

Key points

- **Impact 1: Loss of actives more likely to pose a risk in Group 1**

  For the crops assessed, the estimate of annual economic impact for lost marketable yield and additional costs to amount to close to ***£160 million*** almost entirely due to the loss of ioxynil and linuron and the reduction in yield for leeks, onions, carrots, celery, parsnips, and potatoes. This figure does not include those crops (e.g. parsley for processing, celery and celeriac) that would not be viable, nor the potentially significant impact on resistance management from loss of mancozeb. Loss of thiacloprid and abamectin are important when considered in conjunction with Group 2 chlorpyrifos (Impact 3)

- **Impact 2: Loss of all actives in Group 1**

  When actives categorised as less likely to pose a risk in Group 1 are added the estimate of annual economic impact increases to almost ***£350 million***. Notably loss of metribuzin will add to the difficulties of carrot and potato production, and loss of propyzamide will have a significant impact on lettuce. It also includes a small yield but high value impact of the loss of tebuconazole for wheat.

- **Impact 3: Loss of actives more likely to pose a risk in both Group 1 and Group 2**

  The loss of chlorpyrifos on raspberries and strawberries increases the Impact 1 estimate to almost ***£225 million***. The loss of chlorpyrifos (in addition to thiacloprid) would have a large impact on the ability to control insect pests in fruit and vegetable crops. The estimate excludes a number of other active:crop combinations (mostly chlorpyrifos) that have only been assessed qualitatively. Thus the expected impact is higher.

- **Impact 4: Loss of actives in both Groups 1 and 2.**

  The inclusion of all Group 2 actives increases the Impact 2 estimate to almost ***£440 million***. There are a wide range of crops including soft fruit, potatoes, carrots, onions and sugar beet for which significant yield losses would occur as a result of the withdrawal of these actives. However, this excludes a number of other active:crop combinations that have only been assessed qualitatively. A number of crops including lettuce, soft fruit, top fruit and some other vegetable crops are identified as being potentially unviable. Thus the expected impact is higher.

These estimates assume all other actives remain available and losses could be substantially higher if this is not the case. For example, the modest losses associated with a loss of prothioconazole assume that other triazoles, especially epoxiconazole, remain available. If these other triazoles were to be lost the impact on production would be significantly higher.

- **Wider impacts**

  The four estimated impacts above do not include important wider impacts. With small potential markets, and lost income from existing substances to fund research and development, the development of new products and product extensions could be damaged on top of prior investments that will be lost. Withdrawal could also create problems of resistance to those actives remaining as well as reduce flexibility in control options including IPM. Reduced quality and unreliable supplies, particularly of fruit and vegetables would mean increased imports from outside Europe and potentially increased costs for the consumer. The control of non-native species would also be compromised to some degree.

  Thus the implications are more serious and wider than their monetary loss estimate implies.

These headline figures for the estimated value of the effect of active withdrawal for each of the defined impact are fleshed out a little more below. Those crops with an estimated yield loss valued at more than £10 million are also listed.

		Impact 1		Impact 2	
	Active	**Estimated costs of withdrawal (£000)**	**Crops with high value impact**	**Estimated costs of withdrawal (£000)**	**Crops with high value impact**
Group 1 more likely to pose a risk	Mancozeb	81		81	
	Ioxynil	40,856	Leeks, onions(dry bulb)	43,638	Leeks, onions(dry bulb)
	Linuron	117,361	Carrots, celery, potatoes	108,393	Carrots, celery, parsnips
	Abamectin	*		*	
	Thiacloprid			*	
Group 1 less likely to pose a risk	Bupirimate	Not considered		23,298	Cucurbits
	Iprodione			1,203	
	Myclobutanil			*	
	Prochloraz			3,796	
	Tebuconazole			53,290	OSR, wheat
	Thiophanate -methyl			*	
	Metribuzin			79,762	Potatoes
	Propyzamide			31,315	Lettuce
	Spiromesifen			*	
		£ 158,298		**£ 344,777**	

*Impacts expected but unknown.

It should also be noted that for this table and all others that follow, where no impact has been estimated, this assumes that other actives are available and excludes the potential impact of increased resistance due to fewer actives (e.g. mancozeb as a multisite inhibitor). Where it is assumed that there are alternatives as effective, in a number of cases this comes with the caveat that there will be suitable weather conditions, that the timing and frequency of applications is appropriate, and that IPM systems are not disrupted (e.g. alternatives to abamectin for ornamentals).

For Impact 3 the estimated loss is in addition to that in Impact 1 plus the qualitative assessment of expected large yield losses in other crops due to withdrawal Group 2 actives more likely to pose a risk.

		Impact 3		
		Estimated additional costs of withdrawal (£000)	**Crops with high value impact**	**Qualitative assessment**
Groups 1 and 2 more likely to pose a risk	Thiacloprid & chlorpyrifos	£ 67,378	Strawberry	Chlorpyrifos - 18 crops identified as having potentially large yield losses and viability of production challenged e.g. apples, pears, plums
		£ 225,676		

For Impact 4 the estimated yield loss is in addition to Impact 2 plus the qualitative assessment of expected large yield losses in other crops due to the withdrawal of all Group 2 actives.

		Impact 4		
		Estimated additional costs of withdrawal (£000)	**Crops with high value impact**	**Qualitative assessment**
Groups 1 and 2	Ioxynil & chlorpropham, dimethenamid-P, tepraloxydim	12,792		For all actives in Group 2:
	Ioxynil & chlorpropham, dimethenamid-p, s-metalochlor, tepraloxydim and fluazifop-p-butyl	10,509	Onions(dry bulb)	34 crops identified as having potentially large yield losses and viability of production challenged e.g. prothioconozole on barley, ethofumesate and lenacil on sugar beet
	Linuron & s-metolachlor	4,170		
	Thiacloprid, lambda-cyhalothrin & chlorpyrifos	13,292		57 crops identified as having potentially small yield losses e.g. prothioconozole on wheat and OSR
	Prochloraz & Prothioconazole	17,558	Wheat	
	Thiophanate-methyl & prothioconazole	682		
	Propyzamide & s-metolachlor, chloropropham, dimethanamid-P	33,050	Lettuce	
		£ 436,830		

Wider impacts

The actives under consideration in this report were identified as a result of an earlier assessment of around 25% of those active substances currently available for use in the UK, and impacts are based on the assumption that all non assessed active substances remain available.

Section 3 outlines that substantial costs would be incurred by crop protection companies in undertaking additional studies on potential/suspected EDs.

Section 4 highlights a number of other issues around the loss of diversity of active substances and modes of action that will likely mean:

- **Crop protection investment and costs to growers:** Growers may not have the confidence to maintain investment in high value crops and those requiring high investment costs: There are potentially significant costs to crop protection companies both from lost income streams from older actives and from the loss of the investment in new substance development. Many active substances used in minor crops were not supported in the 91/414 EC review for economic reasons and the high cost of further studies required (many of these active substances have already been lost to the industry and often alternatives are not available to replace them).

  The potential loss of so many actives classified as EDs could act as a disincentive to develop crop protection products for the EU, due to reduced markets, challenges in gaining and maintaining approvals. Significant loss to growers for the loss of investment in extensions of use, the latter estimated at an average of £0.4-£0.5m per active substance. Following the loss of certain actives and resultant loss of production it is expected that an increase in food imports from outside Europe is likely for some crops and a subsequent increase in prices of fruit and vegetables for the consumer is possible. The retailer will find continuity of supply less reliable and there may be problems with quality.

  A reduction in number of active substances will result in the increased use of the few remaining substances and this can be expected to have an impact on water quality[1] (Also a risk of increased use of less effective actives).

- **Increased resistance and lack of flexibility:** maintaining effective control in a changing crop protection landscape (including of non-indigenous species) will be negatively affected by losses of substances like mancozeb, thiacloprid, and abamectin. Thus the implications are more serious and wider than their initial monetary loss estimate implies. There is no known resistance of grass weeds to propyzamide and its' loss would have an impact on resistance management (especially of black-grass, *Alopecurus myoseroides*).

  Any regulatory restrictions arising from the ongoing neonicotinoid review can be expected to compound impacts arising as a result of the ED criteria.

  An EPPO working party in 2008 concluded '*that it is also necessary to draw attention to the need to maintain flexibility … to be able to control important pests in a sustainable way, in particular taking into account resistance management. The need for Integrated Pest Management was emphasized and also the need to have, within such an approach, sufficient effective plant protection products*'.

There could be an increased risk of the establishment of a number of non-native species For example spotted winged drosophila (*Drosophila suzukii*), where some actives of concern are the recommended treatment.

[1] S Wynn & G Hughes (2013) Understanding the changes in pesticide usage to inform water company risk assessments – report for DWI – WT1264

Introduction

Aims: The new European Union Plant Protection Products (PPP) Regulation (1107/2009) introduced an exclusion criterion for approval which indicates that any active substance with endocrine disrupting (ED) properties that may cause adverse effects in humans cannot be approved for marketing and use unless the exposure of humans under realistic proposed conditions of use is negligible.

An evaluation of various substances and their classification as EDs as either more likely or less likely to pose a risk in relation to both human health and ecotoxicology impacts has been undertaken by Defra[2]. This follow up to that work considers the agronomic and economic impact of the non-approval of the 14 substances classified as more or less risky (on a selected range of crops) and provides an indication of impact of 26 substances that were classified as more or less risky after the start of the project on the crops on which they are more widely used (more than 25% of crop area treated).

Scope: The actives to be assessed were provided in two tranches. The first group (Group 1) was assessed in more detail and are those substances highlighted in the second column of Table 1. Red cells indicate that the active is considered more risky and the orange denotes less risky. The second group were still being assessed for level of concern at the beginning of this project and the economic consequences are considered more broadly. The active substances in Group 2 and the resulting classification of these are shown in the third column of Table 1. Full list of those active substances assessed is included in Appendix 1.

		Group 1	Group 2
Fungicides	Carbendazim		Orange
	Mancozeb	Red	
	Bupirimate	Orange	
	Cymoxanil		Orange
	Fluazinam		Red
	Fosetyl aluminium		Orange
	Hymexazol		Orange
	Iprodione	Orange	
	Mandipropamid		Orange
	Myclobutanil	Orange	
	Prochloraz	Orange	
	Prothioconazole		Orange
	Silthiofam		Orange
	Tebuconazole	Orange	
	Thiophanate-methyl	Orange	
	Thiram		Orange
Herbicides	Chlorpropham		Orange
	Dimethenamid-P		Orange
	Ethofumesate		Orange
	Fluazifop-p-butyl		Orange
	Ioxynil	Red	
	Lenacil		Orange
	S-metolachlor		Red
	Metribuzin	Orange	
	Pinoxaden		Orange
	Propyzamide	Orange	
	Tepraloxydim		Orange
	Terbuthylazine		Red
	2,4-D		Orange
	Glufosinate-ammonium		Orange
	Linuron	Red	
Insecticides	Abamectin	Red	
	Clothianidin		Orange
	Beta-cyfluthrin		Orange
	Lamda-cyhalothrin		Orange
	Spinosad		Orange
	Spiromesifen	Orange	
	Spirotetramat		Orange
	Thiacloprid	Red	
	Chlorpyrifos		Red

Table 1: Active substances assessed
(Red cell – more risky; Orange: less risky)

[2] Extended impact assessment study of the human health and environmental criteria for endocrine disrupting substances proposed by HSE, 2012. 101 actives were assessed out of over 400 approved plant protection products chosen on the basis of their usage in arable and horticultural crops (based on Fera surveys) with some adjustment to the latter category to reflect Extensions of Authorisation for Minor Use. The 300 actives not considered would also give rise to economic impacts should they be shown subsequently to be EDs.

The Food and Environment Research Agency

1. Method

Group1:

Based on the list of expected endocrine disruptors provided by CRD data were extracted from the FERA Pesticide Usage Survey Database to identify what crops the actives were used on and what proportion of the crop was treated. Based on this information, ADAS expert knowledge and feedback from the external experts the list of crops was narrowed down to 5-10 key uses per active substance. The total area of crop grown and crop area treated as well as the number of applications were taken from the latest pesticide usage survey data (adjusted for changes in approvals since the latest survey). It was assumed therefore that the impacts would be limited to the proportion of the crop treated with the active substance – not the whole crop area.

NB: The selection process of crop:active combinations has not captured all those crops that could be affected by active withdrawal, just the most important combinations or examples from a group of crops e.g. strawberries to represent soft fruit. In addition, a number of the crop and active substance combinations have impacts but these have not been quantified (e.g. because of the difficulty of quantifying effect on yield on minor crops). Thus the results do not show all the possible impacts of active withdrawal.

A spreadsheet was developed to collect information from a range of experts including pathologists, entomologists, weed scientists and horticultural consultants. They used a combination of expert knowledge, consultation with industry contacts, published data and trials information where that was available to complete the spreadsheet. The information required for each active:crop combination included;

- **What is the main target?** This is the main pest(s)/disease(s)/weed(s) that the active substance is used to control in that crop. It is important to note that, while the assessment is generally restricted to the main pest, in many cases secondary pests are significant that may or may not have many alternatives or have alternatives also subject to potential active withdrawal. No herbicide active substance alone controls the whole weed spectrum and a range of herbicides is used. The loss of one of them may mean failure to control an important species.
- **What are the alternative control options?** Here both chemical and non-chemical alternatives for the control of the pest/disease/weed were identified
- **Are they as effective?** This section allowed the experts to provide both a quantitative answer in terms of a percentage change in marketable yield (where possible) and a qualitative answer in terms of the likely challenges/benefits of using alternative control options. This assessment was reinforced with input from the two external experts.
- **What are the cost implications of the alternative control options?** Again both qualitative and quantitative answers were provided. This included capturing any changes in the cost of chemicals or other alternatives used on the crop, any increases in labour costs (e.g. for hand weeding). In some situations exact costs were not given just an indication of the likely options and the potential costs of these options.

This process was repeated four times effectively creating 4 scenarios;

- Scenario 1 - For each Group 1 active:crop combination the impacts of a loss of the active were looked at in isolation, assuming all alternatives remained available.

- Scenario 2 – Building on scenario 1 - Identifying any of the alternatives within Group 1 that also fell into the *more risky* category and assuming that both the initial active and any alternatives in the more risky category were lost, to determine whether or not the impact would be greater.
- Scenario 3 – Building on scenario 2 - Identifying any of the alternatives within Group 1 that also fell into the *less risky* category to determine the impact on the ability to grow the crop economically of all group 1 endocrine disruptors no longer being available.
- Scenario 4 – Building on scenario 3 – Identifying any of the alternatives that were in Group 2, the previously unclassified group, and determining whether the loss of these would have an additional impact on the ability to grow the crop.

Group 2:

The group two active substances had not been classified at the start of this project and were to be assessed more generally. For the assessment of the impacts of a withdrawal of these a simple decision tree was used. First usage patterns were identified from the PUS data. These were then checked by crop experts to check that approvals still existed (or to identify new approvals) especially relevant for those crops that are surveyed less frequently. The PUS data shows the area of crop grown and proportion of crop treated. These data was used as an initial filter. Any crops in which less than 25% of the area was treated were excluded to reduce the scope of the assessment.

The second phase was to identify which crops had alternatives which were not classified as endocrine disruptors. Expert judgement was then used to identify whether there would be a yield impact (either with a non ED alternative if available, or in the absence of alternatives). This yield impact was classified as small (modest decline in yield, but production still possible) or large (significant reduction in yield, production seriously challenged).

Overall, for both Groups 1 and 2, since only 30% of all UK approved active substances were reviewed for their ED potential the estimated yield impacts are dependent on alternatives outside the scope of this review. There is a chance that the alternatives will also be classified as of concern and thus their availability is not guaranteed. In addition there are likely to be losses due to other risk criteria e.g. persistent, bioaccumulative and toxic actives (PBTs or 2PBTs) and actives with water issues. Pendimethalin is a key herbicide for use in fruit and vegetables and if this is lost due to risk criteria conventional production of these crops would not be possible. For some neo-nicotinoid insecticides, there is a further risk of loss arising from the consideration of possible effects on bees (see section 4.7).

Estimation of Impacts

Four levels of impact were considered:

- Impact 1: Loss of actives categorised as more risky in Group 1 (Scenario 2 as above)
- Impact 2: Loss of all actives in Group 1 (Scenario 3);
- Impact 3: Loss of actives categorised as more risky in both Group 1 and Group 2 (Scenario 4 and qualitative assessment);
- Impact 4: Loss of actives in both Groups 1 and 2 (Scenario 4 and qualitative assessment).

It should be noted that quantifying yield loss is always difficult because it depends on a wide range of issues including pest or disease severity and the conditions prevailing. In the case of weeds the effect depends on population and species, for example thistles and nettles deter pickers of hand-harvested crops, woody species interfere with machine harvesters, fat-hen shades crops. Weeds also reduce quality and are contaminants (sometimes toxic). It is also important to point out that for some situations (especially where multiple pesticide applications are required), while there may be an alternative available, in many cases this may not provide a sufficient frequency or total number of applications to enable adequate control. And where the ED is a different mode of action to the alternative, loss may significantly impair resistance management.

For Group 1 the assessment of the impact on marketable yield and additional costs were applied to crop data on area of crop treated (from the pesticide usage survey), and 5 year average price and yield data from Defra statistics (Basic Horticultural Statistics 2012 and Agriculture in the UK 2012) as well as industry for crops not included in data from these sources.

For Group 2 the assessment was more qualitative. A more appropriate set of crop:active combinations were selected and the impact defined as either small or large.

Thus the economic impacts for Impact 3 and 4 will include some quantitative impacts from the analysis of Group 1 actives plus the qualitative element from the Group 2 assessment.

2. Results

These results reflect the initial annual impact of withdrawal at the farm level with prices remaining unchanged. Reductions in yield might bring about price increases if no new supply sources are available. Further, over time, changes to active substance approval might be expected to bring forward new alternatives[3], or result in further loss or restrictions on use patterns, or the price of those that do exist to fall as their use increases. The speed of such changes is not known and is not addressed here. Thus the impacts in monetary terms expressed here are subject to a number of unknown variables, but this should not obscure the fact that for some crops the yield impact appears sufficiently large to make continued production at current scales unviable.

In many cases there are non-chemical alternatives for weed control (cultivations, mechanical weeding and manual weeding). However, in most crops these are often more expensive than chemical control. Mechanical weeding is ineffective in a wet season because weeds re-root, and after each soil disturbance there is another flush of weeds so the operation has to be repeated. It may not be an option in some systems of vegetable production, for example baby carrots grown at high population on close rows. Hand-weeding (assuming labour is available) to remove weeds within the crop row is costly (and exposes workers to potentially harmful solar radiation).

2.1 Impact 1: Group 1 loss of actives more likely to pose a risk

The estimated impact of the loss of these actives is shown in Table 2 and assumes all other actives remain available (including those classified as less likely to pose a risk in Group 1 or in Group 2), and those not considered for their ED potential. The table shows the crops that were selected to be assessed against each of the five actives categorised as more likely to pose a risk followed by the area planted and proportion of this treated by the active. The next two columns are the assumptions used to estimate the value of reductions in marketable yield and the additional costs that would result from the use of alternatives. These assumptions are then scaled up to provide estimates of the impact of withdrawal using 5 year average price and yield data.

The headline figure for loss of the Group 1 actives categorised as more likely to pose a risk on the selected crops considered is a little over £158 million but this comes with a number of caveats which are addressed in the comments below on the individual actives. The estimates of the economic impact for the individual actives are the cells at the extreme right of the table. There are comments on impacts if alternative actives are lost subsequently. Blanks in the table may be due to uncertainty and an impact is actually expected. In other cases, e.g. onions, this additional input has identified other alternative actives not included in the ADAS assessment.

The impact is dominated by **ioxynil** for onions and leeks, and **linuron** with the impact of withdrawal of the latter on carrots and potatoes accounting for over half of the total (with some crops e.g. parsley for processing, celery and celeriac possibly no longer viable).

[3] This is less likely for herbicides for fruit and vegetables because they are crop specific- crop safety and therefore a smaller market, whereas an aphicide or fungicide for example could be marketed for several crops.

Active	Crop	Area	% treated	Reduction in yield	Change in cost per hectare	Value of lost marketable yield	Additional costs	
Mancozeb	Brassicas	11,325	50%	0%	£ 10	£ -	£ 56,906	
	Bulbs	4,875	60%	0%	£ 5	£ -	£ 14,510	
	Grapevines	1,144	100%	0%	More expensive	£ -	*	
	Herbs	1,980	100%	0%	£ 5	£ -	£ 9,900	£ 81,316
Ioxynil	leeks	1,718	100%	40%	£ 500	£ 14,084,297	£ 859,000	
	Onions(dry bulb)	8,448	100%	20%	£ 500	£ 14,012,216	£ 4,224,000	
	Onions(salad)	1,706	100%	30%	£ 500	£ 6,823,883	£ 853,000	£ 40,856,397
Linuron	Carrots	11,135	100%	30%	£ 600	£ 35,651,603	£ 6,681,000	
	Celeriac	240	100%	50%	Very high	£ 1,332,000	*	
	Celery	859	93%	50%	£ 1,000	£ 11,091,902	£ 796,000	
	French beans	1,280	95%	20%	£ -	£ 2,653,753		
	Parsley (processing)		67%	100%	Very high		*	
	Onions (dry bulb)	8,448	79%	5%	£ -	£ 2,781,544	£ -	
	Leeks	1,718	133%	0%	£ 100	See ioxynil		
	Parsnips	3,341	93%	35%	£ 600	£ 9,558,367	£ 1,857,580	
	Potatoes	116,606	50%	10%	£ 150	£ 36,218,935	£ 8,738,250	£ 117,360,935
Abamectin	Blackberry	112	100%	*	More expensive	*	*	
	Ornamentals		19%	*	£ -	*	*	
	Hops	1,071	3%	*	Minimal	*	*	
	Leeks	1,718	14%	0%	£ -	£ -	0	
	Strawberry	2,472	73%	0%	Very high	£ -	*	*
Thiacloprid	Ornamentals		36%	0%	£ -	£ -	0	
	Blackcurrant	1,795	51%	0%	£ -	£ -	0	
	Brassicas	18,326	33%	0%	£ -	£ -	0	
	OSR	641,115	1%	0%	More expensive	£ -	*	
	Raspberry	1,072	100%	0%	£ -	£ -	0	
	Seed potatoes	16,689	71%	0%	£ -	£ -	0	
	Strawberry	2,472	97%	0%	£ -	£ -	0	
	Wheat	1,927,683	0%	0%	£ -	£ -	0	
	Apples		0%	0%	£ -	£ -	0	*
						£ 134,208,501	£ 24,090,146	£ 158,298,647

Table 2: Impact 1: Group 1 actives more likely to pose a risk

For those actives labelled with * there could be impacts - on quality, harvestability or complete crop rejection (parsley for processing) but these are less certain. Where no impact is estimated, this reflects the specific context whereby all other actives are available.

The comments below should be read in conjunction with the table

Comments on Group 1 Actives more likely to pose a risk

Mancozeb

- Brassicas: for downy mildew, white blister (when used in mixture with metalaxyl-M or chlorothalonil – neither in this review). Alternative is mandipropamid (Group 2 less likely), but varieties may differ in resistance. Potential to use more biocontrol agents but not proven. Increased risk of resistance in other products if this multisite inhibitor is lost.

- Bulbs: for white mould. Alternative - clean fields away from last years crops, do not grow narcissus in very shady sheltered fields, several strobilurins and azoles available. Resistance to azoxystrobin is suspected

- Grapevines: downy mildew. Alternatives - benthiavalicarb-isopropyl (not in this review) and mancozeb, copper oxychloride (not in this review), cymoxanil (Group 2 less likely), metalaxyl – m (not in this review). Losses other than yield - resistance risk with the possible loss of multi site inhibitor. A range of fungicides is needed to prevent resistance occuring and also to ensure full control right up to harvest

- Herbs/lettuce & baby leaf: downy mildew. Alternatives include cropping density, field location, and open field.
- As is apparent in the above, as a multisite inhibitor, mancozeb is very important for resistance management.

Ioxynil

Is a key foliar-acting herbicide for Allium crops. Onions and leeks are poor competitors with weeds and the aim is to achieve 100% control.

- Leeks: low doses of ioxynil are tank-mixed with other herbicides to control the spectrum of broad-leaved weeds. Loss of this active could not be compensated for by any other product. The use of additional mechanical weeding would be more expensive and it is ineffective in wet weather. If extensive hand weeding was required the additional cost would be very high.
- Onion (salad): severely affected by weeds. Salad onions are hand-harvested and weeds reduce harvesting rate. Bromoxynil a potential alternative is not approved for use in salad onions. Hand-weeding within the row would be needed.
- Onion (dry bulb): bromoxynil is now available as an effective alternative. The estimate for the impact on bulb onions is lower than for leeks or salad onions where it is not yet approved. Bromoxynil was classified in this study as 'not an ED'.

Linuron

- Carrots: linuron forms the basis for broad-leaved weed control in carrots but dose rates have been reduced. Aclonifen is an alternative available in other EU Member States, but not in the UK. Carrots (and parsnips) at early growth stages are poor competitors with weeds. Weeds affect quality in terms of size grade and uniformity of crop and failure to meet specifications results in crop rejection or no sales. Linuron is also used in tank-mix with prosulfocarb to control volunteer potatoes (prosulfocarb is not an ED, but used alone is ineffective). Volunteer potatoes uncontrolled in carrots can be a reservoir of potato blight infection.
- Celeriac: production is highly dependent on linuron. Alternatives clomazone (not an ED) and prosulfocarb (not an ED) only control a narrow weed spectrum. Hand-weeding within the crop rows would be needed and the crop could be uneconomic to grow.
- Celery: linuron is the mainstay for weed control post-emergence, and pendimethalin as a pre-emergence residual treatment. Without linuron hand-weeding would be needed but this is difficult because celery plants are close-spaced. Celery would be uneconomic to grow.
- Dwarf French beans: there are very few available herbicides and only low doses of linuron are safe. Pendimethalin is also used but can cause damage if applied late. Hoeing causes damage and soil build-up round plants results in contamination of pods. For the processed crop labour may not be available for hand-weeding.
- Parsley: linuron is the key herbicide for umbelliferous herb crops (e.g. parsley). Although other products are approved (as Extension of Authorisation for Minor Uses) on herbs in general, they are only safe on specific herbs. Parsley is machine harvested for processing and a very high standard of weed control is needed. Weed contaminants are unacceptable and it would be uneconomic to try to separate crop from weed - the crop is

rejected. The crop cannot be hoed and hand-weeding is inadequate. The crop could not be grown.

- Onions (bulb): linuron is used post-emergence in some situations (possibly less usage than the figure given). It is less important than ioxynil, and bromoxynil now available.
- Leeks: have a longer growing period than bulb onions. Linuron as well as ioxynil is very widely used in leek in repeat low dose post-emergence programmes. The loss of both ioxynil and linuron would have a severe impact on this crop.
- Parsnips: are more reliant on linuron than carrots because there are fewer options - metribuzin has an EAMU but it can cause damage. Linuron is also used in tank-mix with prosulfocarb to control volunteer potatoes.
- Potatoes: linuron, the single most important herbicide particularly for seed crops, controls many weed species. Restriction on dose rates means tank-mixes with other herbicides such as pendimethalin are needed to reinforce activity, but pendimethalin may also be under threat. Alternative residual soil acting herbicide metribuzin is classed as a less risky Group 1 ED. Clomazone (not an ED, used for cleaver control), and prosulfocarb (not an ED) only control narrow weed spectra. Post-emergence herbicides do not fill the gap but are used for some weed problems and where low soil moisture has resulted in inadequate residual activity - rimsulfuron (for cleavers) and bentazone. Mechanical control is less effective than herbicides and causes root damage resulting in yield reductions. It is also precluded from production of early potatoes under plastic film or fleece protection.

Abamectin

- Blackberry: alternatives available, but for bud mite and to a lesser extent spider mite yield losses would be expected if thiacloprid (Group 1 more risky), spinosad (Group 2 less risky), and chlorpyrifos (Group 2 more risky) were also lost. However, quantification is difficult. Abamectin may also provide control of blackberry mite an increasingly important pest of protected blackberry crops
- Ornamentals: this crop is a good example of where a range of actives are affected and with a range of challenging pests serious problems can be expected, especially from those targeted by affected actives. Some of the pests, such as leafminers, have limited alternatives. Thus increasing reliance on fewer active substances becomes more problematic if further actives are lost in the future. As in many cases some alternatives are disruptive to IPM.
- Hops: used in the past to target two spotted spider mite - hop growers have also been careful that they do not use insecticides that are harmful to natural predators so in recent years this pest has not been much of a problem.
- Leeks: Linked with chlorpyrifos and spinosad, thrips cause serious quality impairment to the crop (plus there is now high pyrethroid resistance in the target)
- Strawberry: important for tarsonemid control; no chemical alternatives. The increased use of the only alternative biocontrol agents would considerably increase costs and may not provide complete control in some seasons.

Thiacloprid

- Ornamentals: alternative aphicides are available (acetamiprid) so less of a problem than for abamectin

- Blackcurrant: Thiacloprid unlike the other alternatives offers the opportunity to control aphids and scale insects which have waxy bodies or are feeding within rolled up leaves where products with contact action would be ineffective. Alternatives chlorpyrifos and lambda-cyhalothrin (Group 2 less risky) – if lost would see yield reduction particularly in future years due to lack of shoot growth that has been damaged by aphids
- Brassicas: difficult to quantify. Against mealy aphids, loss of this and possible loss of spirotetramet (Group 2 less risky) mean contamination of crops can be expected affecting marketability. Acetamiprid is limited to a single application so for long season crops like sprouts and savoy cabbage some impact from thiacloprid loss would be expected.
- OSR: difficult to quantify - use is only 1% of crop area. Serious yield loss in Germany on more than 200k ha (Heimbach, EPPO) in 2006 due to failure of control of pollen beetle which is now developing pyrethroid resistance. Pyrethroid resistance is spreading among the pollen beetle population. Thiacloprid was an effective alternative and is now one of only two neonicotinoids approved on OSR for pollen beetle (acetamiprid not assessed in this review) although indoxacarb and pymetrozine are also now available, plus several pyrethroids.
- Raspberry; two alternatives, one being chlorpyrifos (Group 2 more risky) and the other potentially highly disruptive to bio-control agents, pollinators etc. Failure to control raspberry beetle can lead to yield losses of c15-20%.
- Seed potatoes: not a yield effect but it is important to keep seed crops virus free so regular aphicide programmes are used and needed, and (given the nature of the aphid) a range of modes of action. Acetamiprid is available so this minimises impact but it is restricted to two applications.
- Wheat: wheat blossom midge, which occurs sporadically, has potential to cause average 3% (but up to 50%) loss on affected crops. Approved alternative products are all EDs. Resistant varieties are available, but not suitable for all markets.
- Apples: Much of the pest management in apples is done using IPM, therefore the initial impact of losing thiacloprid might be minimal. However when combined with the loss of chlorpyrifos the diversity of pests for which these actives give incidental control means that down the line some impacts of withdrawal can be expected, especially as pyrethroid alternatives are incompatible with IPM. Cost of these impacts is difficult to determine as it is unclear how the pest populations will respond to IPM in the absence of these actives.

2.2 Impact 2: Loss of all actives in Group 1

The estimated impact of the loss of these actives is shown in Table 3 and assumes all other actives are available (including those in Group 2). The headline impact is estimated to be a little under £350 million annually. The table shows initially the actives categorised as more risky and these figures differ somewhat from Table 2 as some impacts are due to withdrawal of multiple actives. Thus the impacts are shown against just one active to avoid double counting.

The increase in estimated impact comes primarily from yield reduction in cucurbits (bupirimate and myclobutanil), OSR and wheat (tebuconazole), potatoes (linuron and metribuzin) and lettuce (propyzamide). Comments on the individual actives follow the table.

Table 3: Impact 2: Group 1 loss of all actives

Active	Crop	Area	% treated	Impact 1 Yield impact	Impact 1 Change in costs/ha	Impact 2 Yield impact	Impact 2 Change in costs/ha	Impact 1 Value of lost marketable yield	Impact 1 Additional costs	Impact 2 Value of lost marketable yield	Impact 2 Additional costs	
Mancozeb	Brassicas	11,325	50%	0%	£ 10	0%	£ -	£ -	£ 56,906	£ -	£ -	
	Bulbs	4,875	60%	0%	£ 5	0%	£ -	£ -	£ 14,510	£ -	£ -	
	Grapevines	1,144	100%	0%	More expensive	0%	£ -	£ -	*	£ -	*	
	Herbs	1,980	100%	0%	£ 5	0%	£ -	£ -	£ 9,900	£ -	£ -	£ 81,316
Ioxynil	leeks	1,718	100%	40%	£ 500	40%	£ 500	£ 14,084,297	£ 859,000	£ -	£ -	
	Onions(dry bulb)	8,448	100%	20%	£ 500	25%	£ 500			£ 16,793,760	£ 4,224,000	
	Onions(salad)	1,706	100%	30%	£ 500	0%	£ -	£ 6,823,883	£ 853,000	£ -	£ -	£ 43,637,941
Linuron	Carrots	11,135	100%	30%	£ 600	45%	£ 900		£ 6,681,000	£ 53,477,405	£ 10,021,500	
	Celeriac	240	100%	50%	Very high	0%	£ -	£ 1,332,000	*	£ -	*	
	Celery	859	93%	50%	£ 1,000	0%	£ -	£ 11,091,902	£ 796,000	£ -	£ -	
	French beans	1,280	95%	20%	£ -	0%	£ -	£ 2,653,753	£ -	£ -	£ -	
	Parsely (processing)		67%	100%	Very high	0%	£ -		*	£ -	*	
	Onions (dry bulb)	8,448	79%	5%	£ -	25%	£ 500		£ -	See ioxynil		
	Leeks	1,718	133%	0%	£ 100	0%	£ -	See ioxynil		£ -	£ -	
	Parsnips	3,341	93%	35%	£ 600	40%	£ -	£ 9,558,367	£ 1,857,580	£ 10,923,848	£ -	
	Potatoes	116,606	50%	10%	£ 150	10%	£ 200			See metribuzin		£ 108,393,355
Abamectin	Blackberry	112	100%	*	More expensive	*	£ -	*	*	*	*	
	Ornamentals	233	19%	*	£ -	*	£ -	*	£ -	*	£ -	
	Hops	1,071	3%	*	Minimal	*	£ -	*	*	*	*	
	Leeks	1,718	14%	0%	£ -	0%	£ -	£ -	£ -	£ -	£ -	
	Strawberry	2,472	73%	0%	Very high	0%	£ -	£ -	*	£ -	*	*
Thiacloprid	Ornamentals	8,120	36%	0%	£ -	0%	£ -	£ -	£ -	£ -	£ -	
	Blackcurrant	1,795	51%	0%	£ -	0%	£ -	£ -	£ -	£ -	£ -	
	Brassicas	18,326	33%	0%	£ -	0%	£ -	£ -	£ -	£ -	£ -	
	OSR	641,115	1%	0%	More expensive	0%	£ -	£ -	*	£ -	*	
	Raspberry	1,072	100%	0%	£ -	0%	£ -	£ -	£ -	£ -	£ -	
	Seed potatoes	16,689	71%	0%	£ -	0%	£ -	£ -	£ -	£ -	£ -	
	Strawberry	2,472	97%	0%	£ -	0%	£ -	£ -	£ -	£ -	£ -	
	Wheat	1,927,683	0	0%	£ -	0%	£ -	£ -	£ -	£ -	£ -	
	Apples	-	0%	0%	£ -	0%	£ -	£ -	£ -	£ -	£ -	*

				Impact 1		Impact 2		Impact 1		Impact 2		
Active	**Crop**	**Area**	**% treated**	**Yield impact**	**Change in costs/ha**	**Yield impact**	**Change in costs/ha**	**Value of lost marketable yield**	**Additional costs**	**Value of lost marketable yield**	**Additional costs**	
Bupirimate	Cucurbits	884	30%	0%	£ 10	20%	£ 20			£ 20,614,717	£ 5,304	
	Hops	1,071	100%	10%	£ -	30%	£ -	£ 669,616	£ -	£ 2,008,848	£ -	
	Strawberry	2,472	100%	0%	*	0%	*	£ -	*	£ -	*	£ 23,298,485
Iprodione	Ornamentals	15,566	8%	10%	£ 1,000	>10%	£ -	*	£ 1,202,897	*	*	
	Grapevine	1,144	73%	0%	£ -	0%	£ -	£ -	£ -	£ -	£ -	**£ 1,202,897**
Myclobutanil	Blackcurrant	1,795	85%	0%	£ -	0%	£ -	£ -	£ -	£ -	£ -	
	Cucumber	233	71%	0%	£ 10	20%	£ 20			See bupirimate		
	Grapevine	1,144	100%	0%	Small increase	0%	>0	£ -	*	£ -	*	
	Ornamentals	15,707	100%	0%	£ -	0%	£ -	£ -	£ -	£ -	£ -	
	Pears	1,866	60%	0%	Almost double	0%	£ -	£ -	*	£ -	£ -	
	Strawberry	2,472	100%	0%	Small increase	0%	Small increase	£ -	*	£ -	*	*
Prochloraz	Ornamentals	4,875	20%	0%	£ -	0%	£ -	£ -	£ -	£ -	£ -	
	Linseed	43,839	50%	2%	£ 5	0%	£ -	£ 257,210	£ 108,935	£ -	£ -	
	Oilseed rape	641,115	16%	0%	£ 5	0%	£ -	£ -	£ 521,605	£ -	£ -	
	Wheat	1,927,683	30%	0%	£ 5	0%	£ -	£ -	£ 2,908,345	£ -	£ -	£ 3,796,095
Tebuconazole	Brassicas	18,326	50%	0%	£ 10	0%	£ 10	£ -	£ 92,115	£ -	£ -	
	Bulbs	4,875	100%	0%	£ 5	0%	£ -	£ -	£ 24,375	£ -	£ -	
	Carrots	11,135	100%	0%	£ 20	0%	£ -	£ -	£ 221,720	£ -	£ -	
	Leeks	1,718	100%	0%	£ 10	0%	£ -	£ -	£ 17,180	£ -	£ -	
	Onions (salad)	1,706	49%	0%	£ 20	0%	£ -	£ -	£ 16,620	£ -	£ -	
	OSR	641,115	55%	5%	£ 5	0%	£ -	£ 17,310,516	£ 1,752,585	£ -	£ -	
	Raspberry	1,072	61%	Small	Small increase	0%	£ -	£ -	£ -	£ -	£ -	
	Vicia beans	168,509	31%	0%	£ 6	0%	£ -	£ -	£ 309,294	£ -	£ -	
	Wheat	1,927,683	74%	0%	£ 5	2%	£ -	£ -	£ 7,095,625	£ 26,450,198	£ -	£ 53,290,228
Thiophanate - methyl	Ornamentals	11,135	13%	0%	£ -	*	£ -	£ -	£ -	*	£ -	
	Oilseed rape	641,115	5%	0%	£ -	0%	£ -	£ -	£ -	£ -	£ -	
	Tomato	217	0%	10%	£ -	0%	£ -	£ -	£ -	£ -	£ -	
	Carrots	11,135	13%	0%	£ -	0%	£ -	£ -	£ -	£ -	£ -	*
Metribuzin	Asparagus	1,970	83%	5%	£ -	0%	£ -	£ 778,706	£ -	£ -	£ -	
	Bulbs	4,875	1%	0%	£ -	0%	£ -	£ -	£ -	£ -	£ -	
	Carrots	11,135	63%	10%	£ 100	See Linuron	£ -	See linuron		See linuron		
	Potatoes	116,606	82%	10%	£ 175	10%	£ 200			£ 59,759,533	£ 19,223,600	**£ 79,761,838**
Propyzamide	Ornamentals	1,795	30%	0%	>0	0%	£ -	£ -	£ -	£ -	£ -	
	Christmas trees	10,000	26%	0%	>0	0%	£ -	£ -	£ -	£ -	£ -	
	Hops	1,071	25%	0%	>0	0%	£ -	£ -	£ -	£ -	£ -	
	Lettuce	6,930	95%	25%	£ -	0%	£ -	£ 30,403,009	£ -	£ -	£ -	
	Oilseed rape	641,115	37%	0%	£ -	0%	£ -	£ -	£ -	£ -	£ -	
	Radicchio	124	97%	50%	£ -	0%	£ -	£ 912,000	£ -	£ -	£ -	
	Raspberry	1,072	23%	*	*	*	*	*	*	*	*	
	Strawberry	2,472	25%	*	*	*	*	*	*	*	*	£ 31,315,009
Spiromesifen	Ornamentals	2,636	7%	0%	£ -	0%	£ -	£ -	£ -	£ -	£ -	
	Strawberry	2,472	0%	*	£ -	*	£ -	*	£ -	*	£ -	
	Tomato	217	35%	0%	£ -	0%	£ -	£ -	£ -	£ -	£ -	*
								£ 95,875,259	£ 25,399,192	£ 190,028,308	£ 33,474,404	**£ 344,777,163**

For those actives labelled with * there could be impacts - on quality, harvestability or complete crop rejection (parsley for processing) but these are less certain and difficult to quantify. Where no impact is estimated, this reflects the specific context whereby all other actives are available.

The comments below should be read in conjunction with the table.

Comments on Group 1 Actives categorised less risky

Bupirimate

- Cucurbits: Target – Powdery mildew, Varietal tolerance, mid-season and late season, not suitable for first cucumber crop. Alternatives; Cyflufenamid (not in this review), there are also several other fungicides but do not give good knockdown. Biological control agent - *Ampelomyces quisqalis* strain AQ-10. Cucumber powdery mildew very prone to resistance development, loss of bupirimate means loss of a chemical group
- Hops: Target – Powdery mildew; yield impacts personal communication with National Hops Association. Loss of bupirimate estimated to lead to 10% yield loss. If myclobutanil (Group 1 less risky) is also withdrawn the loss will increase to around 30%.
- Strawberry: Target – Powdery mildew; there are many alternatives including potassium bicarbonate. While the combined loss with myclobutabil (Group 1 less risky) would be a concern there is likely to be no yield effect.

Iprodione

- Ornamentals: Target – Botrytis and rhizoctonia; mostly a quality effect. A number of alternatives - azoxystrobin, *Bacillis subtillis*, chlorthalonil (not in this review), prochloraz (Group 1 less risky), thiram (Group 2 less risky), and mancozeb.(Group 1 more risky). Limited options to eradicate established infections although prochloraz could potentially be more widely utilised. Tolclofos-methyl (not in this review) only viable Rhizoctonia control, resistance likely.
- Grapevine: Target – Botrytis; Alternatives - Cyprodinyl and fludioxonil, fenhexamid, pyrimethanil (none in this review). Most are already used in programmes to avoid resistance. Some alternatives may be marginally more expensive

Myclobutanil

- Blackcurrant: Key fungicide for powdery mildew, noted for its crop safety. Alternatives – bupirimate (Group 1 less risky), boscalid and pyraclostrobin, fenpropimorph, pencanazole, quinoxyfen, kresoxim-methyl, potasium hydrogen carbonate (non in this review).
- Cucumber: Key fungicide for powdery mildew, noted for its crop safety. Varietal tolerance, mid-season and late season, not suitable for first cucumber crop. Cyflufenamid (not in this review) and several other fungicides also available. Biological control agent - Ampelomyces quisqalis strain AQ-10. Cucumber powdery mildew very prone to resistance development, loss of myclobutanil means loss of a chemical group
- Grapevine: An advantage of this fungicide is its short harvest interval. A number of equally effective alternatives - kresoxim-methyl, meptyl dinocap, proquinazad, sulphur, potassium hydrogern carbonate, Tebuconazole (Group 1 less risky) and trifoloxy strobin, fenbuconazole
- Ornamentals: Other actives with protective and curative properties that can be used under protection are limited to azoxystrobin, boscalid+pyraclastrobin, prochloraz+propiconazole

(which has undesirable growth regulatory effects on some crops) or bipirimate (which tends to scorch soft growth). Alternatives bupirimate (Group 1 less risky) and prothioconazole (Group 2 less risky)

- Pears: Alternatives for mildew control sulphur, meptyldinocap. For Scab captan, dithianon, pyrimethanil. As effective but more expensive
- Strawberry: Target – Powdery mildew; a number of effective alternatives bupirimate (Group 1 less risky), fenpropimorph, quinoxyfen, kresoxim-methyl, potassium hydrogen carbonate, meptyldinocap, sulphur, penconazole, boscalid and pyraclostrobin (none of these in this review).

Prochloraz

- Ornamentals: No effective options for Shab on Lavandula so production is unlikely to be viable, import substitution likely. Leafspots would become increasingly difficult to control with increased reliance on protectant fungicides. Stobulurins would be the main control but would not be as effective. Loss of this active could have a substantial impact - UK Lavender production unlikely to be viable (a 2001 study[4] estimated UK production area of 125 ha)
- Linseed: mainly a seed treatment for seed-borne diseases such as Alternaria, Botrytis, Phoma. Supplies of healthy seed may not be available so using clean seed as control may not be so effective. Thiram (Group 2 less risky) seed treatment should be useful though not currently listed. Fluodioxonil + metalaxylM + thiamethoxam (not in this review) seed treatment available. If thiram is not available then the options include the development of new uses for other seed treatments, use of other seed treatment methods (e.g. steam-air) or using untreated seed (albeit tested and known to have low levels of seed-borne pathogens). Slightly higher disease risk because of more seed-borne pathogens becoming established in the crop. If seed-borne pathogens develop in the crop, foliar fungicide inputs could increase. A range of foliar fungicides are available but tebuconazole (Group 1 less risky) may be excluded.
- OSR: Foliar diseases phoma, light leaf spot, alternaria, white leaf spot and stem sclerotinia; some use as seed treatment with thiram. Use of more resistant varieties could be helpful for phoma and light leaf spot, otherwise alternative products (especially prothioconazole, Group 2 less risky) are available. Use disease forecasts and risk assessments. Seed treatment could be replaced by fluodioxonil + metalaxylM + thiamethoxam or thiram alone. Disease warnings are freely available so cost increases will depend on alternative products selected.
- Wheat: Used as a seed treatment (in Kinto) for seed-borne pathogens and as a foliar spray for septoria and eyespot. Alternative seed treatments and sprays based on prothioconazole (Group 2 less risky) could be used.

Tebuconazole

- Brassicas: Target - alternaria, powdery mildew, ringspot, light leaf spot; Alternatives - more resistant varieties, good trash incorporation, grow crops away from last year's field

[4] An economic study of essential oil production in the UKFor the Government Industry Forum for Non-Food Crops

and OSR. Alternative azole products available but likely to cost more, increased resistance with increased use of strobilurins and azoles, loss of chemical group

- Bulbs: Target - smoulder (botrytis spp.); Alternative fungicides, boscalid+pyraclostrobin, cyprodinil + fludioxonil, kresoxim-methyl, pyrimethanil (none of these in this review), and iprodione (Group 1 less risky)
- Carrots: Target - alternaria, powdery mildew, sclerotinia; Alternative - use more resistant varieties, healthy seed, grow crops away from last years fields. Good nitrogen management. Trim foliage for sclerotinia control. Alternative azole products available
- Leeks: Target – rust; Alternative - use more resistant varieties, grow spring crops away from last years overwintered crops. Good nitrogen management. Alternative azole products available. Rusts appear to be less prone to fungicide resistance risks than other pathogens
- Onions (salad): Target - white rot; Alternative - select clean fields, boscalid +pyraclostrobin, Bacillus subtilis (none in this review). Can be as effective but concerns about resistance and enhanced degradation in soil leading to treatment failure if lost
- OSR: Target - Foliar diseases light leaf spot and phoma; sclerotinia and alternaria ; plant growth regulation. Leading option is to replace it with prothioconazole (Group 2 less risky) but more resistant varieties could be grown and dates of sowing adjusted. Use metconazole (not in review) to achieve growth regulation. Later sowing to decrease light leaf spot risk could carry a yield penalty so unlikely to be used very often; more resistant varieties could improve control and output. Loss of tebuconazole could increase risks of fungicide resistance in light leaf spot populations affecting the performance of other azoles in the longer term.
- Raspberry: Target - Cane blight; Alternative - Boscalid pyraclostrobin not as good, small yield effect
- Vicia beans: Target - Chocolate spot and rust; Alternative - later sowing to decrease chocolate spot risks; alternative fungicides products available e.g. cyproconazole + chlorothalonil, boscalid +pyraclostrobin, azoxystrobin, metconazole (none in this review). Loss of chlorothalonil as a product for tank mixing in the last year or so will also increase fears of fungicide resistance, problems in chocolate spot pathogens.
- Wheat: Target - Septoria tritici, yellow and brown rust plus Fusarium ear blight; Some adjustments possible to varietal resistance, date of sowing and crop rotation (e.g. do not grow wheat after maize) but replacement with prothioconazole (Group 2 less risky) is the main option. Prothioconazole is the obvious replacement for tebuconazole because of its fusarium activity. Increased risk of ear blight is the main concern. Metconazole would provide an alternative; possibly in mixture with epoxiconazole. but control may be less efficient and increase mycotoxin risk.

Thiophanate-methyl

- Ornamentals: Target - Thielaviopsis (Black Root Rot) main alternative is prochloraz (Group 1 less risky) and if both actives were lost, losses in key crops particularly Pansy and Viola would have a significant impact on UK production. Few growers would produce such crops without an effective control, increased imports likely.
- OSR: Target - Sclerotinia at flowering; limited use against other diseases when formulated with iprodione (Compass); alternative - decrease use by identification of low risk situations;

use alternative fungicides e.g. boscalid, prothioconazole (Group 1 less risky). As effective but more variable if deciding not to protect the OSR crop at flowering. There is a high risk of fungicide resistance affecting efficacy of Thiophanate-methyl so use in mixtures is preferred.

- Tomato: Target- Verticillium and fusarium wilt diseases, other fungal root rots (black root rot in NFT); alternative - resistant varieties; good hygiene at end of season to prevent carryover; graft onto a vigorous rootstock. Grafted rootstocks double the cost of plants
- Carrots: Target - foliar disease; Plenty of alternatives - use healthy seed, nitrogen management to avoid excessive crop canopy, azoxystrobin, boscalid+pyraclostrobin, azoxystrobin + difenoconazole (none in this review), prothioconazole (Group 1 less risky).

Metribuzin

- Asparagus: Target - broad leaved weeds; Alternatives - Mechanical control is not possible in this crop and hand-weeding is expensive. No herbicides are, or are likely to be, authorised for use during the harvest period so an effective residual herbicide is needed. Groundsel and black nightshade have become problem species. The only means of groundsel control pre-spear emergence in established asparagus was with metribuzin but groundsel could become resistant. New alternative - mesotrione. For a perennial crop a range of different herbicides applied at different timings and years is needed to prevent build-up of certain species, and avoid weed resistance.
- Bulbs: Target - Broad leaved weeds pre-emergence; metribuzin controls a wide weed spectrum which may include willowherb. Metribuzin and a tank-mix of chlorpropham (Group 2 less risky) + linuron are used in dormant period and are important for bulbs. In addition there are new EAMUs for use post-flower cropping: propyzamide (Group 1 less risky) and pendimethalin/ dimethenamid-P (Group 2 less risky). Only a few safe residuals remain: pendimethalin and metazachlor with restricted dose rate. Mechanical control is not an option. Weed control in bulbs will be extremely difficult.
- Carrots: metribuzin is only used post-emergence at low doses (the dose is dependent on crop growth stage). It provides useful control of a wide spectrum of broad-leaved weeds including mayweeds and groundsel. Loss of metribuzin as well as linuron could lead to very severe problems.
- Potatoes: metribuzin has valuable persistent residual activity and will control most weed species. There are options with residual activity, and foliar- acting herbicides are available but all have gaps in the weed spectra and some have varietal restrictions (e.g. bentazone). Dose rate restrictions for linuron and metribuzin will decrease efficacy. After linuron, metribuzin is the most important herbicide used in potatoes the loss of both would create difficulties particularly for seed crop production where there are few alternative approved herbicides.

Propyzamide

- Ornamentals: Target - Grass weeds; no alternative residual authorised for use in forest nurseries although new EAMUs could be issued for actives such as cycloxydim (not in this review). Alternatives: hand weeding (up to 30 times more expensive) and inter row cultivations in dry conditions. There is increased use of contact herbicides such as glufosinate-ammonium (Group 2 less risky).

- Christmas trees: personal communication with Colin Palmer (Rural Services) - The developing use of multi row inter row sprayers means that propyzamide use has fallen considerably over the last few years - probably now less than 10% of Christmas trees are routinely treated in spring with propyzamide, and less than 1% as a winter application. Impact either loss of quality or extra cost - unlikely to be both on a reasonably well managed plantation. Propyzamide is a persistent residual herbicide, but glyphosate is cheaper.
- Hops: propyzamide is applied post-planting on new plantings of hops. As a safe residual for control of grasses and some broad-leaved weeds there is no alternative. For grasses, foliar-acting fluazifop-p-butyl is approved (group 2 less risky). Pendimethalin and oxadiazon can be used for broad leaved weeds.
- Lettuce: propyzamide is essential for weed control in lettuce crops, but groundsel and mayweeds are not controlled. Other herbicides are approved – including chloropropham (Group 2 less risky), some new ones that control groundsel (also group 2 EDs) and pendimethalin which is also under threat. Poor weed control can result in reductions in yield and quality of lettuce. There is zero tolerance of weeds whose seed contaminants reduce product quality (shepherds purse, groundsel) or hinder hand harvesting (nettles and thistles).
- Oilseed Rape (winter): particularly important for black-grass, wild oats and Italian rye-grass that are difficult to control elsewhere in the rotation, because of widespread resistance to ACCase 'fop' and 'dim' herbicides. There is no known resistance to propyzamide or carbetamide (which was assumed available for this project, but is potentially an ED[5]). Propyzamide is more effective than carbetamide on black-grass germinating from the top 5cm of soil. Tri-allate (not an ED) applied pre-emergence provides some control but is not sufficient alone. For broad-leaved weed control there are few herbicides and there is a restriction on metazachlor to be applied at a maximum of 1000g/ha over three years on the same field.
- Radicchio: only three residual herbicide actives are approved for this long-season crop and radicchio is very dependent on propyzamide. A newer approval for pendimethalin/ dimethenamid-P (the latter Group 2 less risky) fills gaps in the weed spectrum (groundsel). If these were lost production would be uneconomic.
- Raspberry: there is no alternative residual for post emergence control of annual and perennial grasses and broad-leaved weeds. Fluazifop-p-butyl (Group 2 less risky) is the only available foliar-acting graminicide for annual grasses (not annual meadow-grass). There are other residual herbicides for broad leaved weeds including lenacil (Group 2 less risky).
- Strawberry: a low growing, perennial where weed management is already difficult because several herbicides were withdrawn and there are few safe alternatives. Propyzamide is a widely used residual and there is no alternative. Effective control of perennial grass weeds is only possible with propyzamide. Foliar-acting fluazifop-p-butyl (Group 2 less risky) and cycloxydim are available. There are other residual herbicides for broad leaved weeds:

[5] Proposal for a regulation of the European Parliament and of the Council concerning the placing of plant protection products on the market. Summary Impact Assessment 2009 http://www.pesticides.gov.uk/Resources/CRD/Migrated-Resources/Documents/O/Outcomes_paper_-_summary_impact_assessment_%28Jan_09%29.pdf

napropamide, metamitron, isoxaben, pendimethalin/imazamox, lenacil (Group 2 less risky) and more recently s-metolachlor (Group 2 more risky)

Spiromesifen

- Ornamentals: Target – Two Spotted Spider Mite (TSSM) and Whitefly; Alternatives - spirotetramat, pymetrozine (not in this review) and abamectin (Group 1 more risky) for whitefly but pesticide resistance is well documented in both pest species and reliance on insecticides from fewer insecticide groups would worsen the current situation
- Strawberry: Target – Whitefly; Alternatives - Thiocloprid, Pymetrozine, Pyrethrin and bio control; Bio-control more expensive, loss of quality due to stickyness on the fruit from this pest.

2.3 Impact 3: Group 1 and 2 loss of actives more likely to pose a risk

Impact 3 is assessed via a mixture of quantitative and qualitative outputs. The only quantitative information applied when assessing scenario 4 in the Group 1 active:crop combinations that incorporated actives deemed more risky from Group 2 alone (as opposed to looking at all the Group 2 actives together) was for thiacloprid and raspberry and strawberry and the additional withdrawal of chlorpyrifos. The estimated yield impacts for these two crops are 15% and 50% respectively that produce economic impacts of £9.9 million and £57.5 million. Thus the headline quantitative impact is £224 million. However, this excludes all the impacts shown in Table 4 below apart from the chlorpyrifos:raspberry and chlorpyrifos:strawberry combinations.

Comments on Group 2 loss of actives more likely to pose a risk

The greatest impact of withdrawal of actives more likely to pose a risk would come with the withdrawal of **chlorpyrifos** (especially given **thiacloprid**, the main alternative, is also affected as a more risky category substance). Chlorpyrifos is used on a wide range of fruit and vegetable crops for the control of a range of pests. There are some alternatives in other crops (including the less risky category products spinosad and spirotetremat), however in many crops there are certain pests for which these alternatives do not provide as effective a level of control as chlorpyrifos, and some of the alternatives are incompatible with IPM. All bar one of the crops listed in Table 4 are predicted to suffer significant yield impacts (orange small yield loss, production still possible, red large yield loss viability of production challenged).

Table 4: Impact 3: Group 2 actives more likely to pose a risk

Active	Crop	Area of crop (ha)	% area treated	Non ED alternative	Yield Change
S-metolachlor	Chicory	28	100%	Yes	-2
Chlorpyrifos	Bean - French	1,280	67%	No	-2
	Blackberry	112	132%	Yes	-2
	Blackcurrant - proc	1,795	131%	Yes	-2
	Broccoli	1,074	34%	No	-2
	Cabbage - Chinese	220	81%	No	-2
	Cider apples & perry pears	7,587	69%	Yes	-2
	Culinary apples (Bramley)	2,401	168%	Yes	-2
	Culinary apples (others)	142	49%	Yes	-2
	Dessert apples (Cox)	2,247	171%	Yes	-2
	Dessert apples (others)	3,330	150%	Yes	-2
	Leek	1,718	79%	No	-2
	Pak choi	43	81%	No	-2
	Pears	1,866	71%	Yes	-2
	Plums	1,009	94%	Yes	-2
	Raspberry	1,072	107%	Yes	-2
	Red/white currant	57	26%	Yes	-2
	Strawberry	2,472	115%	Yes	-2
	Strawberry (protected)	164	40%	Yes	-2
Fluazinam	Raspberry	1,072	37%	Yes	-1

S-metolachlor, a group 2 active categorised as more risky, recently became available for several horticultural crops (some of them after the 2011 Fera survey) that had few other options. These included lettuce, dwarf French beans, brassicas and bulb onion. Use in chicory could not be effectively replaced, despite some alternative herbicides being available.

Terbuthylazine is also categorised as more risky and if lost, could have a minor impact on sweetcorn and maize. It is used in formulation with mesotrione and adds control of annual meadow-grass with improved knotgrass control. Mesotrione is also approved alone.

The loss of **fluazinam** would also have modest yield impact in potatoes (not considered in Table 4 as did not meet criteria), assuming it is being used for the control of late blight.

Comments on Group 2 loss of actives less likely to pose a risk

The withdrawal of actives less likely to pose a risk in Group 2 (tables 6 and 7) would have an impact on an even greater range of crops.

Fungicides: a number of Group 2 actives (cymoxanil, fluazinam, mandipropamid) have use for potato blight. While individually concern/yield loss might be low, the combined effect of losing all of those at risk, including mancozeb, would be significant for blight management and resistance. See comment above re fluazinam

The loss of **prothioconazole** could be particularly important, it is used on a wide range of crops including cereals, oilseeds and vegetable crops. The impact of the loss would be modest on most of these crops assuming that other triazole fungicides (especially epoxiconazole) remained available. If these were affected as ED's or for other reasons the impact of the loss of this active on production could increase further. For example, on wheat, ADAS predicted a 20% loss in production from the loss of triazoles[6].

Carbendazim: could have a large impact on bulbs but not assessed here due to methodology applied

Herbicides: Chlorpropham is an important herbicide in lettuce, onions and leeks and is very effective on nettles. Significant losses in production of these crops would occur. It is also important for bulbs used in tank mix with linuron (Group 1 more risky) at dormant stage for bulbs (narcissus). With metribuzin also included in Group 1, there are few residuals available for dormant stage. Likely to be an issue in the Netherlands. Chlorpropham is used in potato stores as a sprout suppressant – its' loss would mean a significant proportion of the crop could not be stored for more than a few months, resulting in large crop losses. It is essential for potatoes for processing.

Dimethenamid-P in formulation with metazachlor would have a small impact on oilseed rape. The formulation with pendimethalin has recently been introduced for lettuce, onion (salad and bulb) and leek, and at the time of the last Fera survey use was low or none. Thus it does not appear in Table 6: Group 2 actives less likely to pose a risk– large loss of yield. However, it may form the basis for weed control in these crops in future, controlling groundsel which became a nuisance after propachlor was revoked. It is also approved for some brassicas, bulbs (narcissus) and some fruit crops and has potential for asparagus.

[6] Evaluation of the impact on UK agriculture of the proposal for a regulation of the European Parliament and of the council concerning the placing of PPPs on the market (ADAS 2008),

Ethofumesate and **lenacil** are important herbicides for use in a range of beet crops for which there is no non endocrine disruptor alternative. Poor weed control could cause significant yield losses in sugar beet, fodder beet and beetroot. Ethofumesate also has some effect on resistant black-grass. Post-emergence triflusulfuron-methyl is widely used in sugar beet but not assessed in this project and may also be classed as an ED.

Lenacil is a key herbicide for use in spinach - the majority of the crop is grown for baby-leaf production. Spinach would also lose chlorpropham. It is machine-harvested and weed contaminants are uneconomic to separate from produce and if too high a level of contamination was present the crop would be rejected. The only residual herbicide left would be chloridazon (not an ED) but this is damaging on sand soils.

Glufosinate-ammonium, a contact, non-selective, herbicide kills green tissue but does not affect mature bark and if withdrawn would have a significant impact on weed control in bush and cane fruit, but less on tree fruit. For strawberry, glufosinate is the only means of runner control because the permitted dose rate of the alternative, diquat, is too low to be effective. In its absence the crop would not be viable. Use as a pre-harvest treatment in field peas and beans, potatoes and oilseed rape is low.

2,4-D high usage in tree fruit (apples and pears) for perennial. There are alternatives that are not EDs.

Pinoxaden is used in barley for grass weed control, but there are no approvals for horticulture.

Tepraloxydim is used for annual meadow-grass control and is effective for removal of barley cover-crops in bulb onion, leeks and carrots. Other post-emergence gramminicides do not control annual meadow–grass. Carrots, onions and parsnip may also lose **fluazifop-p-butyl** – (Group 2 less risky). Propaquizafop and cycloxydim are potential alternatives but these were not assessed for ED properties. There are guidelines for avoidance of grass weed resistance and several different active substances are needed.

<u>Insecticides:</u> The loss of a range of insecticides in the lesser risk group, on top of a loss of chlorpyrifos and thiacloprid in the more risky group would make control of pests in a range of horticultural crops difficult - onions, strawberries and carrots could see large yield losses making production almost unviable, whilst more modest impacts on yield would be seen in brassicas, beans and horse radish.

Spirotetramat in addition to loss of chlorpyrifos: other crops such as endive, pak choi, raddichio would have at least a small impact

Chlorpyrifos is extensively used as a module drench treatment on brassicas for cabbage root fly control, and a very significant impact (or additional costs) from loss of chlorpyrifos as well as spinosad is expected.

Spirotetramat and **spiromesifen** (Group 1 less risky): The possible loss of these actives (both relatively new) are two of only three substances within the IRAC mode of action class 23, the inhibitors of acetyl CoA carboxylase. The only remaining member of the group, spirodiclofen, has not been assessed for its ED potential. Not only are these important substances particularly for some minor pests (e.g. mussel scale and pear sucker) but it would be very disruptive to lose an entire group from the resistance management perspective.

Clothianidin and beta-cyfluthrin were not considered for linseed and OSR. For these (the latter predominantly available only in mixture either with clothianidin or imidacloprid) there is currently an alternative of thiomethoxam. At best the loss of seed treatments containing beta-cyfluthrin and clothianidin would be a significant inconvenience. If thiomethoxam were also to be affected significant impact and yield reduction in oilseed rape and linseed would be expected

2.4 Impact 4: Loss of all actives in Groups 1 and 2

As for Impact 3, Impact 4 is assessed via a mixture of quantitative and qualitative outputs. The only quantitative information applied when assessing scenario 4 in the Group 1 active:crop combinations that incorporated actives from Group 2 alone was for the following crops in Table 5.

Table 5: Impact 4: loss of actives in both groups

Crop	Group 1 active	Group 2 active	Combined yield impact	Additional economic impact (to impact 2)
Leeks	Linuron, ioxynil	Chlorpropham, dimethenamid-P, tepraloxydim	60%	£7,901,149
Onions	Linuron, ioxynil	Chlorpropham, dimethenamid-P, s-metalochlor, tepraloxydim, fluazifop-p-butyl	40%	£10,509,162
Onions (salad)	Ioxynil	Chlorpropham, tepraloxydim, dimethenamid-P	50%	£4,890,456
French beans	Linuron	S-metolachlor	30%	£4,169,563
Strawberry	Thiacloprid	Lambda-cyhalothrin, chlorpyrifos	60%	£13,292,422
OSR	Prochloraz	Prothioconazole	5%	£6,716,777
Wheat	Prochloraz	Prothioconazole	2%	£10,841,371
Lettuce	Propyzamide	S-metolachlor, chlorpropham, dimethenamid-P	50%	£33,050,144
				£92,053,434

Thus the quantitative estimate of Impact 4 is the sum of Impact 2 plus £92 million - £437 million.

Not included in this estimate is the potential impact of orange wheat blossom midge[7] should thiacloprid, chlorpyrifos and lambda cyhalothrin all be withdrawn. Again this does not include the potentially large impacts as listed in Table 6 and Table 7, the estimated impacts of the Group 2 less risky actives (orange small yield loss, production still possible, red large yield loss, viability of production challenged).

[7] OWBM is a sporadic pest causing yield loss in about one year in ten. However, if all options for chemical control are lost this is likely to have a greater impact on yield simply because chemical control is no longer an option. In such a situation there would be greater reliance on the use of resistant varieties. This is turn is likely to increase the potential for resistance to breakdown. The literature suggests that in the 1993 outbreak up to 50% of yield was lost due to OWBM in the worst hit areas. However, not all areas had significant levels of infestation and when the potential yield loss is averaged over the number of years that this pest is a problem it is unlikely that it will reduce yield by more than 2% annually.

Table 6: Group 2 actives less likely to pose a risk– large loss of yield

Active	Crop	Area of crop	% area treated	Non ED alternative	Yield Change
Fosetyl aluminium	Strawberry	2,472	67%	Yes	-2
Prothioconazole	Spring barley	521,073	43%	Yes	-2
	Winter barley	375,764	47%	Yes	-2
Chlorpropham*	Lettuce	2,942	80%	No	-2
	Onion - dry	8,448	50%	No	-2
	Onion - salad	1,706	131%	No	-2
	Potatoes (sprout suppressant)			No	-2
Ethofumesate	Beetroot	1,565	145%	No	-2
	Fodder beet & mangolds	16,501	188%	No	-2
	Sugar beet	118,494	255%	No	-2
Glufosinate-ammonium	Blackberry	112	88%	Yes	-2
	Blueberry	232	68%	Yes	-2
	Raspberry	1,072	40%	Yes	-2
	Red/white currant	57	33%	Yes	-2
	Strawberry	2,472	78%	No	-2
	Strawberry (protected)	164	27%	No	-2
Lenacil	Fodder beet & mangolds	16,501	80%	No	-2
	Sugar beet	118,494	69%	No	-2
	Spinach	1,025	92%	Yes	-2
Tepraloxydim	Carrot	11,135	29%	No	-2
	Leek	1,718	97%	No	-2
	Onion - dry	8,448	85%	No	-2
Lambda-cyhalothrin	Carrot	11,135	247%	Yes	-2
	Celery	859	170%	Yes	-2
	Parsnip	3,341	312%	Yes	-2
	Strawberry (protected)	164	26%	Yes	-2
Spinosad	Cabbage - Chinese	220	96%	Yes	-2
	Endive	333	26%	Yes	-2
	Leek	1,718	66%	Yes	-2
	Onion - salad	1,706	95%	Yes	-2
	Strawberry	2,472	57%	Yes	-2
	Strawberry (protected)	164	46%	No	-2
Hymexazol	Fodder beet & mangolds	16,501	38%	No	-1
	Sugar beet	118,494	100%	No	-1

* Chlorpropham is used on dormant stage bulbs used in tank mix with linuron. With metribuzin also included in Group 1, there are few residuals available for dormant stage.

Table 7: Group 2 actives less likely to pose a risk – small loss of yield

Active	Crop	Area of crop	% area treated	Non ED alternative	Yield Change
Cymoxanil	Hops	1,071	41%	Yes	-1
Fosetyl aluminium	Edible plants in propagation	340	52%	Yes	-1
	Lettuce (protected)	387	32%	Yes	-1
	Strawberry (protected)	164	33%	Yes	-1
	Hops	1,071	144%	Yes	-1
	Vine	1,144	38%	Yes	-1
	Baby leaf production	1,211	43%	Yes	-1
	Herbs	1,980	27%	Yes	-1
	Spinach	1,025	66%	Yes	-1
Prothioconazole	Brassicas			Yes	-1
	Carrot	11,135	15%	Yes	-1
	Leek	1,718	63%	Yes	-1
	Oats	122,129	35%	Yes	-1
	Oilseed rape	641,115	70%	Yes	-1
	Onion - dry	8,448	226%	Yes	-1
	Parsnip	3,341	44%	Yes	-1
	Rye	5,815	59%	Yes	-1
	Turnip/swede	2835	67%	Yes	-1
	Wheat	1,927,683	54%	Yes	-1
Thiram	Baby leaf production	1,211	59%	No	-1
	Beans			No	-1
	Beetroot	1,565	41%	No	-1
	Cabbage - spring	2,133	33%	No	-1
	Dessert apples (others)	3,330	27%	No	-1
	Fodder beet & mangolds	16,501	44%	No	-1
	Kale, cabbage, rape etc.	10,297	31%	No	-1
	Leek	1,718	50%	No	-1
	Maize	162,360	47%	No	-1
	Onion - dry	8,448	62%	No	-1
	Onion - salad	1,706	42%	No	-1
	Pears	1,866	27%	Yes	-1
	Peas	41,543	45%	No	-1
	Pumpkin	772	39%	No	-1
	Radish	462	84%	No	-1
	Spinach	1,025	73%	No	-1
	Strawberry	2,472	73%	No	-1
	Strawberry (protected)	164	53%	No	-1
	Stubble turnips & catch crops	35,078	34%	No	-1
	Sugar beet	118,494	100%	No	-1
	Sweetcorn	686	57%	No	-1
	Turnip/swede	2835	84%	No	-1

Active	Crop	Area of crop	% area treated	Non ED alternative	Yield Change
Dimethenamid-P	Oilseed rape	641,115	27%	Yes	-1
Glufosinate-ammonium	Cherries	533	26%	Yes	-1
	Other top fruit (incl. nuts)	190	45%	Yes	-1
	Rhubarb	381	19%	Yes	-1
	Vine	1,144	42%	Yes	-1
Lambda-cyhalothrin	Bean - broad	2,601	121%	Yes	-1
	Bean - French	1,280	103%	Yes	-1
	Celeriac	240	275%	Yes	-1
	Horseradish	14	400%	Yes	-1
	Leek	1,718	85%	Yes	-1
	Onion - dry	8,448	76%	Yes	-1
Spirotetramat	Cabbage			Yes	-1
	Calabrese	7,454	26%	Yes	-1
	Cauliflower - aut/sum	5,734	27%	Yes	-1
	Cauliflower - winter	3,172	26%	Yes	-1
	Chinese vegetables	32	59%	Yes	-1

3. Testing costs

This study has been directed chiefly at assessing the potential impact of the loss of active substances identified as Endocrine Disruptors (EDs). Additionally, however, substantial costs would be incurred by crop protection companies in undertaking additional studies to enable that identification to be made. The WRc report[2] suggests that a clear identification/ categorisation of around 25% of all active substances as EDs for human health could not be made on the basis of the regulatory toxicity apical data currently required (i.e. they are only potential/suspected EDs). Further, usually (endocrine) mechanistic, data would be needed.

Mechanistic tests are not as developed as toxicity tests, but there are some internationally standardised endocrine mechanistic tests (those from the OECD Conceptual Framework on EDs) to assess potential disruption of sex hormones and their action. Some broad estimates of the potential costs for these tests for sex hormone modalities have been published by the US Environmental Protection Agency (EPA). The EPA estimates are similar to estimates provided to CRD by a European testing laboratory.

Calculations for Costs for Data Generation Activities					
Assay	**Estimated Costs (in Euros) (€)**				
	Assay	**Paperwork Burden**	**Management Burden**	**Technical Burden**	**Clerical Burden**
Androgen Receptor Binding (Rat Prostrate)	19,400	6,780	1,350	4,400	1,020
Aromatase (Human Recombinant)	24,300	8,520	1,700	5,510	1,270
Estrogen Receptor Binding (Rat Uterine)	19,000	6,640	1,330	4,320	1,000
Estrogen Receptor Transcriptional Activation (Human Cell Line)	19,400	6,800	1,360	4,420	1,020
Hershberger (Rat)	37,100	13,000	2,590	8,440	1,950
Female Pubertal (Rat)	79,100	27,600	5,520	17,950	4,140
Male Pubertal (Rat)	81,400	28,600	5,710	18,560	4,290
Steroidogenesis (Human Cell Line)	14,200	4,970	1,000	3,230	750
Uterotrophic (Rat)	33,500	11,710	2,350	7,600	1,760
Total Burden and Costs:	**327,000**	**114,830**	**22,890**	**74,450**	**17,190**

7 presents the EPA data in summary form. Whilst not all these tests would necessarily be required in each case, testing costs could range up to €555,000 for a single substance.

If the average cost of the package of studies required for each of the 25% of active substances which are potential/suspected EDs is half this amount (€277,500) then the total cost of securing additional information on 100 (25%) of the 400 or so active substances currently approved in the EU will be around €27,750,000 or approximately £23,500,000 (at February 2013 exchange rates - £1=€1.18).

There are no standardised mechanistic tests for thyroid, adrenal or other forms of endocrine toxicity, but testing costs to identify effects relevant to these organs seem likely to be similar to those considered in the table above.

Comparatively little is known of the endocrine system of invertebrates and standardised mechanistic tests for endocrine disruption in organisms other than mammals have not been developed. Given these uncertainties no realistic estimate of the costs of equivalent testing for ecotoxicological EDs can be made. However, given the range of species potentially involved it seems quite possible that costs will be of a similar order to those required to identify an ED for human health.

Thus, whilst major uncertainties surround these estimates particularly on the environmental side, it seems clear that the total costs of requiring endocrine mechanistic tests for the identification of EDs will run into many millions of Euros.

In addition to the financial costs, regulatory criteria for EDs will require a substantial increase in animal testing. The basic suite of in vivo tests for sex hormone modalities specified by the EPA would require a minimum of about 140 rodents per substance. Should some dose ranging and further assays be required demand could run into hundreds of animals per substance. For the mammalian programme as a whole, thousands and perhaps tens of thousands of animals would be required. There is too the question of whether there is the capacity within testing laboratories to undertake a programme on this scale particularly if other chemical regimes require similar testing.

4. Losses other than yield

4.1 Resistance

Increasing reliance on a narrower range of active substances, and more importantly a narrower range of modes of action, especially for those pests/diseases/weeds where multiple applications are required can significantly increase risk of resistance. Loss of active substances is therefore a significant concern for both the longevity of effective control of pests as well as for resistance management. Of particular importance to both effective control and resistance management is the fungicide mancozeb, a multisite inhibitor, which forms a component of resistance management strategies against a very wide range of diseases e.g. potato blight. The importance of the availability of a range of modes of action for insecticides was well demonstrated in Germany with the development of pyrethroid resistance in pollen beetle. In 2006 yield losses of more than 20% occurred on more than 200,000 hectares of oilseed rape and damage of over 80% on 30,000 ha because high numbers of pollen beetle could not be controlled using pyrethroids (Heimbach[8], 2008). Concerns also apply to weeds where there are few herbicides approved for some crops, and particularly in perennial crops where repeated use of single actives results in a build-up of some species and risks development of resistance (e.g. in asparagus and bulbs). The loss of propyzamide, one of the few remaining herbicides where there is no evidence of grass weed resistance [3] would exacerbate the current resistance management problems of grass weeds. Used in winter oilseed rape and field (Vicia) beans it provides an opportunity for control of black-grass that has become resistant to 'fop' and 'dim' herbicides, and is becoming increasingly resistant to sulfonyl urea herbicides. The UK is unlikely to see the introduction of new herbicides with different modes of action in the short or medium term,

4.2 Flexibility to meet challenges

A diversity of active substances and products enables growers to use the most effective substance for any given situation. New challenges do occur, whether new pests, new crops or the need to ensure compatibility with developing cropping and IPM techniques. This need is well illustrated by the occurrence of prolonged dry conditions in the UK during spring 2007. These prolonged dry conditions resulted in seed applied (neo-nicotinoid) insecticide not being taken up by young sugar beet plants and aphid numbers built up to unusually high levels. With monitoring indicating that a high proportion of the main species, *Myzus persicae* were resistant to available foliar insecticides, the British Beet Research Organisation sought and gained emergency approval for thiacloprid the only available foliar insecticide deemed capable of controlling MACE resistant aphids.

4.3 Grower confidence in future crop protection

Availability of an appropriate armoury to deal with crop protection challenges is vital in crops where there is high monetary investment (e.g. hops) if grower confidence to meet those challenges and continue investment is to be maintained.

4.4 Control of alien species

There are many plant pests and diseases, which if they were to become established in Great Britain, could cause serious damage to crops and plants. Official controls and restrictions on the import, movement and keeping of plants, plant pests and other material (e.g. soil) are

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[8] http://archives.eppo.int/MEETINGS/2008_conferences/active_substances/07_Heimbach/heimbach2.HTM

[3] EDMONDS J & CASELEY JC (1997) The role of propyzamide in management of herbicide resistant black-grass in oilseed rape. In: *Proceedings 1997 Brighton Crop Protection Conference - Weeds,* Brighton, UK, 351 – 357.

important to help prevent the introduction and spread of harmful organisms. Protecting plant health is a shared responsibility between Government, growers, traders and the general public. There are two main elements to plant health. Quarantine measures are taken to keep foreign pests out of areas where they could cause damage to crops, trees and wild plants. Measures are based on a scientific assessment of the risks. They may include rules restricting import and movement of plants and plant produce, or specifying treatments or inspections which have to be carried out. In terms of the actives considered within this project, abamectin is regularly recommended for outbreaks of *Bemisia tabaci* (a major vector of over 110 viruses and a very wide range of host plants) and it is also useful for *Liriomyza* (highly polyphagous), feeding on a wide range of plant species, including economically important vegetable and ornamental plants. Spinosad is very important for *Tuta absoluta* (pest of tomatoes) control – growers would be lost without it because there are no alternatives that are as effective and safe to biological control agents. Spiromesifen is often recommended for *Bemisia tabaci* control regularly, spirotetramat is in the same class and is an alternative. Thiacloprid is recommended for *Bemisia tabaci* and also for *Liriomyza*. Lambda-cyhalothrin, chlorpyrifos and thiacloprid are all on the recommended lists for Colorado beetle control. There could be an increased risk of the establishment of a number of non-native species For example spotted winged drosophila (*Drosophila suzukii*), where some actives of concern are the recommended treatment, e.g. chlorpyrifos.

4.5 Cost to growers

Many of the affected active substances have a large number of extensions of authorisation for minor uses. In the UK these are funded by a levy on growers, although in many countries there is substantive government funding. For example there are 22 extension of use authorisations for mancozeb, 5 for ioxynil, 30 for linuron, 17 for abamectin, 38 for chlorpyrifos, and 40 for thiacloprid. Approximate costs for gaining a minor use authorisation vary depending on the number of residue trials required, (8 trials over 2 years for a major crop and 4 trials over 2 years for a minor crop). Including the application fee of £1,700 per crop group, some administrative costs for making the application, and assuming average residue trial costs (total £25k for major and £12.5k for minor crop) per application, costs of between of £15,000 and £27,500 for an extension of use on minor and major crops respectively can be envisaged. Very approximately this can be averaged to approx. £0.4 - £0.5m for an active substance with some 20 extensions of use. This substantive investment is effectively lost when an active substance is lost from use. Alternatives have been sought to replace those lost in the 91/414 EC review and potential losses from identified hazard criteria. The large number now identified as EDs (40 out of only 98 assessed) represents wasted grower and crop protection company investment.

4.6 Cost to industry

Loss of an active substance represents a loss to the company that has developed it. In 2010, Phillips McDougall estimated the expenditure necessary for the discovery and development of a new crop protection product in 2005-2008 to be some $256m[9]. In UK terms this amounts to £168m. A more current estimate puts the figure at £250m (personal communication, P Brain, Bayer Crop Science). Loss to the developing company in the first years post commercial registration will be greatest and whilst many active substances have been approved for some years, several substance are relatively new. For example spiromesifen was first registered in the US in 2005, and spirotetramat in 2008. Given that it takes some 5 to 12 years to recoup the investment costs (personal communication, P Brain), depending on the breadth of use

[4] Phillips McDougall, 2010. The cost of new agrochemical product discovery, development, and registration in 1995, 2000 and 2005-8. A Consultancy Study for Crop Life America and the European Crop Protection Association

pattern and treated area, substantive losses to the developing company can be envisaged. Taking these two substances which have very narrow spectrum of activity, and using the above figures, a combined loss of c £130m could be estimated. Such losses reduce likelihood of further developmental investment.

4.7 Wider issues

There has already been an impact from loss of herbicides for horticulture, because of reasons of crop safety they are crop specific. The market is small and many were not supported by Crop Protection Companies for economic reasons. A report to industry by Phillips McDougall in 2009 showed that very few new herbicide active substances had been introduced over the period 2000-2008, none were in R & D for fruit and vegetables and only two for wheat.

This project has considered the impact of loss of endocrine disruptors, but they, as well as alternatives may be affected by other hazard based criteria. The PSD Impact Assessment (revised January 2009) on the hazard criteria and substitution provisions in the new 91/414/EEC regulation, listed active substances that might be withdrawn (e.g. if they were Persistent, Bioaccumulative and Toxic – a PBT, or vPvB) or candidates for substitution if they had 2PBT properties. None of the actives with ED properties were PBTs but several were candidates for substitution 2PBTs. The only alternative classed as a potential PBT active was pendimethalin (but this was based on data in the public domain). Pendimethalin has over 60 approvals for horticulture (onions, leeks, carrots, parsnips, parsley, peas, beans, strawberry, raspberry, apples, pears, ornamentals etc.), including over 40 EAMUs and there will be no other means of control of Polygonum species if this is lost. There is already an impact from the Water Framework Directive. Many pesticides (nearly all herbicides) have water issues (drinking water quality, toxicity to aquatic organisms) and member states have to mitigate for these. This has resulted in further losses, or dose rates reduced to a level where efficacy is poor.

It should be noted that in organic fruit and vegetables, yields are less than those of conventional production[10], although sometimes yields are too low or quality too poor to make harvesting worthwhile. Production is thus unreliable. In organic onions, severe downy mildew infections regularly results in 40% loss.

Review of neonicotinoid product authorisations: During the very late stages of this study, the EU announced a ban on certain neo-nicotinoid insecticides, used in crops attractive to bees. Affected substances include imidacloprid, clothianidin and thiomethoxam.
These systemic compounds are formulated primarily as seed treatments to control a broad range of establishment and foliar pests, including virus vectors, on a wide range of crops. Their loss will also very significantly increase the importance of other insecticides including thiacloprid and chlorpyrifos. In this study it has been assumed that the 'now to be banned' neo-nicotinoid insecticides were available as alternatives. If these substances are banned, the importance of all other insecticides becomes greater: As such this study underestimates the impacts of the loss of ED's, both from a monetary perspective and for the wider implications of, for example, resistance management.

It is also appropriate to include in this review the conclusions drawn by an EPPO Working Party in considering the impact of revisions to the directive 91/414/EEC in 2008, and the

[10] Seufert, V, Ramankutty, N, & Foley, J A. (2012). Comparing the yields of organic and conventional agriculture. Nature, 485, 229–232, doi:10.1038/nature11069

concern over the potential loss of active substances. ‘The Working Party considered that it is also very necessary to draw the attention to the need to maintain flexibility in a revised Directive in order to be able to control important pests in a sustainable way, in particular taking into account resistance management. Concern was expressed about the potential impact on sustainable crop production and pest control in amenity land and non-crop situations in future. The need for Integrated Pest Management was emphasized and also the need to have, within such an approach, sufficient effective plant protection products.’

4.8 Actives of interest to other MS

A few actives are available to some other EU Member states that are not available in the UK: e.g. herbicides aclonifen, oxyfluorfen and benfluralin, and insecticide fipronil. In the UK co-formulations are often marketed rather than the single active substances either to protect patents or to employ different modes of action. If one of the actives is withdrawn, this would have a greater impact in the UK. In the above assessments if an active is lost in a co-formulation it is assumed that the remaining actives would be reformulated to allow their continued use. This process would incur additional costs to the manufacturers, if they were not prepared to reformulate the co-actives could also be lost resulting in further reductions in the ability to control pests/disease/weeds.

Eurostat data (2011) shows that, for the EU-27, the main arable crops were cereals (in order of area grown FR DE PL UK), followed by sugar beet (FR, DE, PL, UK, NL, BE), potatoes (DE, PL, FR, NL, UK, BE) and oilseeds (FR, DE, UK). Active substances available in these MS are similar to those used in the UK (e.g. hymexazol fungicidal seed treatment for sugar beet is important for DE and FR)

The most important vegetables in terms of production after tomatoes, were onions and carrots. Almost half (about 46 %) of the onions produced came from either the Netherlands or Spain

Withdrawal of herbicide actives EDs may have an impact on:

Carrot, celery celeriac, parsley: withdrawal of linuron will affect FR, NL, BE, PT (already withdrawn DK and DE);

Carrots metribuzin FR

Onion, (leek): ioxynil, dimethenamid-P NL FR BE

Potato: linuron and metribuzin, several MS

Potato sprout suppressant: chlorpropham NL

Flower Bulbs: linuron, chlorpropham, dimethenamid-P, s-metolachlor NL

Dwarf French bean: s-metolachlor FR

Chicory: propyzamide, s-metolachlor BE

Spinach: lenacil DE FR, chlorpropham FR

Lettuce: propyzamide, chlorpropham, s-metolachlor, dimethenamid-P FR DE NL BE

For insecticides and fungicides, it is anticipated that there will be many common problems associated with the loss of the substances. However, in some cases alternatives are available that are not authorised in the UK; for example fipronil is available as a seed treatment for cabbage root fly on brassicas, but not in the UK. In other cases, pest problems may be more significant than in the UK; for example, in Germany thiacloprid and methamidiphos (the latter not permitted in the UK) were extensively used for control of widespread outbreak of pyrethroid resistance pollen beetle although alternatives are now available.

Appendix 1 – Full list of active substances assessed

		Further information required	More likely to pose a risk	Less likely to pose a risk
Fungicide	Azoxystrobin	No	No	No
	Boscalid	No	No	No
	Bupirimate	No	No	Yes
	Captan	No	No	No
	Carbendazim	Yes	No	No
	Chlorothalonil	No	No	No
	Cyazofamid	No	No	No
	Cyflamid	No	No	No
	Cymoxanil	Yes	No	No
	Cyprodinil	No	No	No
	Dimethomorph	No	No	No
	Dimoxystrobin	No	No	No
	Fenhexamid	No	No	No
	Fenpropimorph	No	No	No
	Fluazinam	Yes	No	No
	Fludioxonil	No	No	No
	Fluoxastrobin	No	No	No
	Fosetyl aluminium	Yes	No	No
	Hymexazol	Yes	No	No
	Imazaquin	No	No	No
	Iprodione	No	No	Yes
	Kresoxim-methyl	No	No	No
	Mancozeb	No	Yes	No
	Mandipropamid	Yes	No	No
	Metalaxyl-M	No	No	No
	Metrafenone	No	No	No
	Myclobutanil	No	No	Yes
	Prochloraz	No	No	Yes
	Propamocarb hydrochloride	No	No	No
	Prothioconazole	Yes	No	No
	Pyraclostrobin	No	No	No
	Silthiofam	Yes	No	No
	Tebuconazole	No	No	Yes
	Thiophanate-methyl	No	No	Yes
	Thiram	Yes	No	No
	Toclofos-methyl	No	No	No
	Triazoxide	No	No	No
Herbicide	2,4-D	Yes	No	No
	Bentazone	No	No	No
	Bromoxynil	No	No	No

		Further information required	More likely to pose a risk	Less likely to pose a risk
	Chloridazon	No	No	No
	Chlorpropham	Yes	No	No
	Clomazone	No	No	No
	Clorpyralid	No	No	No
	Dicamba	No	No	No
	Dimethenamid-P	Yes	No	No
	Diquat	No	No	No
	Ethofumesate	Yes	No	No
	Fluazifop-p-butyl	Yes	No	No
	Flufenacet			
	Fluroxypyr	No	No	No
	Glufosinate-ammonium	Yes	No	No
	Glyphosate	No	No	No
	Ioxynil	No	Yes	No
	Isoxaben	No	No	No
	Lenacil	Yes	No	No
	Linuron	No	Yes	No
	Mecoprop	No	No	No
	Mesosulfuron-methyl	No	No	No
	Metamitron	No	No	No
	Metazochlor	No	No	No
	Metribuzin	No	No	Yes
	Metsulfuron-methyl	No	No	No
	Napropamide	No	No	No
	Oxadiazon	No	No	No
	Phenmedipham	No	No	No
	Pinoxaden	Yes	No	No
	Propyzamide	No	No	Yes
	Prosulfocarb	No	No	No
	Pyridate			
	S-metolachlor	Yes	No	No
	Tepraloxydim	Yes	No	No
	Terbuthylazine	Yes	No	No
	Triallate	No	No	No
	Triclopyr	No	No	No
Insecticides	Abamectin	No	Yes	No
	Beta-cyfluthrin	Yes	No	No
	Chlorpyrifos	Yes	No	No
	Clothianidin	Yes	No	No
	Cyflumetofen	No	No	No
	Cypermethrin	No	No	No
	Diflubenzuron	No	No	No

		Further information required	More likely to pose a risk	Less likely to pose a risk
	Dimethoate,	No	No	No
	Fenoxycarb	No	No	No
	Imidacloprid	No	No	No
	Indoxacarb			
	Lambda-cyhalothrin	**Yes**	No	No
	Malathion	No	No	No
	Methiocarb	No	No	No
	Pirimicarb	No	No	No
	Pymetrozine	No	No	No
	Spinosad	**Yes**	No	No
	Spiromesifen	No	No	**Yes**
	Spirotetremat	**Yes**	No	No
	Tebufenpyrad	No	No	No
	Thiacloprid	No	**Yes**	No

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