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SID 5 Research Project Final Report

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Project identification

1. Defra Project code: PS2337
2. Project title: Are pesticide risk assessments for honeybees protective of other pollinators?
3. Contractor organisation(s): CSL, Sand Hutton, York, YO41 1LZ
4. Total Defra project costs (agreed fixed price): £ 20438
5. Project: start date .... 01 July 2007
   end date .... 31 March 2008

6. It is Defra's intention to publish this form.
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Executive Summary

7. The executive summary must not exceed 2 sides in total of A4 and should be understandable to the intelligent non-scientist. It should cover the main objectives, methods and findings of the research, together with any other significant events and options for new work.

Pollinators are organisms that feed at flowers and in doing so move pollen from the male anthers of a flower to the female stigma of a flower resulting in fertilization. In general, pollination is a mutually beneficial interaction with flowers providing pollinators with a source of nutrition, generally in the form of pollen or nectar in exchange for the transfer of pollen. Not all flower-visiting insects bring about pollination. Flowers and pollinators have co-evolved over millions of years. This has resulted in a huge variety of floral and pollinator form. Pollinators have evolved anatomical and behavioral adaptations that allow them to feed upon flowers with compatible floral characteristics. Members of the same genus tend to have similar characteristics and therefore similar floral preferences. Pollinators belonging to different genera and families have different sets of characteristics therefore there are interspecific differences in floral utilization. For example Dipterous species forage predominately on Umbelliferae whilst Lepidopterous species forage predominately on Cruciferous species. The specific characteristics of a flower also determine whether or not it can be pollinated by a diverse range of pollinators or by a single species. It also means some pollinators are better at pollinating some plant species then others. Flowers pollinated by a single species are relatively rare. The interdependency of pollinators and plants also means that if there is a decline in one there may be an associated decline in productivity and abundance of the other. This makes pollinators useful bio-indicators because their abundance and diversity provides a good indicator of the state of the ecosystem in which they are found.

To date, research on pollinators has been focused mainly on managed pollinators (e.g. honeybees) because they are considered the main pollinator of crops and therefore economically important. However concerns for wild pollinators have increased because it has become evident that ecosystems including arable crops are reliant on a variety of pollinators, not just one. Therefore it is important to understand the effects of pesticides on pollinators and the plants they utilize because their decline has significant impacts on both food production and ecosystem biodiversity. This review aimed to assess whether the risk assessment for honeybees is also likely to be protective of other wild pollinators (other than bumble bees which were the subject of an earlier review).

It is difficult to determine the direct effects of pesticides on pollinator populations on a landscape scale because insect populations naturally fluctuate in space and time. The weather during the season can have major impacts on populations with drought and late frost being detrimental to insect populations. Predation and food availability also have a major impact. Therefore this paper highlights the potential risks posed by pesticides to wild pollinators. This is based on their exposure through the use of crops and flowering weeds and on available data on the toxicity of pesticides. Species looked at include hoverflies (Diptera), butterflies (Lepidoptera) and social wasps and solitary bees (Hymenoptera).

Over the last decade there has been a change in pesticide usage on arable land, with an increase in the number of sprays and products applied to crops. Despite these increases there have been declines in the weight of active substances applied. This reflects both the move to newer products that are effective at lower doses and the use of reduced rates by farmers and growers. The most commonly used pesticides on arable land in Great Britain are fungicides accounting for 35% of the total pesticide-treated area of arable farm crops grown. The use of fungicides has increased, however the weight applied has decreased reflecting the use of more frequent lower dose applications. Herbicides and desiccants account for 32% and insecticides & nematicides 10%. Again, new herbicides have come on the market that are applied at very low rates (e.g. sulfonylurea herbicides). Other pesticides used include growth regulators and molluscicides. The pyrethroids are the most extensively used insecticides, accounting for 86% of the insecticide-treated area, followed by the organophosphates 7% and carbamates 5%. There have been declines in the use of organophosphate and carbamate insecticides, while pyrethroids, which are used at lower rates of application, have increased slightly.

The change in pesticide usage has resulted in pollinators becoming exposed more frequently to more products applied at lower rates. Currently there is no data on how this might affect them. There is evidence of decline in the abundance of some wild pollinator species in Britain. This has mainly been attributed to the loss of habitat as a result of increased agricultural intensification. However the strength of this evidence varies among taxa. Long-term population trends for butterflies show a steady decline in abundance, with mobile, habitat generalist predominating. A similar trend is also seen with solitary bees and the hoverflies. However for other pollinator species there is an absence of long-term population data, toxicity data and in some cases an incomplete understanding of even basic taxonomy and ecology. This makes it very difficult to ascertain what part pesticides may play in pollinator declines.

The very limited number of standardised laboratory tests reported have demonstrated that susceptibility to a compound can vary according to species and large differences in toxicity occur between compounds even within the same insecticide class. There are many cases where species are several orders of magnitude more sensitive on a per individual or weight basis than honeybees, e.g. Lepidopteran larvae. Therefore more detailed information on the toxicity of pesticides to a range of species and life stages is required to assess the sensitivity of wild pollinators relative to honeybees.

This review has shown that given their phenology and crop usage the exposure of wild pollinators to pesticides is likely to be at least that of honeybees for which a full risk assessment is undertaken. Current risk assessment considers only crops attractive to honeybees. This literature review showed that some crops (e.g. potatoes) are attractive to other pollinators. The importance of pollen and nectar as food sources also varies between species. Nectar residues may be diluted over time, whereas the rate of decline of residues in pollen will be limited by the degradation of the pesticide.

Exposure profiles of wild pollinators and honeybees are likely to differ significantly, due to respective diurnal activities, flight seasons, foraging habits and life histories. Of particular concern are insecticide applications to flowering crops, such as oilseed rape, at times that, although posing less risk to honeybees are likely to coincide with peak foraging times of wild pollinators (e.g. early morning or late evening). Contamination of flowering weeds in and around sprayed crops is also likely to pose a greater risk to wild pollinators than honeybees. Many pollinators have relatively small foraging area (up to 600m) compared with honeybees (6.5km), which reduces the availability and therefore importance of alternative forage sources. There are also limited data on the repellency of pyrethroid insecticides to other pollinators on which the risk management for honeybees is based. There is therefore a need to confirm that such repellency is apparent in other pollinators and thus confirm that assumptions in the risk assessment for honeybees are also applicable to other pollinators.

For wild pollinator species where the egg-laying female forages on crops either before or during egg-laying the effects of pesticide exposure may have more of an impact at the population level (e.g. mortality or reduced fertility), than in honeybees where the queen is protected within the hive. Honeybee risk assessment is primarily assessed for adults (unless the chemical is a known IGR) however, exposure may occur at all life stages of other pollinators when eggs are laid and larvae exposed within the crop. Therefore it is important that the differences in exposure profiles, including different life stages that may be directly over-sprayed, are considered in the risk assessment process. However, in the absence of toxicity data or quantified exposure data (some data are available through data on invertebrate residues, e.g. for hoverfly and Lepidopteran larvae) any detailed comparative risk assessment would be premature. More detailed toxicity and exposure information for a range of species is required for a robust assessment of the risk posed.

Non-pesticide and indirect pesticide impacts are also likely to have significant effects on pollinators. The loss of floral diversity as a result of the use of herbicides and fertilisers and the fragmentation and loss of habitats through ploughing of headlands and other agricultural practices have been shown to reduce pollinator abundance. Given the wide range of plants species dependent on non-Apis pollinators a reduction in wild pollinators is likely to have knock on effects on the plant species pollinated by them, resulting in less forage.

In the UK, environmental stewardship schemes (Defra) have encouraged farmers to create conservation headlands to improve floral diversity. However with the rise in cereal prices it is likely that more land will be put back into production resulting in further plant and pollinator declines.

There have been reports of dust being generated during drilling of treated seed and drift into flowering margins. The outside of the coat is sealed by a dust free polymer layer, which ensures that the seed treatment is contained within the coat but effectiveness may be limited if the coating is poorly applied or the seed is abraded during drilling. This suggests it may be useful to consider the effect of UK application techniques on the distribution of seed coatings in the environment.

Project Report to Defra

8. As a guide this report should be no longer than 20 sides of A4. This report is to provide Defra with details of the outputs of the research project for internal purposes; to meet the terms of the contract; and to allow Defra to publish details of the outputs to meet Environmental Information Regulation or Freedom of Information obligations. This short report to Defra does not preclude contractors from also seeking to publish a full, formal scientific report/paper in an appropriate scientific or other journal/publication. Indeed, Defra actively encourages such publications as part of the contract terms. The report to Defra should include:
   - the scientific objectives as set out in the contract;
   - the extent to which the objectives set out in the contract have been met;
   - details of methods used and the results obtained, including statistical analysis (if appropriate);
   - a discussion of the results and their reliability;
   - the main implications of the findings;
   - possible future work; and
   - any action resulting from the research (e.g. IP, Knowledge Transfer).

Objective 1. To determine the data available on the effects of pesticides on pollinators other than honeybees

Objective 2. To determine whether issues such as timing of sprays (during day and during season), repellency which are used to address risk management for honeybees can be extrapolated to other pollinators

Objective 3. To determine whether issues such as drift of granules/dust from seed treatments into field margins, particularly systemic compounds, is likely to have a significant effect on honeybees and other pollinators

Objectives 1& 2

Pollinators are organisms that feed at flowers and in doing so move pollen from the male anthers of a flower to the female stigma of a flower resulting in fertilization. In general, pollination is a mutually beneficial interaction with flowers providing pollinators with a source of nutrition, generally in the form of pollen or nectar in exchange for the transfer of pollen. Not all flower visiting insect bring about pollination.

Flowers and pollinators have co-evolved over millions of years. This has resulted in a huge variety of floral and pollinator forms. Pollinators have evolved anatomical and behavioral adaptations that allow them to feed upon flowers with compatible floral characteristics. Members of the same genus tend to have similar characteristics and therefore similar floral preferences. Pollinators belonging to different genera and families have different sets of characteristics therefore there are interspecific differences in floral utilization. For example Dipterous species forage predominately on Umbelliferae whilst Lepidopterous species forage predominately on Cruciferous species. The specific characteristics of a flower also determine whether or not it can be pollinated by a diverse range of pollinators or by a single species. It also means some pollinators are better at pollinating some plant species then others. Flowers pollinated by a single species are relatively rare.

The interdependency of pollinators and plants also means that if there is a decline in one there may be an associated decline in productivity and abundance of the other. This makes pollinators useful bio indicators because their abundance and diversity provides a good indicator of the state of the ecosystem in which they are found.

To date research on pollinators has been focused mainly on managed pollinators (e.g. honeybees) because they are considered the main pollinator of crops and therefore economically important. However concerns for wild pollinators have become more important because it has become evident that ecosystems including arable crops are reliant on a variety of pollinators, not just one. Therefore it is important to understand the effects of pesticides on pollinators and the plants they utilize because their decline has significant impacts on both food production and ecosystem biodiversity.

It is difficult to determine the direct effects of pesticides on pollinator populations on a landscape scale because insect populations naturally fluctuate in space and time. The weather during the season can have major impacts on populations (Pollard. 1988) with drought and late frost being detrimental to insect populations. Predation and food availability also have a major impact. Therefore this paper highlights the potential risks posed by pesticides to wild pollinators. This is based on their exposure through the use of crops and flowering weeds and on available data on toxicity of pesticides. Species looked at include hoverflies (Diptera), butterflies (Lepidoptera) and social wasps and bees (Hymenoptera).

Current pesticide usage in the Great Britain

The most commonly used pesticides on arable land in Great Britain (Table 1) are fungicides accounting for 35% of the total pesticide-treated area of arable farm crops grown. Herbicides and desiccants account for 32% and insecticides & nematicides 10% (Table 2). Other pesticides used include growth regulators and molluscicides (Garthwaite et al, 2006). The most commonly used compounds are presented in Table 1.

Table 1. Pesticides predominately used on arable land in Great Britain in 2006 (Garthwaite et al, 2006)

Pesticide Type	**Compound**
Fungicide	Chlorothalonil Epoxiconazole Prothioconazole Tebuconazole
Herbicide	Glyphosate Isoproturon Fluroxypyr Mecoprop-P Trifluralin
Insecticide	Cypermethrin Lambda-cyhalothrin Alpha-cypermethrin Tau-fluvalinate Deltamethrin Esfenvalerate Chlorpyrifos Pirimicarb

Over the last decade there has been a change in pesticide usage on arable land, with an increase in the number of sprays and products applied to crops. Despite these increases there have been declines in the weight of active substances applied. This reflects both the move to newer products that are effective at lower doses and the use of reduced rates by farmers and growers.

There have been declines in the use of organophosphate and carbamate insecticides, while pyrethroids, which are used at lower rates of application, have increased slightly. The pyrethroids are the most extensively used insecticides, accounting for 86% of the insecticide-treated area, followed by the organophosphates 7% and carbamates 5% (Garthwaite et al, 2006). The use of fungicides has increased, however the weight applied has decreased reflecting the use of more frequent lower dose applications. A similar trend is also seen with herbicide usage, as new herbicides have come on the market that are applied at very low rates (e.g. sulfonylurea herbicides). Therefore pollinators have become exposed more frequently to more products applied at lower rates (Table 3). Currently there is no data on how this might affect them.

Table 2. Average number of pesticide applications made to the main crop species grown in Britain.

Crop	**Fungicide**	**Herbicide**	**Insecticides**	**Plant Growth Regulators**	**Molluscicide**
	Average number of applications per year				
Wheat	3	3	1	2	N/A
Barley	2	2	1	1	N/A
Spring Barley	2	2	N/A	N/A	N/A
Oats	2	2	1	1	N/A
Oilseed rape	2	3	2	N/A	1
Linseed	1	4	1	N/A	N/A
Potatoes	10	3	2	N/A	1
Dry harvest peas	1	3	2	N/A	N/A
Field beans	2	2	2	N/A	N/A
Sugar beet	1	5	1	N/A	N/A

Table 3. Seasonal patterns of pesticide usage in Britain

Crop	**Main Periods of Application**			
	Fungicide	**Herbicide**	**Insecticides**	**Growth Regulators**
Wheat	April to June	Oct to Dec & April to May	June & Oct to Dec	March to May
Barley	April to May	Sep to Dec & April to May	Oct to Dec	March to May
Spring Barley	May to June	May to June	April to June	April to June
Oats	April to June	Sep to Dec & March to May	Nov to Dec & March	April to May
Oilseed rape	Oct to Dec or Feb to May	July to Dec	Sept to Dec & March to May	N/A
Linseed	June	May to June	April to May	June
Potatoes	June and Aug	April to June & Sep	June to July	July to August
Dry harvest peas	June to July	March to May	April to July	N/A
Field beans	April to June	Oct to Nov & Feb to May	April to June	N/A
Sugar beet	July to August	April to June	March & May to July	N/A

Diptera

Standardised laboratory tests demonstrated that intrinsic toxicity of pesticides is highly variable even within the same insecticide category. Many papers report the relative rather than the absolute toxicity making comparison with the sensitivity of honeybees difficult. Therefore more detailed information on the toxicity to range of species and life stages is required to assess the risk posed by pesticides relative to honeybees.

Table 4. Selectivity list of insecticides according to their toxicity towards *Episyrphus balteatus* larvae (Dinter et al. 2000, Drescheret al. 1991, Hasan et al 1987 + 1988, Jansen, et al 1974, Jansen 1998).

Type	Insecticide	Toxicity
Carbamate	Carbaryl	**4**
	Ethiophencarb	**4**
	Methomyl	**4**
	Pirimicarb	**3**
Organochlorine	Endosulfan	**4**
	Lindane	**4**
Organophosphate	Acephate	**4**
	Azinphos-methyl	**4**
	Bromophos	**4**
	Chlorfenvinphos	**4**
	Chlorpyrifos	**4**
	Diazinon	**4**
	Dimethoate	**4**
	Etrimfos	**4**
	Fenitrothion	**4**
	Heptenophos	**4**
	Mevinphos	**4**
	Phosalone	**2**
	Phosphamidon	**4**
	Pirimiphos-methyl	**4**
	Triazophos	**4**
	Vamidothion	**4**
	Thiometron	**4**
Pyrethroid	Alpha-Cypermethrin	**1**
	Bifenthrin	**2**
	Cyfluthrin	**4**
	Cypermethrin	**3**
	Deltametrin	**2**
	Esfenvalerate	**2**
	Fluvalinate	**1**
	Lambda-cyhalothrin	**4**
	Permethrin	**4**
	Zeta-cypermethrin	**2**
Selective feeding blocker	Pymetrozin	**1**

4 = Harmful (>99%), 3 = Moderately harmful (80 – 99%), 2= Slightly Harmful (50 – 79%), 1 = Harmless (<50%)

Table 5. Selectivity list of fungicides and herbicides according to their toxicity towards *Episyrphus balteatus* larvae (Colignon et al. 2000, Hasan et al. 1987 & 1988, Hautier et al. 2005 & 2006, Miles et al. 2000).

Fungicide	Toxicity	Herbicide	Toxicity
Azoxystrobin	1	Atrazine	2
Captan	3	Bromacil	1
Carbendazim*	1	Bromofenoxim	2
Chinomethionate	3	Chlormequat	1
Chlorothalonil	1	Desmetryn	1
Copper hydroxide	1	Diclofop-methyl	2
Copper Oxychlorid	1	Difenzoquat	3
Copper sulphate	1	Dinoseb	4
Cyazofamide	1	Fluazifop-butyl	4
Dichlofluanide	3	Monolinuron	3
Difenoconazole	1	Phenmedipham	4
Dithianon	1	Propachlor	3
Ethirimol	1	Propyzamide	3
Fenarimol	1	Simazin	1
Fenpropimorph	1		
Fluazinam	1		
Folpet	2		
Iprodione*	1		
Mancozeb	1		
Maneb	1		
Metiram	3		
Penconazole	2		
Propiconazole	2		
Prochloraz	3		
Propineb	1		
Pyrazophos	4		
Quinoxyfen	1		
Sulphur	1		
Thiram	1		
Tebuconazole	1		
Vinclozolin*	1		

4 = Harmful (>99%), 3 = Moderately harmful (80 – 99%), 2= Slightly Harmful (50 – 79%), 1 = Harmless (<50%)

The review showed that the exposure of hoverfly to pesticides is likely to be at least that of honeybees. Exposure profiles of hoverfly and honeybees differ significantly, due to respective diurnal activities, flight seasons, foraging habits and natural histories. Of particular concern are insecticide applications to flowering crops, (Table 6), at times that, although posing less risk to honeybees are likely to coincide with foraging hoverfly. Contamination of flowering weeds in and around sprayed crops is also likely to pose a greater risk to hoverfly than honeybees. In addition pesticide exposure may occur at all life stages because eggs are laid and larvae are exposed within the crop whereas honeybee risk assessment is primarily assessed for adults (unless known IGR). Therefore it is important that the differences in exposure profiles are considered in the risk assessment process. Limited data are available on the residues on over-sprayed hoverfly larvae generated to assess residues on invertebrate food items however these cannot currently be directly compared as the toxicity data are based on relative toxicity rather than actual dose levels.

Current risk assessment considers only crops attractive to honeybees. This literature review has shown that some crops (e.g. potatoes) are attractive to other pollinators (Table 6).

Table 6. Crop species used by pollinating flies

Family	Species	Common name	Flowering
Alliaceae	Allium cepa	Onion	June - Sept
Chenopodiaceous	Beta vulgaris altissima	Sugar beet	
Cruciferae	*Brassica napus/ campestris* *Brassica oleracea capitata* *Brassica oleracea gemmifera* *Brassica oleracea botrytis* *Brassica rapa* *Sinapis alba*	Oilseed rape Cabbage Brussels sprouts Cauliflower Turnip White mustard	April – Aug May - Aug May - Aug May - Aug May - Aug April - Oct
Gramineae	*Zea mays*	Sweet Corn	July - Oct
Labiatae	*Origanum* spp.	Marjoram	July - Sept
Lamiaceae	*Rosmarinus officinalis*	Rosemary	March - Oct
Leguminosae	*Medicago sativa* *Melilotus officinalis* *Pisum sativum* *Vicia faba* *Trifolium pratense* *Trifolium repens* *Lupinus albus*	Alfalfa Sweet Clover Peas Field/ broad bean Red Clover White Clover White Lupin	June - July July - Sept May - Sept June – July May – Sept June – Sept June - July
Rosaceae	*Fragaria x ananassa* *Malus* spp. *Prunus* spp. *Rubus idaeus*	Strawberries Apple Cherries / plums Raspberry	April - July March - May April - May May - Aug
Solanaceae	*Solanum tuberosum*	Potato	July to Sept
Umbelliferae	*Coriandrum sativum* *Daucus carota* *Pastinaca sativa* *Petroselinum crispum* *Apium graveolens* *Foeniculum Vulgare*	Coriander Carrot Parsnip Parsley Celery Fennel	June - July June – Aug July - Aug June - Aug June - Aug Aug - Oct

Pesticide exposure may have more of an impact at the population level (e.g. mortality or reduced fertility), than in honeybees because the exposure of the egg-laying female is much higher than in honeybees, which is protected within the hive. However studies have shown that fly populations can return to pre application levels within a few months of application. This may be the result of hoverfly laying a large number of eggs, in different location and different times and because the larvae are self-sufficient therefore are not affected by the loss of the adult.

The importance of pollen and nectar as food sources varies between species. Syrphids are either nectar specialists, pollen specialists or collect both, while honeybees are equally interested in collecting both resources. Therefore the oral exposure profiles are different. Nectar residues may be diluted over time, whereas the rate of decline of residues in pollen will be limited by the degradation of the pesticide

Non-pesticide and indirect pesticide impacts also has a significant effect on hoverfly populations. The loss of floral diversity as a result of the use of herbicides and fertilisers and the loss of habitats through ploughing of headlands and other agricultural practices have been shown to reduce abundance and is probably the main reason for their declines. Given the wide range of plants species dependant on hoverfly for pollination, the reduction in populations is likely to have a knock on effects on the plant species pollinated by them, resulting in less forage.

Lepidoptera

Standardised laboratory tests have demonstrated that intrinsic toxicity of pesticides is highly variable even within the same insecticide category (Tables 7, 8 and 9). In some cases, eg fenitrothion, lepidopteran larvae are several orders of magnitude more sensitive than adult honeybees when compared per insect (Table 7) and many are more toxic when compared on a weight basis (Table 8). Therefore more detailed information on a range of species and life stages is required to assess the risk posed by pesticides relative to honeybees.

Table 7. Contact toxicity (LD50) of insecticides to butterfly larvae and honeybee (µg/insect)

Type	Insecticide	***Pieris brassicae*** (Sinha et al, 1990)	***Pieris napi*** (Davis et al, 1991)	***Polyommatus icarus*** (Davis et al, 1991)	***Pyronia tithonus*** (Davis et al, 1991)	***Apis mellifera***
Organophosphate	Dimethoate	0.52	0.83	-	-	0.12
Carbamate	Pirimicarb	0.40		-	-	-
Organophosphate	Phosalone	0.027	0.069	-	0.027	-
Cyclodiene organochlorine	Endosulfan	0.016	-	-	-	-
Organophosphate	Fenitrothion	0.003	0.0077	0.024	0.0051	0.18
Organophosphate	Pirimiphos-methyl	0.0028	-	-	-	-
Pyrethroid	Fenvalerate	0.0013	-	-	-	-
Benzoylurea (IGR)	Diflubenzuron	0.00063	0.0013	-	-	-

Table 8. Comparative susceptibility of first instars *Pieris brassicae* larvae and adult *Apis mellifera* to insecticides (Sinha et al, 1990, Stevenson, 1978 & Smart & Stevenson, 1982).

Type	**Insecticide**	***Pieris brassicae***	***Apis mellifera***
		LD_{50} µg/g	
Organophosphate	Dimethoate	744	1.2
Carbamate	Pirimicarb	564	5400
Organophosphate	Phosalone	38.9	890
Cyclodiene organochlorine	Endosulfan	23.2	710
Organophosphate	Fenitrothion	4.29	1.8
Organophosphate	Pirimiphos-methyl	3.93	39
Pyrethroid	Fenvalerate	1.79	23
Benzoylurea (IGR)	Diflubenzuron	1.07	3000

Table 9. Selectivity list of insecticides according to their toxicity towards *Pieris brassicae*

Type	**Insecticide**	**Toxic**	**Reference**
Pyrethroid	Cypermethrin	**4**	Singh et al, 2003.
	Fenvalerate	**4**	Halimie et al, 1997.
	Deltametrin	**4**	Thakur & Parmar, 2000.
	Lambda-cyhalothrin	**4**	Halimie et al, 1997.
	Etofenprox	**4**	Khattak et al, 1999.
Carbamate	Pirimicarb	**4**	Halimie et al, 1997.
Benzoylurea	Flufenoxuron	**4**	Halimie et al, 1997.
	Chlorfluazuron	**4**	

The exposure of butterflies to pesticides is likely to be at least that of honeybees. Exposure profiles of butterflies and honeybees differ significantly, due to respective diurnal activities, flight seasons, foraging habits and natural histories (Table 10). Contamination of flowering weeds in and around sprayed crops is likely to pose a greater risk to butterflies than honeybees. In addition pesticide exposure may occur at all life stages because eggs are laid and larvae are exposed within the crop whereas honeybee risk assessment is primarily assessed for adults (unless known IGR). Therefore it is important that the differences in exposure profiles are considered in the risk assessment process. The data generated in PS2323 suggested a mean residue for *P. brassicae* larvae of 12.8mg/kg larva per kg ai applied. Many organophosphates are applied at 500-750g ai/ha which would suggest residues in the range 6.4-9.6 ug/g and thus according to Table 8 adverse effects would be observed in *P.brassicae* larvae following applications of fenitrothion and pirimiphos methyl. As first tier risk assessment for the honeybee (HQ=Application rate (g ai/ha) /LD50) would suggest that based on the same application rates the HQ for fenitrothion would be 2800-4200 which also suggests a risk to bees following direct application to flowering crops.

Surveys have shown butterflies have a strong association with field margins and hedgerow rather than the crop (Dover, 1990). Therefore they are more at risk to spray drift rather than direct applications.

Pesticide exposure may have more of an impact at the population level (e.g. mortality or reduced fertility), than in honeybees because the exposure of the egg-laying female is much higher than in honeybees, which is protected within the hive.

Table 10: Phenology of six common butterfly species found in field margins.

Species	Ova	Larva	Pupa	Adult
P. napi (Green-veined)	Early May – late June Late July – mid Sept	Mid May – early July Early Aug – late Sept	Early Sep – early May Late June – late July	Mid April – mid Sept
P. rapae (Small White)	Early May – early July Late July – mid Sept	Mid May – mid July Early Aug – early Sept	Late Sept – mid May Early July – late July	Mid April – early Oct
P. brassicae (Large White)	Early May – early July Early Aug – mid Sept	Late May – late July Mid Aug – late Sept	Mid Sept – early May Early July – mid Aug	Early April – late Oct
M. jurtina (Meadow Brown)	Early July – early Oct	Mid July – mid June	Late May – late Aug	Early June – late Sept
P. tithonus (Hedge Brown)	Late July – mid Sept	Mid Aug – late June	Early June – early Aug	Early July – late Aug
A. hyperantus (Ringlet)	Early July – late Aug	Late July – late June	June – mid July	Mid June – mid July

The importance of pollen and nectar as food sources varies between species. Butterflies are nectar specialist and generally don't consume pollen, while honeybees are equally interested in collecting both resources. Therefore the oral exposure profiles are different. Nectar residues may be diluted over time, whereas the rate of decline of residues in pollen will be limited by the degradation of the pesticide

Non-pesticide and indirect pesticide impacts also have a significant effect on butterfly populations. The loss of floral diversity as a result of the use of herbicides and fertilisers and the loss of habitats through ploughing of headlands and other agricultural practices have been shown to reduce abundance and is probably the main reason for their declines. Given the wide range of plants species dependant on butterflies for pollination, the reduction in populations is likely to have a knock on effects on the plant species pollinated by them, resulting in less forage.

Hymenoptera –social wasps

The toxicity of pesticides to wasps is poorly reported and the only report identified was on the oral toxicity of six insecticides on *Vespula germanica* (F.) larvae in the laboratory (Uolla, 2006). Which showed that the following pesticides were toxic: Spinosad at 0.29 mg l^{-1}; abamectin at 1.40 mg l^{-1}; fipronil at 3.34 mg l^{-1}; triflumuron at 11.83 mg l^{-1} and Methoxyfenozide at 9600 mg l^{-1} . However such data are not directly comparable with those generated for other species including honeybees and therefore the relative sensitivity is unknown.

Exposure profiles of social wasps and honeybees differ significantly, due to respective diurnal activities, flight seasons, foraging habits and nesting behaviour (Tables 11 and 12). Of particular concern are insecticide applications to flowering crops, such as oilseed rape, at times that, although posing less risk to honeybees are likely to coincide with foraging solitary bees. In addition contamination of flowering weeds in and around sprayed crops is likely to pose a greater risk to wasps than honeybees. Therefore it is important that the differences in exposure profiles are considered in the risk assessment process.

Table 11. Crop species used by Vespidae

Family	**Species**	**Common name**	**Flowering Season**
Cruciferae	*Brassica napus napus* *Brassica rapa*	Oilseed rape Turnip	May - Aug May - Aug
Ericaceous	*Vaccinium macrocarpon* *Vaccinium myrtillus*	Cranberry Bilberry	June – Aug April - June
Grossulariaceae	*Ribes nigrum* *Ribes uva-crispa*	Black Current Gooseberry	April – May March - May
Labiatae	*Origanum spp.*	Marjoram	July - Sept
Leguminosae	*Melilotus officinalis*	Sweet Clover	July - Sept
Rosaceae	*Rubus idaeus*	Raspberry	June - Aug
Umbelliferae	*Coriandrum sativum* *Daucus carota* *Foeniculum vulgare* *Pastinaca sativa*	Coriander Carrot Fennel Parsnip	June -July June – Aug Aug – Oct July - Aug

Pesticide exposure may have more of an impact at the population level (e.g. mortality or reduced fertility), than in honeybees because the exposure of the egg-laying female is much higher than in honeybees, which is protected within the hive. The potential exposure of the queen wasps early in the season when she is establishing her colony is likely to have the greatest impact on a wasp colony (Table 12). The exposure of workers later in the season to pesticides is also a concern especially for short cycle wasps, which have relatively small colony size and fewer workers.

Table 12. Phenologies of six social wasps species

Species	**Queen emergence**	**Emergence of workers**	**Emergence of males**	**Emergence of new queens**	**Total season**
Vespa crabro [a]	Early April – early June	Early April – mid Oct	Late Aug – late Nov	Late Aug – mid Nov	Early April – late Nov
Vespula vulgaris [a]	Late April – early June	Early June – late Oct	Early Aug – early Nov	Early Aug – late Oct	Late April – early Nov
Vespula germanic [a]	Early May – mid June	Mid June – early Nov	Late Aug – early Nov	Early Sept – mid Oct	Early May – early Nov
Dolichovespula norwegica [b]	Mid April – mid June	Early June – early Aug	Late July – early Aug	Late July – early Aug	Mid April – early Aug
Dolichovespula sylvestris [b]	Late April – mid July	Early June –late Aug	Late July – late Aug	Early Aug – mid Sept	Late April – mid Sept
Vespula rufa [b]	Mid April – late June	Mid June – mid Aug	Early Aug – early Sept	Early Aug – early Sept	Mid April – early Sept

a **= Long cycle colonies, b = Short cycle colonies**

The importance of pollen and nectar as food sources varies between species. Wasps forage for nectar and prey on insects, while honeybees are equally interested in collecting both resources. Therefore the oral exposure profiles are different.

Wasps have a relatively small foraging area (up to 3.7km) compared with honeybees (6.5km), which reduces the availability of alternative forage sources.

Non-pesticide and indirect pesticide impacts also has a significant effect on wasp populations. The loss of floral diversity as a result of the use of herbicides and fertilisers and the loss of habitats through ploughing of headlands and other agricultural practices have been shown to reduce abundance and is probably the main reason for their declines. Given the wide range of plants species dependant on wasps for pollination, the reduction in populations is likely to have a knock on effects on the plant species pollinated by them, resulting in less forage.

Hymenoptera – solitary bees

Standardised laboratory tests have demonstrated that susceptibility to a compound can vary according to species (Tables 15 and 16). In addition, large differences in toxicity to a bee species appear within the same insecticide category. Therefore more detailed information on a range of species is required to assess the risk posed by pesticides relative to honeybees.

This review has shown that the exposure of solitary bees to pesticides is likely to be at least that of honeybees. Exposure profiles of solitary bees and honeybees differ significantly, due to respective diurnal activities, flight seasons, foraging habits and nesting behaviour (Table 14). Of particular concern are insecticide applications to flowering crops, such as oilseed rape, at times that, although posing less risk to honeybees are likely to coincide with foraging solitary bees (Table 13). In addition contamination of flowering weeds in and around sprayed crops is likely to pose a greater risk to solitary bees than honeybees. Therefore it is important that the differences in exposure profiles are considered in the risk assessment process. A number of authors have demonstrated that pyrethroids have a repellent effect on honeybees (Cox et al, 1984, Mayer et al 1993, 1998). However there are very few reported cases of repellency for solitary bee species. Tasei et al (1981) reported a short term repellent effect of three pyrethroids: fenvalerate, deltamethrin and lambda-cyhalothrin on *Megachile rotundata.* Heller et al (1990) also found fenvalerate and deltamethrin to be repellent to *Megachile rotundata* for a short period after application.

Table 13.Crop species used by Solitary bees

Family	Species	Common name	Flowering Season
Alliaceae	*Allium cepa*	Onion	June – Sept
Boraginaceae	*Borago officinalis*	Borage	May – Sept
Compositae	*Helinathus annuus*	Sunflower	Aug - Oct
Cucurbitaceae	*Cucurbita spp.*	Pumpkins, etc.	July – Sept
Cruciferae	*Brassica napus napus* *Brassica napus napobrassica* *Brassica rapa* *Brassica oleracea* *Sinapis alba*	Oilseed rape Swede Turnip Cabbage, etc. White Mustard	Apr – Aug May – Aug May – Aug May – Sept April – Oct
Ericaceae	*Vaccinium spp.*	Blueberry	April – July
Labiatae	*Origanum vulgare*	Oregano	July - Sept
Leguminosae	*Lotus corniculatus* *Medicago sativa* *Melilotus albus* *Trifolium repens* *Trifolium pratense* *Vicia faba*	Bird's Foot Trefoil Alfalfa Sweet clover White Clover Red Clover Field /Broad bean	May – Sept June – Oct June – Oct May – Oct May – Oct June – July
Rosaceae	*Fragaria* *Mallus spp.* *Prunus spp.* *Pyrus spp* *Rubus fruticosus* *Rubus idaeus*	Strawberries Apples Cherries/ Plums Pears Blackberry Raspberry	April – July March – May April – May April May – Nov May – Aug
Umbelliferae	*Foeniculum vulgare* *Daucus carota sativus*	Fennel Carrot	Aug – Oct June - Aug

Pesticide exposure has a more significant impact at the population level (e.g. mortality or reduced fecundity), than in honeybees because the exposure of the egg-laying female is much higher than in honeybees, which is protected within the hive. The death of a solitary female bee means the end of reproductive activity, while in honeybees losses as a result of pesticide applications may be compensated for by workers and by new bees emerging from the brood.

Table 14 Phenologies of 8 solitary bee species

Family	Species	Total Season
Andreninae	*Andrena fulva*	April - early June
Anthophorinae	*Anthidium manicatum*	Late May – early Sept
	Anthophora plumipes	Mid March – end of May
Colletinae	*Colletes daviesanus*	Mid June – end of Aug
Halictinae	*Lasioglossum smeathmanellum*	March – early Sept
Megachillinae	*Megachile centuncularis*	May – end of Aug
	Osmia rufa	April – June
	Osmia leaiana	May – end of Aug

Table 15. Contact toxicity of insecticides to honeybee and solitary bee species (24 hr unless stated) (Tasei et al, 1988, Mayer et al 1993,1998,1999, Helson et al, 1994, Stark et al, 1995)

Chemical Type	**Name**	***Nomia melanderi*** **LD_{50} (µg/ bee)**	***Apis mellifera*** **LD_{50} (µg/ bee)**	***Megachile rotundata*** **LD_{50} (µg/ bee)**
Carbamate	Aminocarb	*	0.121	0.068
	Carbaryl	*	0.385	0.592
	Mexacarbamate	*	0.061	0.071
Chloronicotinyl	Imidacloprid	0.04	0.04	0.04
Organophosphate	Diazinon	0.45	0.23	0.12
	Fenitrothion	*	0.171	0.039
	Trichlorfon	*	5.137	10.3
Pyrethroid	Bifenthrin	0.14	0.05	0.006
	Cyhalothrin	0.036	0.022	0.002
	Deltamethrin	*	*	0.005
	Permethrin	*	0.024	0.018
Phenyl pyrazole	Fipronil	1.130	0.013	0.004

* No Data

Table 16. Selectivity list of different insecticide age residues according to their toxicity towards 3 species of bee (Mayer et al, 1987, 1993, 1997)

Chemical Type	**Name**	**Toxicity**					
		Nomia melanderi		***Apis mellifera***		***Megachile rotundata***	
		2 hr	**8 hr**	**2 hr**	**8 hr**	**2 hr**	**8 hr**
Carbamate	Carbofuran	4	4	4	4	4	4
	Formetanate	4	1	1	1	4	4
	Oxamyl	4	4	4	4	4	4
	Thiocarb	2	1	1	1	2	2
Organophosphate	Methamidophos	4	3	4	3	4	4
	Methidathion	4	4	4	4	4	4
	Methyl parathion	4	4	4	4	4	4
	Phosmet	4	4	4	4	4	4
	Trichlorfon	1	1	2	3	1	1
Pyrethoid	Cypermethrin	2	1	2	2	3	2
	Bifenthrin	1	1	1	1	1	1
	Deltamethrin	1	1	1	1	1	1
	Fenvalerate	2	1	2	1	3	1
	Fenpropathrin	4	4	2	1	4	4
	Permethrin	2	1	4	2	4	3
Pyridazinone	Pyridaben	1	1	1	1	1	1

4 = Harmful (>99%), 3 = Moderately harmful (80 – 99%), 2= Slightly Harmful (50 – 79%), 1 = Harmless (<50%)

The importance of pollen and nectar as food sources varies between species. Solitary bees primarily forage for pollen, while honeybees are equally interested in collecting both resources. Therefore the oral exposure profiles are different. Nectar residues may be diluted over time, whereas the rate of decline of residues in pollen will be limited by the degradation of the pesticide.

Solitary bees have a relatively small foraging area (up to 600m) compared with honeybees (6.5km), which reduces the availability of alternative forage sources.

Non-pesticide and indirect pesticide impacts may also have a significant effect on bee populations. The loss of floral diversity as a result of the use of herbicides and fertilisers and the fragmentation and loss of habitats through ploughing of headlands and other agricultural practices have been shown to reduce solitary bee abundance. Given the wide range of plants species dependant on solitary bees for pollination the reduction in bee populations is likely to have knock on effects on the plant species pollinated by them, resulting in less forage.

This review has shown that there is very little data on the effects of pesticides on solitary bees. More detailed information on a range of species is required.

Conclusions

There is evidence of decline in the abundance of some wild pollinator species in Britain (Archer, 2001, Biesmeijer, et al, 2006, Cowley et al, 1999). This has mainly been attributed to the loss of habitat as a result of increased agricultural intensification. However the strength of this evidence varies among taxa. Long-term population trends for butterflies show a steady decline in abundance, with mobile, habitat generalist predominating. A similar trend is also seen with solitary bees and hoverfly. However for other pollinator species there is an absence of long-term population data, toxicity data and an incomplete understanding of even basic taxonomy and ecology. This makes it very difficult to ascertain what part pesticides may play in pollinator declines.

This review has shown that the exposure of wild pollinators to pesticides is likely to be at least that of honeybees.

Standardised laboratory tests have demonstrated that susceptibility to a compound can vary according to species and large differences in toxicity occur within the same insecticide category. Therefore more detailed information on a range of species and life stages is required to assess the risk posed by pesticides relative to honeybees

Exposure profiles of wild pollinators and honeybees differ significantly, due to respective diurnal activities, flight seasons, foraging habits and life histories. Of particular concern are insecticide applications to flowering crops, such as oilseed rape, at times that, although posing less risk to honeybees are likely to coincide with peak foraging times of wild pollinators. Contamination of flowering weeds in and around sprayed crops is also likely to pose a greater risk to wild pollinators than honeybees. There are also limited data on the repellency of pyrethroid insecticides to pollinators other than bee species. This is of importance as risk management decisions, e.g. spraying early morning or late evening, are based on these behavioural responses in honeybees and other species may either be directly over-sprayed or not exhibit the same avoidance of treated crops.

Pesticide exposure may also have more of an impact at the population level (e.g. mortality or reduced fertility), than in honeybees because the exposure of the egg-laying female is much higher than in honeybees, which is protected within the hive. In addition exposure may occur at all life stages for because eggs can be laid and larvae exposed within the crop, whereas honeybee risk assessment is primarily assessed for adults (unless known IGR). Therefore it is important that the differences in exposure profiles are considered in the risk assessment process.

Current risk assessment considers only crops attractive to honeybees. This literature review has shown that some crops (e.g. potatoes) are attractive to other pollinators.

The importance of pollen and nectar as food sources varies between species. Nectar residues may be diluted over time, whereas the rate of decline of residues in pollen will be limited by the degradation of the pesticide.

Many pollinators have relatively small foraging area (up to 600m) compared with honeybees (6.5km), which reduces the availability of alternative forage sources.

Non-pesticide and indirect pesticide impacts are likely to have significant effects on pollinators. The loss of floral diversity as a result of the use of herbicides and fertilisers and the fragmentation and loss of habitats through ploughing of headlands and other agricultural practices have been shown to reduce pollinator abundance. Given the wide range of plants species dependant on non apis pollinators a reduction in wild pollinators is likely to have knock on effects on the plant species pollinated by them, resulting in less forage.

In the UK, environmental stewardship schemes (Defra) have encouraged farmers to create conservation headlands to improve floral diversity. However with the rise in cereal prices it is likely that more land will be put back into production resulting in further plant and pollinator declines.

This review has shown that there is very little data on the effects of pesticides on wild pollinators. More detailed information for a range of species is required

Objective 3

Recently there have been some concerns with the potential for drift of fine particles and dust from granule and seed applications onto field margins containing flowers. Currently risk assessment for honeybees doesn't include any consideration of the drift of pesticide dust. However exposure to such dusts may result in exposure of pollinators through flowering plants present in the field margins. This review evaluates the available data to determine whether there is the potential for significant risk to pollinators.

Granular formulations

The use of granular formulations is widespread and can offer important advantages in terms of handling, application safety and reduced weight and volume. Granules usually consist of an inert material (e.g. sepiolite sand, limestone, gypsum and kaolin) and the pesticide, which is usually sprayed onto the granule (Goss et al, 1996). They are applied to either the surface or sub soil of a field to control pests living at ground level or underground (e.g. nematodes, wireworms and slugs). The primary granular pesticides used in the UK are molluscicides, insecticides and nematicides.

A major concern for the producer of granular pesticides is the maintenance of the homogeneity of particle size because the performance of these products is dependant on particle size (Farnish, 2007). Any degradation may result in under or over application of chemicals and ineffective pest control. Manufacturers are also subject to international standards (CIPAC) to ensure that fine particles and dust make up only a small fraction by weight of the product. Manufacturers usually sieve their products to ensure uniform size with minimal dust content. Despite these measures, granules are subjected to abrasion during handling and application, which can generate fine particles and dust (Harrington et al, 2004).

Over the last few decades the general trend in granule application has been a steady move to using reduced quantities of smaller more concentrated granules. As granules become smaller and lighter and more concentrated, the potential for drift during application and impact on wildlife has also increased.

Historically assessments of granular drift has involved counting the number of granules at given distances from the application area. The drift of dust has largely been ignored because granules were considered to fall within the application area and produce few emissions. However there is evidence that dust is generated during application, which may drift down wind of the applicator (Holterman, 2006, Harrington, 2004). What impact this may have on organisms that are exposed is not known.

Holterman (2006) theorised that under worst-case conditions 1.5% – 3% of the applied dosage of granule could reach the field margins, with dust travelling in excess of 50m downwind of the applicator. However this was based on a model used for spray drift and assumes all particles are perfectly spherical.

Kranzler et al, (1986) investigated the drift of two granules with different characteristics (carrier material, bulk density and size range) broadcast from a pneumatic applicator in a wind tunnel. They found that drift was affected by particle shape, density and the airspeed. On average the lightweight granules (560kg/m^3) were displaced 1.2m with a maximum displacement of 3.4m. The heavier granules (1450 kg/m^3) were typically carried less than half as far. At air speeds of 10 – 15 mph, smaller particles were transported further than large ones. However at higher air speeds the shape of the particles was more important. The more a particle differs from an ideal sphere, the more air friction will increase with respect to mass. Therefore irregular shaped particle will travel less distance at high wind speeds than spherical particles of equal mass. Although dust was not investigated the study suggests that it has the potential to travel a significant distance from a broadcast applicator.

Harrington et al (2004) investigated granular drift using fluorescent granules and a rig to simulate granules applied using a large gravity fed granule applicator. Beyond 25cm very few granules could be physically counted, however analytical methods showed that fine particles and dust could be deposited at distances beyond 2m, with occasional positive results up to 5m.

Therefore the application method has a significant effect on drift. Broadcast type applicators (spinning disc or pneumatic applicators) are more likely to displace particles further and generate more dust than gravity fed applicators because the granules are released with energy from a height.

Molluscicides are predominately used on wheat, oilseed rape and potato crops to control slugs and snails. Metaldehyde (80%) and methiocarb (16%) are the two most commonly used, with thiodicarb accounting for a further 2% of the total molluscicide treated area in the UK (Garthwaite et al, 2006). The majority of products are pelleted bait formulations, which rely for their effectiveness on first being found by slugs and snails and then being sufficiently palatable to be consumed by them in lethal quantities. They are usually applied broadcast via tractor mounted granule applicators, with a fertilizer spreader with spinner frequently being used for this purpose. They may also be applied at drilling admixture.

The risk posed by the drift of fine particles and dust from granular applications of molluscicides onto field margins is low. Although they are usually applied broadcast, therefore dust generation and drift is possible there is no evidence that these compounds are toxic to honeybees.

Granular insecticides/nematicides are predominately used on a variety of crops (e.g. potatoes, carrots, onions and sugar beet) to control arthropod soil pests (e.g. wireworm) and nematode pests (e.g. potato cyst nematodes). In the UK the systemic carbamates aldicarb and oxamyl have been the two most commonly used compounds (Garthwaite et al, 2006). Being systemic they also provide early protection from sucking and chewing pests (e.g. aphids, thrips and mites).

Although many of these compounds are toxic to pollinators the likelihood of them coming to contact with the active ingredient through drift is low. Modern granular pesticides are systemic (e.g. aldicarb and oxamyl) and are targeted at the soil. They work by pests in the soil coming into contact with the granules and by the active ingredient being taken up by plant roots, providing protection from sucking and chewing pests. They are usually injected just before drilling or applied at soil level then incorporated with a rotary-powered cultivator. The likelihood of drift occurring using these products is very low, because any dust will be trapped in the soil.

During a typical granule application the headlands and row ends are particularly high-risk areas for spills because if the applicator is not fitted with a devise that cuts off the flow of granules as the operator lifts the rig, granules are left un-incorporated.

Granular fertilizer

Fertilizers are generally considered to be non-toxic to pollinators however indirectly they can have significant effects on pollinator populations by reducing the floral diversity of field margins.

Granular fertilizers are commonly applied broadcast to arable field before or after drilling using a spinner or air blown applicator therefore the risk of drift of granules and dust into the field margins is high. In addition because they are considered harmless less consideration is given by the farmer to where the granules go.

Seed treatments

The use of seed treatment is widespread (see Table 17). Traditionally, they were used to control seed and soil-borne diseases and insects. However more recently, seeds are being treated with fungicides and insecticides with strong systemic properties to provide protection from a wide range of pathogens and early foliar and insect pests.

Most seeds today are at treated with at least one fungicide however depending on the requirements a cocktail of up to four different compounds can be applied. Imidacloprid and clothianidin are used to provide systemic protection from early aphid attack, whilst beta-cyfluthrin and tefluthrin are for the protection of the seed from soil-borne invertebrates.

There have been reports of dust being generated during drilling of treated seed and drift into flowering margins. The outside of the coat is sealed by a dust free polymer layer, which ensures that the seed treatment is contained within the coat but effectiveness may be limited if the coating is poorly applied or the seed is abraded during drilling. A large-scale bee mortality in southern France in 2003 this was attributed to a poor seed treatment process resulting in fipronil dust. Greatti et al (2003) showed imidacloprid residues in air and on weeds and grass on headlands following drilling of Gaucho treated corn using a pneumatic seed drill. When the residues (max 54 µg/kg on flowers) were compared with the published LD50 data (approx 9 ng/bee) this shows that it would require the bee to take up the residues from just 0.2g of flowers. This suggests it may be useful to consider the effect of application techniques on the distribution of seed coatings in the environment.

Table 17. Predominantly used seed treatment for arable crops in the UK (Garthwaite et al, 2006).

Crop	Seed treatment(s)	Class of pesticide(s)
Wheat	Fludioxonil	Fungicide
	Bitertanol / fuberidazole	Fungicide / Fungicide
	Bitertanol /fuberidazole/ imidacloprid	Fungicide/ Fungicide/ Systemic Insecticide
Barley	Tebuconazole	Fungicide
	Tebuconazole / triazoxide	Fungicide / Fungicide
	Prothioconazole / tebuconazole / triazoxide	Fungicide / Fungicide / Fungicide
Oats	Fludioxonil	Fungicide
	Bitertanol / fuberidazole	Fungicide / Fungicide
Oilseed rape	Beta-cyfluthrin / imidacloprid	Insecticide / Systemic Insecticide
	Thiram	Fungicide
	Iprodione	Fungicide
Ware Potato	Imazalil	Fungicide
	Pencycuron	Fungicide
Peas	Thiram	Fungicide
	Cymoxanil / fludioxonil / metalaxyl-m	Fungicide / Fungicide / Fungicide
Field beans	Thiram	Fungicide
Sugar beet	Thiram / hymexazol	Fungicide / Fungicide
	Thiram / hymexazol / imidacloprid	Fungicide/ Fungicide / Systemic Insecticide
	Thiram / hymexazol / beta-cyfluthrin / clothianidin	Fungicide / Fungicide / Insecticide / Systemic Insecticide
	Thiram / hymexazol / tefluthrin	Fungicide / Fungicide/ Insecticide

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9. This section should be used to record links (hypertext links where possible) or references to other published material generated by, or relating to this project.

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