FOOD STANDARDS AGENCY

PESTICIDE RESIDUE MINIMISATION

CROP GUIDE

APPLES

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November 2006

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Every effort is made to ensure that the information provided in these guides is accurate. The information contained within the guides was correct to the best of the author's knowledge up to March 2006. No legal responsibility is accepted for any errors, omissions or misleading statements.

The guide offers broad approaches to be explored further. They are not intended to be used as detailed protocols and it would be advisable for users to consider the guidance in relation to an integrated crop management system.

Up-to-date information on pesticide regulations is available on the Pesticides Safety Directorate's website (www.pesticides.gov.uk). However, approvals and MRLs are subject to change over time and the users of the guide are reminded that it is their responsibility to ensure that any chemical intended for use by them is approved for use at the time of intended application. The user is reminded to carefully read the label attached to any chemical product and follow the instructions regarding application.

Products are mentioned as examples of those that contain particular active ingredients and no endorsement is intended.

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Preface

Why choose apples for pesticide residue minimisation?

The FSA has a policy of pesticide residue minimisation because it recognises that people want residues reduced further than the current safe levels. Therefore the crop guides have not been produced because of any food safety concerns but with the aim of meeting people's choice in the food they buy. Further information on the rationale for the crop guides and on the safety of pesticides can be found in the General Introduction.

In producing the crop guides the FSA focussed on UK production because it is more practicable, in the first instance, to apply guidance at home than abroad. Apples form a significant part of the UK diet and monitoring shows that each year some of the crop contains pesticide residues, albeit at safe levels.

Much work has been done by those involved in the UK food industry to keep pesticide residues to a minimum. Many of the measures recommended in this guide have already being adopted by growers. The FSA hopes to build on this body of knowledge, to help to maintain the momentum to keep residues to a minimum.

FSA Pesticide Residue Minimisation

Crop Guide - Apples

1. Introduction

1.1 Crop description

Apples are the most important tree fruit grown commercially in the UK at the present time in terms of area cropped, volume and value. It is also one of the major food crops grown in the world. The cultivated apple belongs to the genus *Malus*, which comprises of some 25 to 30 species and several subspecies distributed almost continuously throughout temperate Eurasia and North America. The primary centre of diversity appears to be in the region of Asia Minor and Western China where forests of wild apple are known to exist. The centre of origin for the domesticated apple is now thought to be eastern Kazakhstan and the northern slopes of the Tien Shan Mountains (Juniper *et al*., 1999). Apples have been grown for thousands of years and were gathered by pre-historic man.

Today, apples are grown in orchards with known varieties being grown on rootstocks which have been selected for their agronomic qualities, such as size control, tolerance of soil conditions and pest and disease tolerance. Varieties are selected for fruit quality, eating attributes, storage potential and agronomic traits, such as yield, fruit size distribution, tolerance to pest, disease and disorders. Whilst there are varieties that are characteristic of particular fruit growing areas of the world, increasingly the market is dominated by varieties that are grown in many of the major production areas. This enables marketing organisations to source fruit to supply customers over most of the year from a combination of UK and overseas orchards.

Orchards have an economic life of 12 to 15 years, although apple trees can live for over 100 years in many situations. Fruit quality and yield declines as trees age, whilst pest and disease levels can build up and be difficult to control. Apple orchards are often surrounded by windbreaks, which provide protection from strong winds and minimise drift from sprays applied for crop protection purposes. Trees are usually grown in strips of bare earth, maintained by herbicides, with grass alleyways between the rows of trees. Often, weeds are allowed to develop later in the season within the row, in an attempt to reduce rain splash from the ground reaching the fruit.

Whilst early UK varieties may be marketed immediately after picking, most are stored in cold stores prior to marketing. Over-winter storage has been practised for hundreds of years using simple structures and clamps, for varieties which can be stored. Advances in storage technology since the 1950's have resulted in the use of refrigerated cold stores, often in combination with atmospheric control of the levels of oxygen and carbon dioxide within the store. This allows fruit to be held in good condition for prolonged periods. Some varieties are capable of being stored in these conditions for almost 12 months of the year e.g. Bramley.

1.2 Uses and markets

Dessert, culinary and cider apples are grown in the UK. The major dessert variety is Cox's Orange Pippin and the main culinary variety is Bramley Seedling. Both are old varieties dating from 1825 and 1813 respectively. Even "new" varieties in UK, such as Braeburn (found in the late 1940s in New Zealand), often have their origins over 50 years ago. Cox and Bramley are complemented by other varieties which help to provide pollination in the orchard and/or are grown to extend the range of apples offered to customers, to provide differing eating characteristics and seasons of use. Bramley is however effectively available 12 months of the year from cold store.

Table 1. Areas of apple production in England & Wales (ha)

Apple	1999	2000	2001	2002	2003
Dessert	8323	7662	6630	5628	5350
Culinary	3690	3795	3340	2745	2446
Cider	-	5043	7010	6738	6551

Source: Defra Orchard Fruit Survey, July 2003

All cider fruit is used in processing with significant areas under contract to cider manufacturers. Dessert fruit is sold as fresh fruit by growers, through marketing organisations, to the main retailers and the food service industry. The "umbrella" organisation for UK marketing organisations is English Apples and Pears Ltd, which performs various industry wide functions especially representation within for example, the World Apple and Pear Association and elsewhere, together with public relations activities such as the Bramley Campaign. Culinary fruit is sold to processors and directly to retailers. The British Independent Fruit Growers Association (BIFGA) represents growers, who prefer to market their own fruit directly. The high quality specification required by many retailers can result in significant volumes of otherwise sound dessert fruit being sold into the processing market particularly for use in juice and to add to cider varieties for cider production.

1.3 Area grown in the UK, volume produced and value

In 2003, the total orchard area in England and Wales was 17,671 ha of which 30% was dessert apples, 13.8% culinary apples and 37% cider apples (Defra Orchard Fruit Survey, July 2003). Bramley is by far the most important culinary variety with over 92% of all the culinary fruit area being down to Bramley.

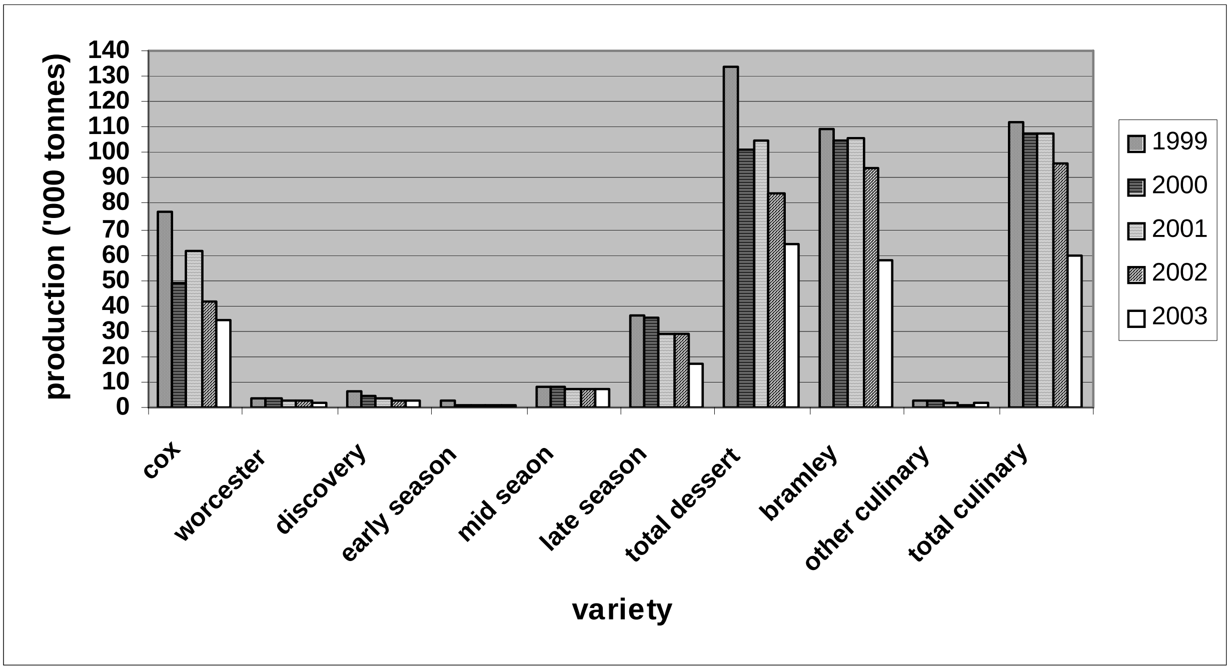
Table 2. Area of dessert apple varieties in England and Wales (ha)

Variety	1999	2000	2001	2002	2003
Discovery	577	484	420	339	264
Worcester Pearmain	294	283	207	196	147
Cox	4694	4186	3489	3015	2738
Egremont Russet	325	334	331	268	264
Gala	757	828	719	663	674
Spartan	299	286	257	195	142
Jonagold	400	353	257	201	227
Fiesta/RedPippin	186	163	133	109	n/a
Braeburn	n/a	n/a	n/a	n/a	306
Others	791	745	819	641	588
Total	8323	7662	6630	5628	5360

Source: Defra Orchard Fruit Survey, July 2003

The total area of dessert apples grown in England and Wales declined between 2002 and 2003 by 5% (Table 2). Over the same period, the culinary apple area declined by 11%. These changes reflect the economic pressure the UK industry is facing and the restructuring that is taking place in response to these pressures. The area of traditional cider orchards declined by 33% but modern bush orchards of cider fruit increased by 14% indicating the cider industry's restructuring.

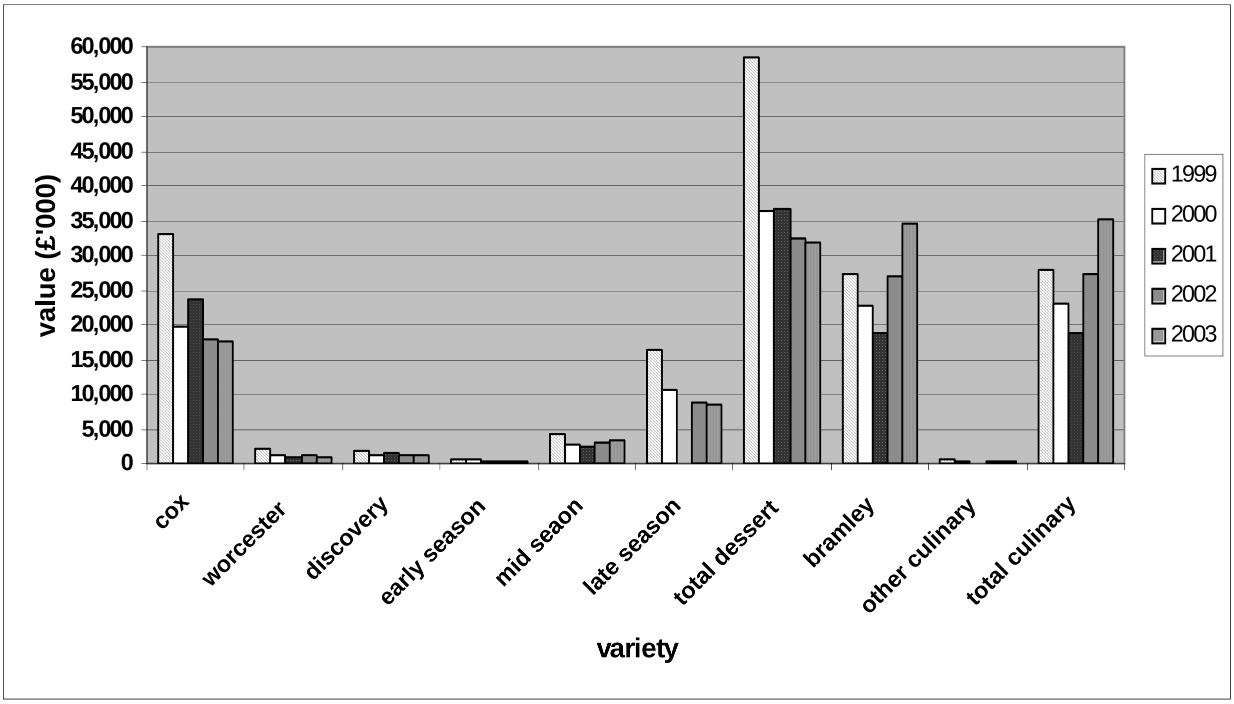
Figure 1. UK apple production ('000 tonnes)



Source: Defra, Basic Horticultural Statistics for the UK, 2004

Variation in the volume of fruit produced year on year reflects not only the changes in areas being grown but also the variable yield per hectare from year to year which is influenced primarily by the weather during the blossom period and following growing season.

Figure 2. Value of UK apple production (£'000)



Source: Defra, Basic Horticultural Statistics for the UK, 2004

The value of the UK crops also varies year on year depending upon world trading conditions and the volume of crop in the UK and elsewhere. UK producers operate within a world market for fresh apples and apple products, such as juice concentrate and pulped fruit.

In 1993, it is estimated that 44.6% of the total supply of apples to the UK market came from UK growers. This proportion had declined by 2002, with an estimated 29% of the market supplied from UK production (Defra, Basic Horticultural Statistics, 2004).

Only very small volumes of apple fruit are exported from the UK, barely 19,000 tonnes in 2003, of which some may well be re-exports.

1.4 Volume imported and value

Apples are a commodity food, which is traded extensively on the world market. China is now the largest producer of apples in the world, accounting for about a third of all apples produced. Total EU production is about half that of China and double that of the USA. Of the 15 EU countries, Italy and France are the largest producers of apples by a significant margin ahead of Germany and Spain. The UK is one of the smallest producers by volume.

Of the 10 new EU member states, Poland is by far the largest producer of apples by volume, with the next largest producer, Hungary, growing only about a quarter of Poland's crop. Whilst much of Poland's export crop is destined for the German market, it is not unreasonable to expect a re-distribution of at least some of these exports to other EU markets including the UK.

Table 3. Volume and value of imports into UK 2003

Country of Origin	Volume ('000 tonnes)	Value (£'000)
France	163,924	90,568
South Africa	95,110	53,565
New Zealand	74,217	53,498
Italy	28,849	20,268
Chile	18,660	11,124
USA	18,477	11,958
Germany	16,767	7,207
Netherlands	10,961	5,037
Brazil	8,189	4,765
Canada	9,719	6,538
Belgium	7,264	2,805
China	6,555	3,983
Australia	4,337	3,322
Austria	3,183	2,082
Spain	2,635	1,664
Singapore	1,604	1,193
Argentina	923	533
Portugal	1,726	1,045
Irish Republic	1,350	800
Turkey	639	404
Uruguay	355	172
Poland	426	149
Iran	198	91
Hungary	105	58
Finland	16	9
Zimbabwe	66	39
Costa Rica	21	17
Israel	42	23
Norway	21	16
Taiwan	19	11
Slovakia	19	11
Abu Dhabi	18	9
Romania	15	8
Greece	1	0
Total	476,409	282,973

[Source: HM Revenue and Customs 2004)

Some of the smaller volumes imported into the UK are likely to be either experimental imports or re-exports, with many being “one-off” consignments in a single month of the year. France, New Zealand, South Africa and Italy are the largest exporters to the UK. Significant volumes also come into the UK from 11 other countries.

2. Pesticide use on apples

2.1 Problems requiring the use of pesticides

The key pest and disease problems in apples, which may require the use of pesticides, are listed in Table 4. The problems are rated for their importance according to their effect on crop yield and also for the occurrence of residues that might arise from the use of pesticides to control the problem.

Table 4. Key pest and disease problems in apples requiring the use of pesticides, and their relative importance to the crop and pesticide residues (*** high: ** medium: * low: - no importance because associated pesticides not found or not sought)

Problem	**Species name**	**Importance**		**Description**
		Crop	**Residues**	
Orchard pests				
Codling moth	*Cydia pomonella*	***	***	Key pest which causes direct damage to the fruit.
Apple sawfly	*Hoplocampa testudinea*	***	*	Caterpillars burrow into fruit.
Winter moth	*Operophtera brumata*	***	*	Causes direct damage to fruit.
Rosy apple aphid	*Dysaphis plantaginea*	***	**	Causes leaf and severe fruit distortion and premature ripening.
Blastobasis	*Blastobasis decolorella*	**/ *	*	Caterpillars feed on flesh of ripening fruit around the stalk or where fruits touch.
Apple blossom weevil	*Anthonomus pomorum*	**	*	Causes blossom damage and loss.
Fruit tree red spider mite	*Panonychus ulmi*	**	*	Causes leaf bronzing and premature leaf fall, decreasing yield.
Common green capsid	*Lygocoris pabulinus*	**	*	Leaves and fruit are attacked, with corky blemishes on apples.
Apple rust mite	*Aculus schlechtentali*	**	-	Causes russeting around the stalk on the fruit.
Fruit tree tortrix moth	*Archips podana*	**	**	Caterpillars feed on foliage and feed on the fruit around the calyx.
Summer fruit tortrix moth	*Adoxophyses orana*	**	***	Feeding damage to fruit.
Rosy leaf curling aphid	*Dysaphis devecta*	*/ *	*	Causes leaf distortion.
Woolly aphid	*Eriosoma lanigerum*	*/ *	*	Causes minor damage to trees.
Apple-grass aphid	*Rhopalosiphum insertum*	*	*	Causes slight leaf curling.
Apple leaf midge	*Dasineura mali*	*	*	Causes leaf rolling.
Apple sucker	*Psylla mali*	*	-	Insects suck sap in blossom trusses and cause bud death.
Green apple aphid	*Aphis pomi*	*	*	Causes leaf curl and reduction in growth.
Leafhoppers	*Edwardsiana crataegi*	*	-	Causes speckling damage on leaves.
Mussel scale	*Lepidosaphes ulmi*	*	-	Can debilitate host tree and also secretes honeydew.

Orchard diseases				
Apple powdery mildew	*Podosphaera leucotricha*	***	**	Causes reduction in photosynthetic efficiency and to loss of fruit size and yield and ultimately loss of leaves and blossoms.
Apple scab	*Venturia inaequalis*	***	***	All parts of the tree are attacked, but scab infection of fruit is most obvious symptom.
Apple canker	*Nectria galligena*	***	**	This fungus causes cankers on trees and also a fruit rot both in the orchard and in store.
Crown rot and collar rot	*Phytophthora cactorum & P. syringae*	**	-	Collar rot is a disease of the scion and crown rot a disease of the rootstock.
Blossom wilt	*Monilinia laxa f.sp. mali*	**	-	Causes loss of blossoms.
Sooty blotch & fly speck	*Gloeodes pomigena & Schizothyrium pomi*	**	-	The symptoms are superficial blemishes which cause down-grading of fruit.
Fireblight	*Erwinia amylovora*	**/ *	-	Bacteria causes blossom wilt and loss of fruit-bearing shoots.
Silver leaf	*Chondrostereum purpureum*	*	-	Causes silvering of the foliage and shoot loss.
Apple replant disease	-	*	-	Apple trees grow poorly when replanted in non-sterilised soil, especially in old orchard land.
Storage diseases				
Botrytis rot	*Botrytis cinerea*	***	**	Fruit rots either as a result of wound infection or as calyx end rot from infection during flowering. Latter most important in Cox.
Brown rot	*Monilinia fructigena*	***	***	Rot infects fruit through wounds caused in the orchard.
Gloeosporium rot	*Gloeosporium spp*	***	***	Infection remains latent in fruit, developing as a rot later in store.
Penicillium rot	*Penicillium expansum*	***	-	This rot occurs as a secondary invader of other rots and damage.
Nectria rot	*Nectria galligena*	**/ *	***	Causes sunken mid brown or greeny brown rot either at eye or stalk end or on fruit cheek.
Phytophthora rot	*Phytophthora cactorum & P. syringae*	**/ *	***	Symptomless infected fruit initiate rotting, which then spreads in store.
Mucor rot	*Mucor piriformis*	**/ *	-	This wound rot invades through damage to the fruit.
Storage physiological disorders				
Bitter pit, lenticel blotch and late storage corking		***	-	Causes breakdown of cell walls with brown corky depressions or internal spots, as a result of low calcium levels.
Superficial scald		**/ *	***	Causes a bronzing of skin of the fruit and sunken brown areas, principally on Bramley apples.
Low temperature breakdown and scenescent breakdown		**	-	Causes a browning of cortical tissues of the fruit, associated with low calcium and phosphate levels.

Pest and disease pressure varies considerably from year to year and this affects the relative importance of the problem and the likely risk of residues arising from pesticide treatment. Changing weather patterns are also impacting on incidence of pests and diseases and their life cycles, e.g. pheromone trap catches of both codling moth and summer fruit tortrix have been higher for a longer period in recent seasons leading to a need for control measures being applied closer to harvest.

2.2 Pesticide use on apples

Details of pesticides currently approved for use on apples in the UK are available on the Pesticides Safety Directorate website (https://secure.pesticides.gov.uk/pestreg/ and https://secure.pesticides.gov.uk/offlabels/search.asp). Defra and the Scottish Executive Environment and Rural Affairs Department (SEERAD) survey the use of pesticides on apples every four years. The survey data are published in the Pesticide Usage Survey Reports, and these are available on the Central Science Laboratory (CSL) website (www.csl.gov.uk/science/organ/pvm/puskm/reports.cfm). Information on the use of pesticides in the growing apple crop can be found in Pesticide Usage Survey Reports – Orchards and Fruit Stores in Great Britain. Comparative data for 1992, 1996 and the survey in 2000 are presented. Anecdotal information from the industry indicates that there has been a significant reduction in the use of post harvest drenches since 2004. A summary of the usage of pesticides on top fruit crops grown in Great Britain from 1992 to 2000 (spray hectares & kg of active substances applied) is given in Tables 5 & 6.

2.2.1 Pesticide use on the growing crop

Table 5. Comparison of pesticide usage on apples (excluding cider apples) by area treated (ha), 1992, 1996 and 2000

Type of pesticide	1992	1996	2000
Fungicides	296,564	224,388	235,876
Insecticides/acaricides	84,783	59,123	46,139
Herbicides	47,266	52,755	36,811
Growth regulators	41,235	36,300	47,353
Biological Control Agents	7,474	5,269	476
Sulphur	3,330	10,784	1,837
Pruning paints	2,622	6,135	-
Urea	-	18,813*	7,210
Repellents	-	614	-
Winter washes	645	637	69
Total all pesticides	480,954	401,174*	375,771
Total area grown	18,044	14,134	12,432

Source: Defra, Pesticide Usage Survey Reports, 115 – 1992, 142 – 1996, 172 - 2000.

Table 6. Comparison of pesticide usage on apples (excluding cider apples) by amount used (kg active substance), 1992, 1996, 2000

Type of pesticide	1992	1996	2000
Fungicides	114,841	96,639	89,993
Insecticides/acaricides	48,129	31,196	21,615
Herbicides	67,847	42,755	23,683
Growth regulators	7,715	5,195	3,486
Biological Control Agents	1,184	997	43
Sulphur	4,251	2,936	5,332
Pruning paints	68	22	-
Urea	-	25,278*	10,049
Repellents	-	674	-
Winter washes	6,183	158	7,591
Total all pesticides	250,218	205,850*	161,792

Source: Defra, Pesticide Usage Survey Reports, 115 – 1992, 142 – 1996, 172 - 2000.
* The area & quantity of urea used has been estimated on the basis of the percentage total quantity used on apples in 2000 (66%) of the total orchard usage.

The area of apple growing has declined from 18,044 ha to 12,432 ha over the eight years between 1992 and 2000, and although the total area treated and the total quantity of pesticide used has declined, the actual use of pesticides applied to crops has not declined greatly. On average, each hectare of apple orchard was treated 26.7, 28.4, and 20.2 times in 1992, 1996 and 2000 respectively and the average weight of pesticides applied per hectare of apples was 13.9, 14.6 and 13.0 kg/ha for 1992, 1996 and 2000 respectively. Fungicides were the most frequently used pesticide. Between 1996 and 2000, there was a small increase in the number of active substances used, which were from increased fungicide use.

Apples receive a large number of pesticide sprays. In 2000, there were between 14-18 separate spray applications, with 30-38 active substances applied, of which 10-14 were fungicides, 4 insecticides, 2-4 plant growth regulators (PGRs), 2 herbicides and 1 spray of urea, depending on the type of apple. Cox dessert apples receive the greatest number of sprays. The most commonly used pesticides in apple orchards (excluding herbicides) in 2000 were:

Fungicides - captan, myclobutanil, dithianon and penconazole

Insecticides/acaricides – chlorpyrifos, fenoxycarb and pirimicarb

PGRs – paclobutrazol, gibberellins

2.2.2 Pesticide use on the stored crop

Table 7. Comparison of pesticide used on apples prior to storage – amount of fruit treated (tonnes)

Active substance	1992	1996	2000
Antioxidants			
Diphenylamine	37,193	54,346	41,060
Ethoxyquin	21,935	1,939	2,661
All antioxidants	59,128	56,285	43,721
Fungicides			
Benomyl	51,367	345	-
Captan	584	-	1,493
Carbendazim	9,282	63,101	28,523
Carbendazim/metalaxyl	59,324	68,385	64,258
Iprodione	-	613	1,505
Thiophanate-methyl	10,421	-	-
All fungicides	130,977	132,444	95,779
All pesticides	190,105	188,729	139,500
Basic tonnage treated	142,277	126,308	80,232
Untreated	52,570	26,135	29,274
Tonnage of fruit stored	194,847	152,443	109,506

Source: Defra, Pesticide Usage Survey Reports, 115 – 1992, 142 – 1996, 172 - 2000.

There was a significant reduction in the volume of apples stored (21.7 % between 1992 and 1996 and 27% between 1996 and 2000). The proportion of untreated fruit rose from 19% in 1996 to 28% in 2000. This may reflect the diminishing range of chemicals available for treatment of fruit but also a move by the industry to improve hygiene, reduce pesticide rates and minimise residues where possible and undertake risk assessments for rotting. Extensive use of fruit mineral analysis and application of calcium in the orchard has improved the integrity of fruit with a consequent improvement in its susceptibility to post-harvest diseases and disorders. The economic pressure that the industry has faced has focussed attention on reducing the cost of pesticide inputs where this is possible without adversely affecting fruit quality or yield.

Table 8. Comparison of pesticide use on apples prior to storage – amount of active substance used (kg)

Active substance	1992	1996	2000
Antioxidants			
Diphenylamine	1,460	1,513	977
Ethoxyquin	877	104	24
All antioxidants	2,337	1,617	1,000
Fungicides			
Benomyl	553	4	-
Captan	11	-	17
Carbendazim	123	505	485
Carbendazim/metalaxyl	633	588	586
Iprodione	-	31	3
Thiophanate-methyl	238	-	-
All fungicides	1,558	1,127	1,091
All pesticides	3,895	2,744	2,091

Source: Defra, Pesticide Usage Survey Reports, 115 – 1992, 142 – 1996, 172 - 2000.

The total amount of active ingredients used to manage post-harvest diseases and disorders declined markedly between 1992 and 1996 with a further reduction by 2000. Only 54% of the amount of chemical used in 1992 was used in 2000, but the average weight of pesticide per tonne treated was similar at 0.02 – 0.03 kg/tonne between the years.

3. Pesticide residues on apples

3.1 Pesticide residue survey data

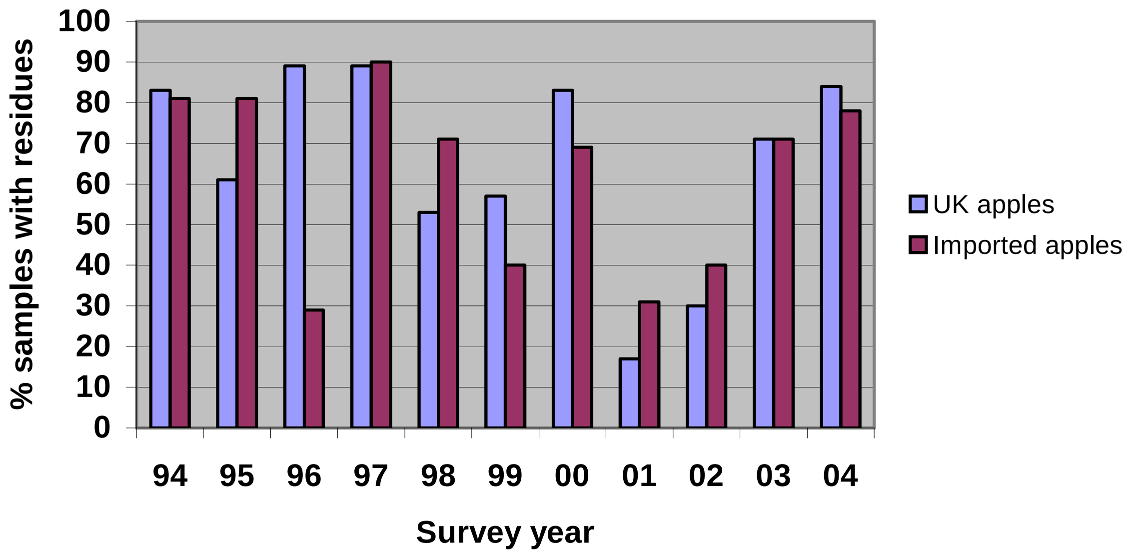
Data on pesticide residues in apples have been taken from the annual reports of the Working Party on Pesticide Residues (WPPR) from 1994 to 1999, and then from the quarterly Pesticide Residue Committee (PRC) survey reports from 2000 to 2004 (www.pesticides.gov.uk/prc_home.asp). Apples are monitored on a routine basis, as they are an important food staple, and dessert varieties are usually eaten without any preparation. Details of the pesticide residues sought and found in the surveys between 1994 and 2004 are listed in Appendix A.

The number of pesticides sought in the standard surveys over this period has varied from 32 to 119 active ingredients per year. The PRC choose which pesticides to look for based on information from the Pesticide Usage Surveys, the likely occurrence of a residue appearing based on degradation data and time of application, and the availability of a cost-effective analytical test. The main fungicides and insecticides applied to apples are sought as residues in the current PRC surveys.

3.2 Pesticide residue trends

Over the eleven year period from 1994 to 2004, 497 UK and 1089 imported samples of apples were tested for pesticide residues (Appendix B). Overall, residues were found in 308 samples (62%) of UK apples and 628 samples (58%) of imported apples respectively. The yearly percentages are presented in Figure 3, and these range from 17 % to 83 % of samples with residues in individual years. This reflects the seasonal approach to pesticide use, which depends on weather conditions and the incidence of pest and disease problems. The occurrence of residues was lowest in 2001 and 2002, with 30 % or less of the UK samples containing residues. In contrast in 2004, the occurrence of residues was back up to 84% and 78% for the UK and imported crops respectively. There is no evidence for an overall decline in the percentage of apple samples containing pesticide residues from the WPPR/PRC data over the eleven years, because of the seasonal peak in 2000 and the gradual increase in levels from the low point in 2001.

Figure 3: UK and imported apple samples containing pesticide residues 1994-2004 (%)
(Source: WPPR/PRC survey data)



MRL exceedances

Only four MRL exceedances were recorded on apple samples over the 11 survey years reported here (only 0.27% of the total samples taken). These were found in imported apple samples taken in 2003 and 2004, as detailed in Table 9.

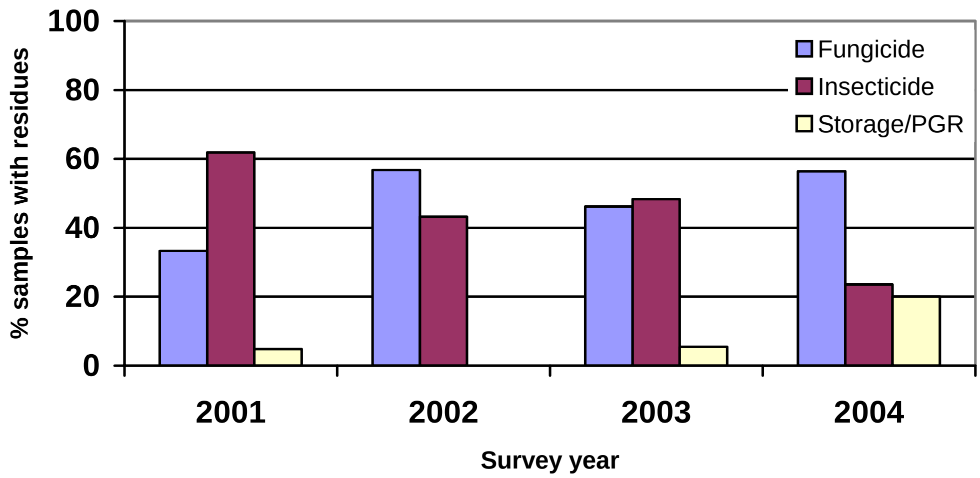
Table 9. MRL exceedances in imported apples 2003-04 (mg/kg)
(Source: PRC survey data)

Pesticide	Year	MRL	Residue found	Country of origin
Dimethoate	2003	0.02	0.03, 0.08	Brazil
Dimethoate	2003	0.02	0.04	France
Captan	2004	3	3.6	Argentina

3.2.1 UK produced apples

The most commonly occurring pesticide residues (i.e. found on >10% of samples tested), on UK apples in the 2004 PRC survey, were chlorpyrifos, carbendazim, captan and diphenylamine, (Appendix B). The 2000 Pesticide Usage Survey shows that, with the exception of diphenylamine, these pesticides were frequently used on apples. In total in 2004, residues of 11 pesticides were found on UK samples: eight fungicides, one insecticide, one storage chemical and one plant growth regulator. The proportion of fungicide residues has increased over the last four years.

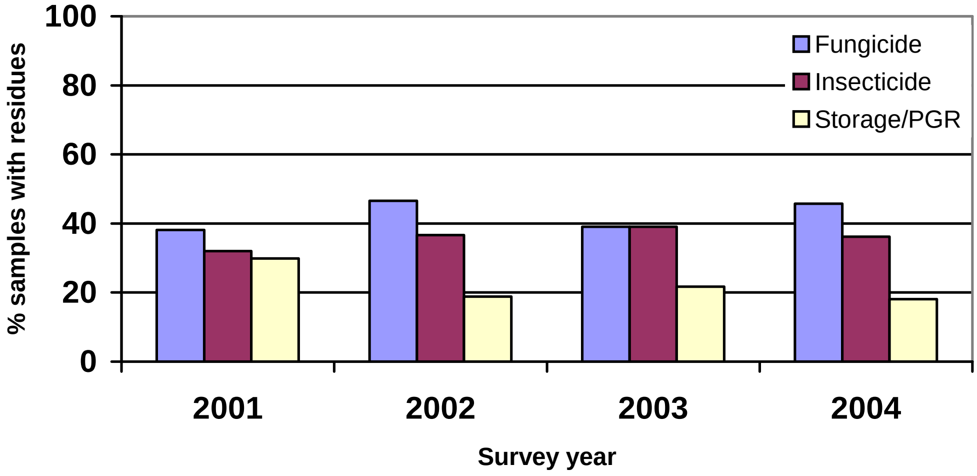
Figure 4. Type of pesticide residue found on UK apple samples 2001-2004 (% of residues found)
(Source: PRC survey data)



3.2.2 Imported apples

The most commonly occurring (>10%) pesticide residues, on imported apples in 2004, were diphenylamine, thiabendazole, captan, carbaryl, azinphos-methyl and dithiocarbamates (Appendix B). Overall in 2004, residues of 17 pesticides were found on the imported samples, and there was one MRL exceedance of the fungicide captan. Eight of the pesticide residues were fungicides, eight were insecticides and acaricides, and there was one storage chemical.

Figure 5. Type of pesticide residue found on imported apple samples 2001-2004 (% of residues found) (Source: PRC survey data)



The occurrence of insecticide and fungicide residues was very similar for all four years, although there was a slightly higher proportion of fungicide residues in 2002 and 2004, in line with the UK data. The proportion of samples with residues of storage chemicals/ and plant growth regulators (PGRs) was higher than on UK produce over the four years. It should also be noted that some residues detected in imported fruit were of pesticides not now approved for use in the UK or may never have been approved for use on apples in the UK. Pesticides may have an acceptable use in one country but not another, because of different agricultural, climatic and pest conditions.

4. Approaches to reduce pesticide residues

4.1 General approaches and policies to reduce use and residues

To reduce pesticide use and minimise residues, conventional apple growers follow the principles of Integrated Crop Management (ICM). ICM is a cropping strategy in which growers aim to conserve and enhance the environment whilst producing safe and wholesome food economically. ICM recognises that profitability is vital to the success and sustainability of any farmer/grower business.

ICM is built on sound existing knowledge and good agronomy practices and is regularly updated to take account of new research findings. Knowledge of pest, disease and weed biology and environmental awareness is vital. Integrated Pest Management (IPM) is a part of ICM and involves developing pest control strategies based on environmental control, bio-control and the use of physical and chemical control agents. IPM relies on representative and diligent regular crop monitoring carried out at regular intervals.

A recommended protocol for practicing IPM in apple production is contained within the Defra Best Practice Guide for UK Apple Production (2001).

4.2 Assurance schemes

Assured Produce Scheme (APS) – www.assuredproduce.co.uk
UK apple growers were in the vanguard of developing assured produce protocols with their own GroAct scheme, instigated by English Apples and Pears Ltd. This has now been integrated within the Assured Produce Scheme with which the majority of commercial apple growers in the UK are registered. The crop protocol for apples promotes ICM practice and includes advice on pesticide use reduction and minimisation of residues. Assured Produce has developed a specific residue minimisation protocol for apples.

4.3 Decision support systems

Decision support systems (DSS's) are available for a number of pests and diseases of apples. The most commonly used DSS is based on pheromone trapping to monitor insect levels to determine when the threshold for spraying is reached – the threshold might not occur in some seasons. Also, they can be used to determine the time of egg laying for some pests, and together with daily temperature records, can calculate the subsequent hatching of the pest eggs. This results in more effective pesticide application. Assessments of risk for many diseases are also available to growers, which help determine the need for treatments to be applied.

There are a number of DSS's available for pest and disease prediction based on weather data including the PESTMAN and ADEM systems developed by Horticulture Research International (HRI) at East Malling for apple diseases. They are used by the National Association of Cider Makers in the south west and Hereford to provide information on scab risk to growers. The systems are run by Bulmers (Hereford) and Gaymers (Shepton Mallet). Other DSS models exist in other apple growing regions of the world. The uptake of these systems has been limited by the direct costs for automatic weather stations, software costs etc and the indirect costs of maintaining the weather station and running the programmes. Some Defra and Apple and Pear Research Council (APRC) funded work at HRI East Malling demonstrated that both cost and pesticide savings could be achieved in some seasons by adopting these systems. Further research and development should focus on demonstrating these savings over a number of seasons. It is however unlikely that significant uptake will occur unless the approach is made more accessible to growers and the systems are simple to use. This might occur by means of a "bureau" system where the operation of the programme is carried out for growers who receive advice from the bureau without the need to master the underlying science and computer technology. Some consultants and agronomy support companies operate services of this type on behalf of their clients.

5. Approaches for specific problems related to residues

The Defra Best Practice Guide for UK Apple Production sets out best practice at the time of its publication in 2001. The approach advocated by the guide is to build up the levels of the natural predators of pests within orchards, to use pesticides which will not adversely affect predator levels, and to apply pesticides only when there is significant risk of damage and when the pests are most susceptible. There has also been a trend within the industry to reduce the rates of pesticide used where possible, and more recently, to apply appropriate pesticides earlier rather than later in the cycle of crop development to reduce the likelihood of residues occurring on the fruit. Apple growth stages and a Pest and Disease Action Calendar used by the industry are shown in Appendices C and D respectively.

Residues found in UK apples in 2002, 2003 and 2004 are grouped into the following categories, according to the frequency of occurrence:

High frequency – found in each of three years
- Chlorpyrifos (insecticide)
- Captan (fungicide)
- Carbendazim (fungicide)

Moderate frequency
- Diphenylamine (scald prevention)
- Metalaxyl (fungicide)

Low frequency
- Buprimate (fungicide)
- Dithianon (fungicide)
- Dithiocarbamates (fungicide)
- Iprodione (fungicide)
- Myclobutanil (fungicide)
- Penconazole (fungicide)
- Pyrimethanil (fungicide)
- Tolyfluanid (fungicide)
- Pirimicarb (insecticide)
- Paclobutrazol (plant growth regulator)

5.1 Approaches to reduce high frequency residues

5.1.1 Chlorpyrifos

Chlorpyrifos is a widely used organophosphate insecticide which is very cost effective, and is used to control a wide range of pests, whilst at the same time being safe towards the key natural enemy of pest mites, *Typhlodromus pyri.* It is used for control of moth caterpillars, aphids, sawfly, weevils and capsids. Alternative treatments to chlorpyrifos to minimise residues are listed below for the key pests. There is however an increasing incidence of pests, once considered minor or rarely seen, for which chlorpyrifos remains one of the few options available to growers. Other options could be the use of pyrethroids but these may adversely affect key predator populations. The ACP reviewed the use of chlorpyrifos in 2004 and concluded that on top fruit one application pre-flowering and up to three applications after blossom might be necessary to combat a range of pests that might be present whilst minimising risk of resistance and permitting a successful IPM programme to be followed.

Moth caterpillars including, codling moth, fruit tree tortrix, summer fruit tortrix and winter moth can be controlled by other insecticides such as diflubenzuron, fenoxycarb and methoxyfenozide, spinosad and also the bacterial insecticide, *Bacillus thuringiensis* (Bt), when applied at suitable timings.

Aphids, including apple grass aphid and rosy apple aphid can be controlled by thiacloprid, pirimicarb or triazamate. Work at East Malling Research (EMR) suggests that pirimicarb applied in October after harvest will provide good control of over-wintering aphids if the weather is favourable. Other insecticides e.g. thiacloprid, may also be useful at this stage in the season.

Apple blossom weevil is mainly controlled by chlorpyrifos or pyrethroids, but the latter group of insecticides are harmful to beneficial insects.

Apple sawfly can be partially controlled by sprays of certain fungicides during flowering, notably fenarimol. Insecticides applied before blossom or at petal fall for aphids, such as thiacloprid, will give incidental control and diflubenzuron will give partial control.

Capsids and scale insects are also controlled by thiacloprid.

Approaches to minimise chlorpyrifos residues
Chlorpyrifos use could be restricted to one application at or shortly after bud burst in March to target blossom weevil, winter moth and sucker, which could help to reduce the likelihood of it appearing as a residue on fruit. Alternatively, other pesticides and *Bacillus thuringiensis* (Bt) could be used to replace chlorpyrifos, however, this approach will be more costly. Diflubenzuron was last sought in 2002 (no residues found in 250 samples) but thiacloprid has not been sought in PRC surveys and therefore the possibility of residues occurring is unknown. Applications of chlorpyrifos after blossom may be necessary in some seasons for other pest problems.

EMR is currently evaluating a zero (below detection level) pesticide approach, using *Bacillus thuringiensis* (Bt) and fatty acids, which should result in nil pesticide residues, but will carry a greater risk of pest damage to fruit. Control measures used in other countries, which are not approved for use in the UK, include: pheromone mating disruption; pheromone lure and kill; and biocontrol with granulovirus. These would all have a positive impact on the reduction of chlorpyrifos residues.

5.1.2 Captan

Captan is a fungicide used for the control of apple scab, *Gloeosporium*, storage rots, sooty blotch and fly speck. It is widely used because of its cost effectiveness and additional broad-spectrum activity against other pathogens, especially those responsible for storage rots. It is also useful as part of a resistance management strategy. It is usually sprayed routinely every 14 days from bud-burst in March until the end of June for scab control, and July to August for control of post-harvest storage rots, if no other control is used. Alternative treatments to minimise residues of captan are listed below for the key diseases.

Approaches to minimise captan residues - apple scab
A strategy combining a mixture of orchard hygiene measures, fungicide timing and the use of other chemicals such as sulphur and urea could be used for the control of apple scab and to minimise the occurrence of captan residues, as follows:

1. Urea sprays post-harvest and pre-leaf fall have two effects, disrupting the sexual stage of the disease and encouraging leaf rotting.
2. Mowing or pulverising after leaf fall to facilitate rapid breakdown of leaves and other orchard litter.
3. Fungicides to achieve control early in the season as follows:

- Pre-bud burst application of copper, where justified by the previous season's infection levels.
- A bud burst spray of protectant fungicide, eg dodine or dithianon. Dithianon usage is related to variety. On some varieties e.g. Gala, it is less likely to be used after green cluster as it may cause russet on fruit.
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- A petal fall spray of protectant fungicide eg dithianon, kresoxim-methyl, pyrimethanil (although occasional residues of dithianon and pyrimethanil have been found).

4. Other actions:
   - Adoption of the EMR strategy of no fungicide between petal fall and harvest except for low rate sulphur.
   - A post-harvest application of a demethylation-inhibiting (DMI) fungicide (eg. fenarimol, fenbuconazole, mycobutanil).
   - Late season, pre-harvest applications of boscalid+pyrclostrobin (Bellis) for scab and post harvest diseases.

Approaches to minimise captan residues - post-harvest storage rots
Crop hygiene measures can be used to reduce the incidence of post-harvest storage rots and the need for fungicide treatments which should result in lower captan residues. A strategy could include the following measures:

1. Pruning out cankers, removing mummified fruits, removing low hanging branches, pulverising prunings and other litter thoroughly, maximising grass alley width together with close supervision of picking to eliminate damage to fruit.
2. Thorough cleaning of bulk bins with physical removal of debris by scrubbing followed by use of a suitable disinfectant. Bins are best cleaned immediately after emptying in the pack house, it is more difficult to clean them if left to just before harvest. Bins are a major source of inoculum, especially of *Penicillium*.
3. Using the rot risk assessment tool (Appendix E) or the Assured Produce protocol and then planning treatment actions accordingly.
4. Using alternative fungicide treatments to captan e.g. tolyfluanid and/or boscalid+pyroclostrobin which have some activity against some of the storage diseases, *Botrytis, Gloeosporium* and *Phytophthora,* and has a short harvest interval.

5.1.3 Carbendazim

Carbendazim is widely used for control of apple canker, for which it is the most effective product, and storage rots. Orchard application is used for canker (*Nectria galligena*) for which it remains the most effective treatment and gives incidental control of mildew, blossom wilt, Botrytis and sawfly. However, other pesticides do give better control of these when specifically targeted.

Both pre-harvest sprays and post-harvest dips or drenches of carbendazim have been used to control storage rots, brown rot, *Gloeosporium, Botrytis* and *Nectria*. Nectria rot is however not well controlled by post-harvest treatments, pre-harvest sprays are more effective. Tolerance of some isolates of *Gloeosporium* and *Botrytis* to carbendazim is widespread.

Approaches to minimise carbendazim residues - apple canker
Whilst there is no immediately available alternative to carbendazim for apple canker control, the following measures have a good prospect of commercial control. Recent Horticultural Development Council (HDC) funded research has evaluated potential alternatives and application timings after harvest to reduce residues. Carbendazim was the most effective autumn treatment, with three applications over the leaf-fall period. Tebuconazole (as Folicur) has recently been granted a Specific Off-Label Approval (SOLA) for use at this time of the

season. Tolyfluanid gives some control but is not as effective as carbendazim. These treatments could replace autumn copper usage where canker is very severe.

Orchard hygiene is essential in reducing use of carbendazim. Cankers need to be removed and prunings pulverised. A bud burst spray of a protectant fungicide, e.g. dodine or dithianon can protect bud leaf scars. This could be repeated at mouse ear growth stage (see Appendix C). The use of tolyfluanid for scab control may also give some incidental control of canker. Lastly, a post-harvest application of an approved copper fungicide at 10% leaf-fall and again at 50% leaf fall may be used.

Approaches to minimise carbendazim residues - post-harvest storage rots

The use of carbendazim for the control of storage rots is being phased out in response to concerns about residues from retailers and because of its decreasing effectiveness against certain target organisms. Alternative strategies for the following diseases include:

1. *Gloeosporium* – pruning out cankers, dead stubs and die back, removing mummified fruit, and using the rot risk assessment tool (Appendix E), late season pre-harvest sprays of boscalid+pyroclostrobin.
2. *Botrytis* – late season pre-harvest sprays of boscalid+pyroclostrobin, keeping mud and leaves off bulk bins, cleaning bulk bins, careful picking to avoid damage, and using the rot risk assessment tool.
3. *Brown Rot* – pruning out cankers, removing mummified fruits, avoiding damage such as skin punctures, cracks *etc*, at harvest, and using the rot risk assessment tool.

Crop hygiene measures, especially cleaning and disinfection of bins, are essential for all these diseases. Infected growth should be physically removed from the orchard during the growing season and destroyed. Tree architecture can be modified by pruning to create improved air movement through the tree canopy and thus reduce risks.

5.2 Approaches to reduce medium frequency residues

5.2.1 Diphenylamine

Diphenylamine (DPA) is used as a post-harvest dip or drench to prevent scald development, principally in Bramley cooking apples. The incidence of scald varies in response to seasonal weather conditions and the risk is increased by early harvesting. The following approaches can be used to minimise residues:

1. Correct harvest date for intended market.
2. Fruit which is stored in ventilated, controlled atmosphere (CA) stores at 8 to 10% carbon dioxide until marketing in November need not be treated.
3. Fruit stored in 5% carbon dioxide and 1% oxygen and marketed before the end of March need not be treated, provided CA conditions are established slowly to avoid carbon dioxide injury occurring i.e. delay establishing CA for 10 –15 days.
4. Fruit stored in 5% carbon dioxide and 1% oxygen for marketing beyond March can be treated with half-rate DPA to control scald.
5. The use of heated catalyst scrubbers to remove ethylene from storage atmospheres is a proven alternative to DPA for delaying scald development. Scald control can be achieved for 6 months when ethylene scrubbers are used on CA stores operating at 8 to 10% carbon dioxide and at least 10 months in stores operating at 5% carbon dioxide and 1% oxygen. This method involves high capital costs and high running costs. However, engineering developments may alter the economics of this approach, as ethylene management is a key issue within the fresh produce industry worldwide.
6. The use of 1-methylcyclopropene (1-mcp), as an in-store fumigation treatment, inhibits ethylene production and can control scald for 6 to 9 months in CA storage. Management of stores will need to be modified where 1-mcp is used, as stores cannot be sealed as rapidly as with other treatments.

7. The development of aminoethoxyvinylglycine (AVG) (as ReTain) for orchard use, would be helpful in managing fruit ripeness and ethylene production.

5.2.2 Metalaxyl-M

Metalaxyl-M (SL567A) (SOLA) is used as a post-harvest dip or drench treatment for control of Phytophthora storage rots. Control of this disease in store can be achieved without metalaxyl by using the EMR rot risk assessment strategy (Appendix E), or the Assured Produce protocol. Reducing risk factors by management of orchard ground cover can include mulching to reduce soil splash, pruning out low hanging branches and selective picking (harvesting no fruit below 0.5m from the soil surface). These measures have been shown to be very effective. Late season sprays of tolyfluanid, one month and again two weeks before harvest have also been effective. In some circumstances, a pre-harvest application of mancozeb+metalaxyl-M (Fubol Gold WG) to the soil surface within the herbicide strip may be appropriate (SOLA).

5.3 Approaches to reduce low frequency residues

Bupirimate - is used for the specific control of powdery mildew, as part of a disease resistance management strategy, as it is not a DMI fungicide. Adoption of the EMR Zero (below detection level) Pesticide Residue strategy would reduce the use of this active ingredient between petal fall and harvest, with reliance on sulphur for control of powdery mildew over the summer period. Reduced dose fungicides or sulphur have given good control of mildew provided that primary mildew is maintained at a very low level. Use of late season pre-harvest sprays of boscalid+pyroclostrobin would also be useful too as part of a resistance management strategy. Potassium bicarbonate has been useful in controlling mildew in other crops and could have a role to control this disease in apple.

Dithianon – used for control of apple scab and suppression of canker. Minimising the use of this fungicide after flowering will reduce the risk of residues. (Post-blossom sprays are mainly used on Bramleys.)

Pyrimethanil – used for control of apple scab with activity against blossom wilt and *Botrytis*. Using this fungicide early in the season will reduce the risk of residues. Its use after petal fall is not recommended.

Myclobutanil – used for mildew with activity against scab. (DMI fungicide)

Penconazole – used for mildew with activity against scab. (DMI fungicide).

Use of these four fungicides, especially near to harvest would be reduced by the adoption of the EMR Zero (below detection level) Pesticide Residue strategy with sulphur being used at low rates during this period of the season. Dithianon could be restricted to pre-flowering use to minimise the risk of residues appearing.

Pirimicarb – used for the control of aphids. The use of aphicides is likely to change as recent research at EMR suggests good control of some species can be achieved by appropriate timing between harvest and blossom period. This pesticide may have a place as a post-harvest treatment in October.

Tolyfluanid – used for apple scab control with activity against *Nectria* eye-rot, *Botrytis, Gloeosporium* and *Phytophthora*. Residues of this fungicide found in PRC surveys may be associated with the atypical use profile following the initial launch of this fungicide. If the use of captan decreases, the use of tolyfluanid may increase, because of its activity against *Botrytis, Gloeosporium* and *Phytophthora*. However, recent studies by EMR and Bayer on the use of tolyfluanid for rot control indicate no detectable residues at the PRC monitoring level of 0.05mg/kg. Use of late season pre-harvest sprays of boscalid+pyroclostrobin would be an alternative.

Iprodione – is not approved for use on apples.

6. Research

6.1 Recent and ongoing research

Research on apples is primarily funded by Defra and the Horticultural Development Council (HDC), with some other funding from the Biotechnology and Biological Sciences Research Council (BBSRC). A significant part of the HDC portfolio (and previously the APRC) has addressed the availability of pesticides for specific problems and has resulted in a Specific Off-Label Approvals programme to meet growers' immediate needs. The HDC has recently undertaken a Gap-Analysis of pesticide availability and the implications of this for the horticulture industry in the UK. Other work has covered breeding and assessment of new varieties, rootstock evaluation and fruit storage work.

6.2 Gaps in knowledge and research needs

There is a need to test the effect of alternative pesticide strategies on pesticide residues otherwise one residue problem may be exchanged for another. Simply extending the harvest interval to ensure fruit with minimum residues could result in serious pest and disease problems without careful consideration of the implications and the initiation of alternative control strategies.

There is little or no readily available information on the degradation characteristics of pesticides used in apple production. Neither growers nor their advisors are in a position to build this information into their decision making processes when considering the need for control of specific pests and diseases. Such information could become an important tool for minimising pesticide residues, with pesticide degradation profiles and half-life characteristics being especially useful. The development of the concept of Residue Interval (RI) analogous to the current Harvest Interval (HI) could also be a useful advisory tool. The RI would be the period required to elapse between the last application of a pesticide and the presence of residues in fruit below the Limit of Determination (LOD). This would need further research. Of course, LODs might get lower and the RI might need adjusting accordingly.

The whole area of biopesticide use and availability is relatively under-researched in respect to fruit crops in the UK. These offer real alternatives to conventional pesticides and, in theory, meet many of the policy aims of moving towards more sustainable crop production systems. Initially, trials evaluating commercially-available biocontrol agent formulations from other parts of the fruit growing world would be very useful. More research work is urgently required to identify other potential organisms and to determine how best to use them in practice.

The commercialisation of these control agents is difficult because registration costs are relatively high compared to the potential commercial returns for use on "minor" crops. This issue is currently being addressed by the EU Steering Group on Minor Uses which was set up to co-ordinate the work of the Technical Group on Minor Uses and to look at procedures, finance and strategic issues to do with minor uses. A literature review of the available options for the use of barriers and deterrents in orchard pest & disease control would also be useful. Recent changes to the registration system have been introduced by PSD which are aimed at addressing this issue.

More research work is urgently required in the area of biological control of post-harvest rotting. Whilst biological control is currently an option in pears where major problems arise from wound pathogens, in apple major post-harvest rots arise from infection in the orchard. Manipulation of storage environment may offer scope for reducing incidence of some rots in apple by fluctuating store conditions. Research and development of "smart" storage technologies i.e. that monitor fruit physiology in store and utilise this information to control store conditions, could work alongside biocontrol of rots to eliminate the need for fungicide application at or near to harvest.

The use of food grade antioxidants may offer scope for controlling scald on fruit and this should be investigated. 1- methylcyclopropene is proving to be useful in ethylene inhibition and scald control but it requires monitoring to ensure most effective use. Other means of ethylene management require continued investigation, especially as new equipment becomes available.

There is considerable scope for improvements in pesticide application technology in fruit crops aimed at more effectively reaching the target organisms and minimising use of pesticide as well as reducing drift. Work funded by Defra to develop the pesticide application rate adjustment to the crop environment (PACE) approach to linking application to tree form and size needs to be more widely promulgated.

The role of plant nutrition, and its interaction with crop susceptibility to pests and diseases, needs investigation. Also useful would be an understanding of systemically-acquired resistance and how this could contribute to the development of sustainable pest and disease management strategies, and minimise the need for pesticide use and so reduce residues on fruit.

7. Knowledge/Technology transfer initiatives

Knowledge transfer is largely undertaken for the apple industry by the Horticultural Development Council (HDC), which has taken over the activities of the Apple and Pear Research Council (APRC). Defra also funds some knowledge transfer activities, such as the Best Practice Guide for Apples, either alone or in partnership with the HDC.

Some of the grower-producer organisations undertake a limited amount of knowledge transfer activity as part of their operational programmes or stimulated by marketing organisations in response to customers' requirements or commercial pressures.

A major initiative has been the Defra funded 'The Best Practice Guide for UK Apple Production', published in 2001 as a hard copy sent to all APRC levy payers and to consultants and advisers. A fuller version of the Guide was prepared on CD and made available to all apple growers who requested a copy but was primarily aimed at consultants, advisers and technologists who assist growers. It is not always appreciated how much they influence pesticide choice and use.

7.1 Ongoing activities

The HDC communications programme (knowledge transfer) includes a regular news magazine featuring new R&D results and SOLA's which have been granted.

The HDC is funding the design and production of posters or wall charts to aid growers in crop monitoring at critical crop growth stages in apples and has also commissioned another focusing on storage diseases and disorders. The need for other knowledge transfer by the HDC has been limited by the publication of the Defra Best Practice Guide, which has served the industry well for the last three years.

English Apples and Pears Ltd has funded, initially with Defra grant aid, Quality Fruit Group work on fruit maturity and storage potential which provides growers with general guidance on the correct harvest date and risks of diseases and disorders. This work is ongoing. Fruit harvested at the correct stage of maturity is more likely to be able to be stored with the minimum of losses to disease and disorders.

The East Malling Research Association (EMRA) holds regular members' days on various subjects, to present the results of work undertaken at East Malling Research (EMR) (previously HRI East Malling). EMR is the main organisation in the UK for research on top-fruit and both crop protection and fruit storage (including diseases and disorders) have featured prominently over recent years in the knowledge transfer programme. Defra and HDC-funded work is often featured, together with appropriate commercially-funded work. EMRA Members Days on "Top Fruit Crop Protection" covered their most recent research, much of which will help towards achieving lower pesticide residue levels in apples.

Professional fruit consultants through their continued professional development activities also ensure that the latest developments and techniques are brought to the attention of the fruit growing community

Assured Produce is incorporating information aimed at minimising pesticide residues into the Crop Protocol for apples.

7.2 Required activities

- The Best Practice Guide for UK Apple Production now needs updating, and a sustainable means of enabling future updates needs to be put in place. New sections covering weed control, soil management, orchard hygiene and residue reduction, are needed, with the aim of working towards a comprehensive reference tool for the industry. This is most likely to be achieved by utilising CD media rather than producing a hard copy for all growers. (Defra/HDC)

- Hold workshops on the management and enhancement of natural enemies in apple orchards (Defra/HDC). This could also cover pear orchards to present a comprehensive picture to growers (Defra/HDC).
- Hold workshops and/or produce factsheets on using improved pesticide application techniques, including appropriate nozzle selection and the use of PACE systems.
- Collate available knowledge on pesticide degradation characterisation and make this available to growers and their consultants so that they can make informed decisions about pesticide use and the risk of residues occurring with a better knowledge of the characteristics of pesticides.
- EMRA Members Day “Achieving Minimal Pesticide Residues in UK Apples, and improved IPM approaches”, would be timely. (EMR/EMRA)
- Demonstrate “going for Zero (below detection level) Pesticide Residues” in a commercial block of fruit and conduct an economic evaluation of the outcome each season. This is now taking place in four Kent orchards by EMR in collaboration with WorldWide Fruit. This will end in 2007. Further work is likely to be needed to extend to other areas, notably the West Midlands and to other varieties particularly Bramley and late harvested varieties like Braeburn. The cost implications of this approach as well as the success of pest and disease control together with residue data needs to be reported to growers. (Defra/HDC – part of the ongoing Defra R&D project at EMR.)
- Crop Walkers’ Guide for Apples. HDC has recently produced a Crop Walkers’ Guide for Strawberry Growers, a similar guide for apple producers and their staff would aid earlier recognition of problems and facilitate timely application of control measures. This would complement the Best Practice Guide and would be useful in the orchard (HDC).
- Implementation of decision support systems. Ways of making information and benefits available to growers which do not require growers to become familiar with the underlying technology nor expose them to high costs. Some consultancy organisations have begun to provide this type of service. Improvements in models are however needed.
- Factsheet: Managing ethylene in stored apples to include potential for ethylene scrubbing (HDC).
- Interactive seminars involving both research workers and consultants/agronomists should be developed to improve interchange of information and aid rapid dissemination of R&D findings to the industry. It is essential that independent consultants and those employed by service companies are included in this invitation.

8. Conclusions

The apple industry has made substantial progress in reducing its use of pesticides in recent years in response to pressure from its customers. There is a willingness within the industry to continue to reduce pesticide inputs wherever possible.

Much can be achieved by the application of currently available knowledge. However, it must be recognised that there will inevitably be some seasons where certain pests and/or diseases will necessitate pesticide interventions that may not be routinely needed in other seasons. The development of the concept of advisory “minimal residue thresholds or intervals” would greatly help growers’ decision making when under pressure during the growing season. These thresholds would be determined from knowledge of the pesticide activity and degradation characteristics together with industry experience of its use. This is an extension of the harvest interval concept that is already an integral part of Good Agricultural Practice (GAP) in relation to pesticide use but would set the timing of the latest treatment with the aim of achieving minimal residues.

The move in recent years away from broad spectrum pesticides to those with more targeted action against specific pests and diseases has resulted in some minor pests and diseases emerging as problems and this trend is likely to continue. These organisms have previously been controlled by the broader spectrum pesticides. Changes in weather patterns are also likely to influence pest and disease pressure.

8.1 Key actions to minimise pesticide residues on apples

Apple Variety	Variety development offers the potential to exploit genetic resistance to pest and disease but this is a long-term solution with between 5 to 10 years required to introduce a variety into the market place.
Orchard Hygiene	Remove diseased and damaged wood and fruit, macerate prunings and other litter. Apply urea to encourage rapid breakdown of this material Apply pest and disease control measures where possible post-harvest and before flowering.
Agronomic Practice	Develop strategies to encourage the build up of natural enemies and predators, and introduce biological control options as soon as they become available. Use pesticides as early in the crop growth cycle as possible to achieve the earliest possible control of a pest or disease and thereby allow the maximum period for degradation of pesticide residues. Use the most benign (least likely to result in residue issues) pesticide that is effective for control and which has the most appropriate degradation and residue profile. Use the most appropriate application rate of pesticide for the pest or disease concerned. If a lower rate of pesticide is used this should not compromise effective control of the target pest/disease or risking build-up of resistance to the pesticide. This approach should always be based on a comprehensive understanding of the target organism and be based on the principles of sound science. Adopt optimum pesticide application techniques, e.g. choice of nozzles and PACE. Continue to use regular monitoring and introduce new or improved decision support systems as they become available to establish the need to apply a pesticide and to improve the timing of application for optimum control. Produce a residue reduction plan for orchard operations.
Key residues and actions (*** = high, ** = medium, * = low importance)	
Chlorpyrifos *******	**Scope for residue minimisation – short to medium term** Residues could be minimised by using chlorpyrifos early in the season to extend the harvest interval, modifying orchard management to encourage natural predators, using alternative pesticides, applying aphid control overwinter, optimising spray application and timing, and adopting alternative treatments such as *Bacillis thuringiensis* and fatty acids post-petal fall, as being tested in the EMR strategy.

	The risk of residues occurring from other insecticide treatments such as diflubenzuron and thiacloprid, which are currently not sought in PRC surveys, needs to be investigated. Alternative control techniques such as pheromone mating disruption, lure and kill, and granulosis virus, which are available for use outside of the UK, need to be evaluated in the UK. Identification of barrier treatments and deterrents would also reduce the need to apply insecticides.
Captan *****	**Scope for residue minimisation – short to medium term** ***Apple scab*** Residues resulting from the use of captan to control apple scab could be minimised by combining a mixture of orchard hygiene measures, fungicide timing and the use of other chemicals including dithianon, pyrimethanil, sulphur, boscalid+pryaclostrobin. The EMR strategy to reduce the risk of captan residues is to use no fungicide between petal fall and harvest except for low rate sulphur. However, eliminating fungicide use during this period may result in other minor diseases such as sooty blotch, fruit spot and fly speck becoming more prominent. ***Post-harvest storage rots*** Crop, store and bin hygiene measures can be used to reduce the incidence of storage rots, and combined with the rot risk assessment to treat, market or store fruit, will help minimise residues of captan.
Carbendazim *****	**Scope to minimise residues – short to medium term** ***Apple canker*** Residues could be minimised by limiting carbendazim treatments to the autumn after harvest, ensuring cankers are removed and prunings macerated, using a fungicide such as dodine or dithianon to protect bud leaf scars at bud burst and mouse ear growth stages, and applying copper at 10% and 50% leaf fall. Further work is ongoing to find alternative treatments to control apple canker and also to improve the understanding of the disease to make treatment more effective. ***Post-harvest storage rots*** Use of carbendazim for control of storage rots is declining. Alternative strategies include orchard, crop, harvesting and store hygiene measures, optimising fruit nutrient levels and harvest timing, careful picking to avoid damage, and using the rot risk assessment to advise on the need to market, store or treat fruit. Techniques to reduce the disease spore load in the store by filtering air and using pre-storage food grade surface sterilants are being investigated. Alternative application techniques of conventional pesticides, such as fogging, are also being tested, but this may not reduce the risk of residues occurring.
Diphenylamine ****	**Scope to reduce residues – medium term** This is mainly applicable to Bramley cooking apples. Adjusting carbon dioxide and oxygen levels in store all help minimise

	scald developing on fruit and the need to treat with diphenylamine. Using the EMR annual risk prediction warning to inform storage and marketing decisions, so that only fruit being stored beyond the risk-free period is treated. Use of 1-methylcyclopropene can control scald for 6 to 9 months in controlled atmosphere storage but DPA is still needed for longer storage. Store upgrades may be needed to provide the high level of atmosphere controls required.
Metalaxyl-M ******	**Scope to reduce residues – short to medium term** Residues can be reduced by using orchard hygiene, pruning, selective picking and the rot risk assessment tool, as with captan and carbendazim. Late season sprays of tolyfluanid may also help.
EMR Strategy to minimise residues	The strategic approach suggested by research at EMR is to modify crop protection in line with period of risk and stage of crop growth, and when pesticides are required ensuring the harvest interval is as long as possible to allow natural decay of residues before fruit enters the supply chain. • Adopt an integrated pest and disease management programme between bud burst and petal fall. • From petal fall to harvest, use biocontrol agents for insect control and low dose sulphur only for disease control. Incorporate potassium bicarbonate into the programme to help control mildew, and prune out severe infections of canker and mildew. • Post-harvest in orchards use DMI fungicides for scab and mildew control, urea over leaf-fall to enhance leaf rotting and reduce inoculum carryover, copper leaf-fall spray for Nectria canker and post-harvest aphicide for Rosy apple aphid. • For post-harvest rots use cultural control to remove Nectria canker and brown rot. Conduct rot risk assessment and use this to indicate marketing strategy i.e. fruit at most risk from rot in long-term storage is marketed early in the season. Selectively pick fruit to escape Phytophthora and brown rot infections. • For post-harvest scald, treat susceptible varieties where necessary with 1-methylcyclopropene or use ethylene scrubbing of store atmospheres.
Medium to long-term proposals	Biological control measures in use in other parts of the world need to be identified and then evaluated in the UK. Research and development of “smart” storage technologies, which monitor fruit physiology in store and utilise this information to control store conditions, could work alongside biocontrol of rots to eliminate the need for fungicide application at or near to harvest. A major revision of the relevant sections of the Defra Best Practice Guide for UK Apple Production is required to take account of the EMR strategy and other research.
Advice	A Crop Walkers’ Guide to identify key apple pests would help growers recognise and monitor pest problems. Factsheets on management of natural enemies in apple orchards, pesticide application techniques and managing ethylene in stored apples.
Training	Knowledge transfer workshops will be required to explain the EMR approach to agronomists and then directly to growers.

Acknowledgements

We are grateful to those in the top fruit industry involved in various discussions during this project, and in particular to Dr Angela Berrie and Jerry Cross of East Malling Research for helpful discussion of various issues.

Glossary of terms – (This glossary applies to all 5 crop guides)

Acceptable Daily Intake (ADI):- the estimated amount of a substance that can be consumed every day for a lifetime by humans without presenting a significant risk to their health, based on current scientific evidence.

Active ingredient:- Synonym for active substance.

Active substance:- Any substance or micro-organism, including a virus, that has a general or specific action: against harmful organisms; or on plants, parts of plants or plant products. Active substances are usually formulated with other materials in a pesticide product.

BASIS:- An independent registration, standards, certification and training organisation (serving pesticide, fertiliser, horticulture, forestry and other relevant interests), working with and through industry organisations to implement relevant sections of 'The Food and Environment Protection Act 1985' and other legislative and industry Code of Practice requirements.

Bio-control or Biological Control Agent (BCA):- Biological control of pests by use of other organisms.

Conservation Grade:- Conservation Grade farming is a system which encourages biodiversity and ensures a sound environmental provenance for food production (www. Conservationgrade.co.uk).

Desiccants:- Products used to dry out unwanted plant material.

Diatomaceous earth:- Fine hygroscopic clay material used for controlling grain storage pests.

Disease:- A condition causing damage to a plant usually by a fungal or viral infection.

DMI:- demethylation inhibitors, group of fungicides, affect a particular biochemical step in the production of ergosterol.

Early potatoes:- Crops harvested before 31 July.

Fungicides: - Chemical substances that kill or inhibit the growth of fungal pathogens affecting plants.

Good Agricultural Practice (GAP):- The way products should be used according to the statutory conditions of approval, which are stated on the label.

HACCP: - **H**azard **A**nalysis & **C**ritical **C**ontrol **P**oints. A system, which identifies, evaluates and controls hazards which are significant for food safety.

Hagberg Falling Number (HFN): – a measure of bread making quality. Values of >250 seconds are required by millers.

Harvest Interval (HI): The time which must elapse between the final treatment with an individual pesticide and the harvest of the crop, as detailed on the pesticide label.

Haulm:- Potato foliage.

Herbicide:- A pesticide used to control unwanted vegetation (weed killer). A chemical that kills plants, sometimes designed to kill specific weeds.

Insecticide:- A pesticide used to control unwanted insects.

Integrated Crop Management (ICM):- ICM is a method of farming that balances the requirements of running a profitable business with responsibility and sensitivity to the environment. It includes practices that avoid waste, enhance energy efficiency and minimise pollution. ICM combines the best of modern technology with some basic principles of good farming practice and is a whole farm, long-term strategy including:
the use of crop rotations;

- appropriate cultivation techniques;
- careful choice of seed varieties;
- minimum reliance on artificial inputs such as fertilisers, pesticides and fossil fuels;
- maintenance of the landscape;
- enhancement of wildlife habitats.

Limit of Determination (LOD):- The limit of determination is the lowest concentration of a pesticide residue or contaminant that can be routinely identified and quantitatively measured in a specified food, agricultural commodity or animal feed with an acceptable degree of certainty by the method of analysis. It is also known as the Limit of Quantification (LOQ).

Lodging:- Term used to describe crops that are flattened by wind and rain.

Maximum Residue Level (MRL):- A legal limit for the maximum amount of residue that will be left on a food when a pesticide is applied according to instructions based on good agricultural practice. The MRL is a maximum legal level based on what would be expected if the pesticide was used correctly, it is not a safety limit. MRLs are intended primarily as a check that good agricultural practice is being followed and to assist international trade in produce treated with pesticides. MRLs are not safety limits and exposure to residues in excess of an MRL does not automatically imply a hazard to health.

In cases where there are no UK or EC MRLs, the acceptability of residues may be judged against Codex Maximum Residue Levels (Codex Alimentarius Commission **(CAC) MRL**). These limits give an indication of the likely residue that should occur in edible crops.

MBC:- Group of fungicides, methylbenzimidazole carbamates, the active component of carbendazim and thiophanate-methyl.

Molluscicide:- A pesticide used to control unwanted slugs and snails.

Nematicide:- A pesticide used to control harmful nematodes.

Pest:- Any organism harmful to plants or to wood or other plant products, any undesired plant and any harmful creature.

Pesticide:- Any substance, preparation or organism prepared or used for controlling any pest. A pesticide product consists of one or more active substances co-formulated with other materials. Formulated pesticides exist in many forms, such as solid granules, powders or liquids. Sometimes called a plant protection product.

Pesticide Usage Survey Group (PUSG):- The group that regularly surveys the UK use of agricultural pesticides. It is based at the Central Science Laboratory.

Pheromone:- A chemical substance secreted by an animal which influences the behaviour of others of its species.

Plant Growth Regulator (PGR):- A substance that has a marked and specific effect on plant growth, without killing the plant.

Plant Protection Product:- An active substance or preparation containing one or more active substances, formulated as it is supplied to the user, intended to:

- protect plants or plant products against all harmful organisms or prevent the action of such organisms;
- influence the life processes of plants other than as a nutrient (e.g. as a growth regulator);
- preserve plant products, in so far as such substances or products are not subject to the provisions of Community law on preservatives;
- destroy unwanted plants;
- destroy parts of plants or check or prevent the undesired growth of plants.

Sometimes used as a synonym for ‘pesticide’, but not in the strict legal sense.

QoI: – Class of fungicides that work by inhibiting mitochondrial respiration by binding at the Qo site of cytochrome b

Sclerotia:- Also known as fungal resting bodies. Pathogenic fungal sclerotia are able to survive long periods in the absence of the host plant.

SOLA (Specific Off-Label Approval):- For many reasons, label recommendations of approved pesticides do not cover the control of every problem which may arise. This is particularly true for crops that are grown on a comparatively small scale in the UK as well as for sporadic pests and diseases. It is for this reason that the extrapolations presented in the Long Term Arrangements for Extension of Use have been developed. If these do not address particular needs growers or their representatives may apply to PSD for a specific off-label approval (SOLA). Such approvals are only granted after consumer, operator, bystander and environmental safety have been assessed and found acceptable.

Sprout suppressant:- A chemical or treatment that inhibits dormancy break and growth of potatoes during the storage period.

Steep:- Barley is soaked or ‘steeped’ in water to stimulate the embryo in the grain to grow to begin the malting process.

Trap cropping:- The planting of a potato crop to encourage the hatching of the potato cyst nematode (PCN) and invasion of the roots. The trap crop is subsequently sacrificed before the PCN matures and in this way populations are reduced.

Volunteer potatoes:- Self-set potatoes from a commercial crop growing as weeds in other crops.

Ware potatoes:- Crops grown for human consumption either before or after processing (excludes seed potatoes grown for planting).

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Useful contacts

ADAS UK Ltd
Woodthorne, Wergs Road, Wolverhampton WV6 8TQ. Tel 01902 754190
www.adas.co.uk

Assured Produce Ltd
48-50 Ashley Road, Hampton, Middlesex TW12 2HU. Tel 0208 979 8966
www.assuredproduce.co.uk

BASIS Registration Ltd.
34 St John Street, Ashbourne, Derbyshire. DE6 1GH. Tel 01335 343945
www.basis-reg.com

Central Science Laboratory
Sand Hutton, York YO41 1LZ. Tel 01904 462000
www.csl.gov.uk

Crop Protection Association
Units 18 & 20 Evans Business Centre, Cully Court, Bakewell Road, Orton Southgate, Peterborough PE2 6XS. Tel 01733 367213
www.cropprotection.org.uk

Department of Environment, Food & Rural Affairs
Nobel House, Smith Square, London SW1P 3JR. Tel 0207 238 6000
www.defra.gov.uk

Food Standards Agency
Aviation House, 125 Kingsway, London WC2B 6NH. Tel 0207 276 8000
www.food.gov.uk

LEAF (Linking Farming And Environment)
The National Agricultural Centre, Stoneleigh Park, Warwickshire CV8 2LZ
www.leafmarque.co.uk

Organic Farmers & Growers
Elim Centre, Lancaster Rd, Shrewsbury, Shropshire SY1 3LE. Tel 0845 3305122
www.efsis.com/htm/en/subp4page5.php

Pesticide Residues Committee
Mallard House, Kings Pool, 3 Peasholme Green, York YO1 7PX. Tel 10904 445775
www.pesticides.gov.uk/prc_home.asp

Pesticides Safety Directorate
Mallard House, Kings Pool, Peasholme Green, York YO1 2PX. Tel 01904 640500
www.pesticides.gov.uk

Soil Association
Bristol House, 40-56 Victoria Street, Bristol BS1 6BY. Tel 0117 3145000
www.soilassociation.org/farmassurance

APPENDIX A. Pesticide residues sought on UK and imported apples in WPPR/PRC surveys 1994-2004 (See footnote below table for key to abbreviations)

Pesticide active substance	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Abamectin	-	-	-	-	-	-	-	Y	Y	-	-
Acephate	Y	Y	Y	Y	Y	-	-	Y	Y	**F**	Y
Aldicarb	-	-	-	-	-	-	-	-	-	-	Y
Azinphos-ethyl	-	-	-	**F**	-	Y	Y	-	-	-	-
Azinphos-methyl	Y	**F**	-	Y	-	**F**	**F**	**F**	**F**	**F**	**F**
Azoxystrobin	-	-	-	-	-	-	-	Y	Y	Y	Y
Bendiocarb	Y	Y	-	Y	-	Y	Y	Y	Y	-	-
Bifenthrin	**F**	Y	-	**F**	-	-	-	-	Y	Y	Y
Biphenyl	**F**	Y	-	Y	-	-	-	-	-	Y	Y
Bitertanol	Y	-	-	-	-	-	-	-	-	-	-
Bromopropylate	**F**	**F**	-	**F**	**F**	-	-	**F**	**F**	**F**	Y
Bupirimate	**F**	**F**	-	**F**	**F**	-	-	**F**	**F**	**F**	Y
Buprofezin	Y	Y	-	Y	-	-	-	-	-	**F**	Y
Butocarboxim	-	-	-	Y	-	-	Y	Y	Y	-	-
Cadusofos	-	-	-	Y	-	Y	Y	Y	Y	-	-
Captan	**F**	**F**	-	**F**	**F**	-	-	**F**	**F**	**F**	**F**
Carbaryl	**F**	**F**	-	**F**	**F**	**F**	**F**	**F**	**F**	**F**	**F**
Carbendazim	**F**	**F**	-	**F**	**F**	-	**F**	**F**	**F**	**F**	**F**
Carbofuran	-	-	-	Y	-	Y	Y	Y	Y	-	Y
Chlorfenvinphos	Y	Y	-	Y	-	Y	Y	Y	Y	Y	Y
Chlormequat	-	-	-	-	Y	-	-	-	-	-	-
Chlorothalonil	Y	Y	-	Y	-	-	-	Y	-	Y	Y
Chlorpropham	-	Y	-	Y	-	-	-	-	-	-	-
Chlorpyrifos	**F**	**F**	**F**	**F**	**F**	**F**	**F**	**F**	**F**	**F**	**F**
Chlorpyrifos-methyl	Y	Y	Y	Y	-	Y	Y	Y	Y	Y	Y
Chlozolinate	Y	Y	-	Y	-	-	-	-	-	Y	Y
Cyfluthrin	Y	Y	-	Y	-	-	-	-	-	Y	Y
Cyhalothrin	Y	Y	-	Y	-	-	-	Y	Y	Y	Y
Cypermethrin	Y	Y	-	Y	-	-	-	-	Y	Y	Y
Cyprodinil	-	-	-	-	-	-	-	Y	Y	-	Y
DDT	Y	Y	-	Y	-	-	-	-	-	Y	Y
Deltamethrin	Y	Y	-	Y	-	-	-	Y	Y	Y	Y
Demeton-s-methyl	-	-	-	-	-	-	-	-	-	-	Y
Diazinon	Y	Y	-	**F**	-	Y	**F**	**F**	Y	Y	Y
Dichlofluanid	Y	Y	-	Y	-	-	-	Y	-	Y	Y
Dichlorvos	Y	Y	-	Y	-	-	-	-	-	Y	Y
Dichloran	Y	Y	-	Y	-	-	-	-	-	Y	Y
Dicofol	**F**	Y	-	Y	**F**	-	-	Y	-	Y	Y
Dicrotophos	-	-	-	Y	-	Y	Y	Y	Y	-	-
Diethofencarb	-	-	-	Y	-	Y	Y	Y	Y	**F**	-
Difenoconazole	-	-	-	-	-	-	-	Y	Y	Y	Y
Diflubenzuron	-	-	-	-	-	-	-	-	Y	-	-
Dimethoate	**F**	**F**	-	**F**	**F**	**F**	**F**	**F**	**F**	**F**	Y
Dinocap	-	-	-	-	-	-	Y	Y	Y	-	-
Dioxabenzophos	-	-	-	-	-	Y	Y	Y	Y	-	-
Diphenylamine	**F**	Y	-	**F**	**F**	-	-	**F**	**F**	**F**	**F**
Dithianon	-	-	-	-	-	-	**F**	Y	**F**	**F**	**F**
Dithiocarbamates	-	**F**	-	**F**	**F**	-	**F**	**F**	**F**	**F**	**F**
Dodine	-	-	-	-	-	-	**F**	**F**	**F**	**F**	**F**
Endosulfan	Y	Y	-	Y	-	-	-	Y	Y	**F**	Y
EPN	-	-	-	Y	-	Y	Y	Y	Y	-	-
Ethiofencarb	-	-	-	Y	Y	-	-	Y	Y	-	-
Ethion	Y	Y	-	Y	Y	Y	Y	Y	Y	Y	Y
Ethofumesate	-	Y	-	Y	-	-	-	-	-	-	-
Ethoprophos	Y	Y	-	Y	-	-	-	Y	Y	Y	Y
Ethoxyquin	**F**	**F**	-	**F**	Y	-	-	-	-	-	-
Ethylenethiourea	Y	-	-	-	-	-	-	-	-	-	-
Etriadiazole	Y	Y	-	Y	-	-	-	-	-	-	-
Etrimfos	Y	Y	-	Y	-	Y	Y	Y	Y	-	-

Pesticide	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Fenarimol	-	-	-	-	-	-	-	Y	Y	Y	Y
Fenazaquin	-	-	-	-	-	-	-	Y	**F**	Y	Y
Fenbuconazole								Y	Y	Y	Y
Fenhexamid											Y
Fenitrothion	Y	Y		Y		Y	**F**	Y	Y	Y	Y
Fenoxycarb					Y				Y	Y	
Fenpropathrin		Y		Y						**F**	Y
Fenpropidin	Y	Y		Y							
Fenpropimorph		Y		Y						Y	Y
Fenpyroximate								Y		Y	Y
Fenvalerate	Y	Y		Y						Y	Y
Flucythrinate				Y							
Flurochloridone	Y	Y		Y							
Flusilazole	Y	Y		Y				Y	Y	Y	Y
Folpet	Y							Y		**F**	**F**
Fonofos	Y	Y		Y		Y	Y	Y	Y	Y	Y
Formetanate					Y						
Formothion				Y		Y	Y	Y	Y		
Fosthiazate										Y	Y
Furalaxyl	Y	Y		Y						Y	Y
Furathiocarb				Y		Y			Y		
HCB	Y										
Gamma HCH	Y	Y		Y							
Heptenophos	Y	Y		Y		Y	Y	Y	Y	Y	Y
Hexachlorobenzene		Y		Y							
Imazalil	Y	Y		Y				Y		**F**	Y
Imidacloprid								Y	Y	Y	Y
Iodofenphos	Y										
Iprodione	Y	Y	Y	**F**	Y			**F**	Y	**F**	**F**
Isazophos				Y		Y	Y	Y	Y		
Isofenphos	Y	Y		Y		Y	Y	Y	Y	Y	Y
Isoprocarb				Y		Y	Y	Y	Y		
Kresoxyim-methyl								Y	Y	Y	Y
Lindane										Y	Y
Malathion	Y	Y		Y	Y	Y	Y	Y	Y	Y	**F**
Mecarbam				Y	Y	Y	Y	Y	Y	Y	Y
Mepanipyrim										Y	Y
Mephosfolan				Y		Y	Y	Y	Y		
Metalaxyl	**F**	**F**		**F**	**F**			**F**	**F**	**F**	**F**
Methamidophos	Y	Y	Y	Y	Y			Y	Y	Y	Y
Methidathion				Y	Y			Y	Y	Y	Y
Methiocarb				Y		Y	Y	Y			
Methomyl				Y		Y	**F**	Y	Y		Y
Metolcarb				Y		Y	Y	Y	Y		
Mevinphos	Y			Y		Y	Y	Y	Y		
Monocrotophos	Y	Y		Y				Y	Y	Y	Y
Myclobutanil	Y	Y		**F**					Y	**F**	**F**
Naled				Y		Y	Y	Y	Y		
Napropamide		Y		Y							
Nicotine		Y		Y							
Nitrophal-isopropyl	Y	Y		Y							
Norflurazon	Y										
Ofurace	Y	Y		Y						Y	Y
Omethoate	Y	**F**		**F**	Y			Y	Y	Y	Y
Oxadixyl	Y	Y		Y						Y	Y
Oxamyl				Y		Y	Y	Y	Y		
Oxydemeton-methyl											Y
Paclobutrazol	Y	Y		**F**				**F**	Y	Y	Y
Parathion	Y	Y		Y		Y	Y	Y	Y	Y	Y
Parathion-methyl	Y	Y		Y	Y	Y	Y	**F**	Y	Y	Y

Pesticide	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Penconazole	Y	Y		Y					Y	**F**	Y
Pendimethalin		Y		Y						Y	Y
Permethrin	Y	Y		Y				Y	Y	Y	Y
Phenthoate	Y	Y		Y		Y	Y	Y	Y	Y	Y
2 Phenylphenol	Y								Y	Y	Y
Phorate											Y
Phosalone	**F**	**F**		**F**	**F**	**F**	**F**	**F**	**F**	**F**	**F**
Phosmet	Y	**F**		**F**		**F**	**F**	**F**	**F**	**F**	**F**
Phosphamidon				Y		Y	Y	Y	Y		Y
Pirimicarb	Y	Y		**F**	**F**	**F**	**F**	**F**	**F**	**F**	**F**
Pirimiphos-ethyl	Y	Y		Y		Y	Y	Y	Y	Y	
Pirimiphos-methyl	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y
Prochloraz	Y										Y
Procymidone	Y	Y	Y	Y				Y		Y	Y
Profenofos	Y	Y		Y		Y	Y	Y	Y	Y	Y
Prometryn		Y		Y							
Propamocarb				Y							
Propanil	Y	Y		Y							
Propargite	Y	**F**		**F**				**F**	**F**	**F**	**F**
Propiconazole	Y	Y		Y						Y	Y
Propoxur	Y	Y		Y		Y	Y	Y	Y	Y	Y
Propyzamide	Y	Y		Y				Y		Y	Y
Prothiofos				Y		Y	Y	Y	Y	**F**	Y
Pyrazophos	Y	Y		Y		Y	Y	Y	Y	Y	Y
Pyridaphenthion	Y	Y		Y		Y	Y	Y	Y	Y	Y
Pyrifenox								Y	Y	Y	Y
Pyrimethanil								Y	**F**	Y	Y
Quinalphos	Y	Y		Y		Y	Y	Y	Y	Y	Y
Quinomethionate	Y	Y		Y							
Quintozene		Y		Y						Y	Y
Simazine		Y		Y						Y	Y
Spiroxamine											Y
Tebuconazole	Y	Y		Y						Y	Y
Tebufenpyrad							**F**	Y	Y	**F**	Y
Tecnazene	Y	Y		**F**						Y	Y
Tefluthrin											Y
2,3,5,6 tetrachloroaniline	Y										
2,3,5,6 tetrachloro thioanisole	Y										
Tetrachlorvinphos	Y	Y		Y		Y	Y	Y	Y	Y	Y
Tetradifon	Y	Y		Y	Y					Y	Y
Thiabendazole	**F**	**F**		**F**				**F**	**F**	**F**	**F**
Thiodicarb				Y							
Thiophanate-methyl	Y	Y		Y	Y			Y			
Tolclofos-methyl	Y	Y		Y		Y	Y	Y	Y	Y	Y
Tolyfluanid	Y	**F**		**F**				Y	Y	**F**	**F**
Triadimefon									Y	Y	Y
Triadimenol											Y
Triazamate									Y	Y	Y
Triazophos	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y
Trifloxystrobin								Y	Y	Y	Y
Trifluralin		Y		Y						Y	Y
Vinclozolin	Y	Y		Y	Y			Y	Y	Y	Y
Total residues sought	98	100	6	126	32	52	58	100	100	109	119

(NB Not all residues are sought on all samples taken in any one year.)

Key to symbols and abbreviations:

- = pesticide not sought

Y = pesticide sought but not found

F = pesticide above the Limit of Detection (LOD) found

APPENDIX B. Pesticide residues found in apples from WPPR/PRC surveys 1994-2004, number of samples with residues (range of residues found mg/kg) – (See page 43 for the key to the abbreviations in these tables.)

UK apples

Pesticide residue	1994	1995	1996 EU prog.	1997	1998	1999	2000	2001	2002	2003	2004
Total samples	54	26	9	19	17	54	36	65	67	82	68
No. samples with no residues detected	9	10	1	2	8	23	0	54	47	24	11
% samples with no residues detected	16.7	38.5	11.1	10.5	47.1	42.6	0	83.1	70.1	29.3	16.2
Bifenthrin (I)	1 (0.04)	Nil	-	Nil	-	-	-	-	Nil	Nil	Nil
Bromopropylate (A) (CAC MRL=2)	Nil	Nil	-	2 (0.1-0.6)	Nil	-	-	Nil	Nil	Nil	Nil
Bupirimate (F)	5 (0.01-0.05)	1 (0.2)	-	1 (0.02)	2 (0.04)	-	-	2 (0.05-0.07)	1 (0.1)	1 (0.05)	Nil
Captan (F) (MRL=3)	12 (0.05-1.9)	4 (0.05-0.9)	-	4 (0.06-0.5)	Nil	-	-	3 (0.06-0.3)	6 (0.06-0.4)	21 (0.05-0.5	23 (0.02-0.2)
Carbaryl (I) (MRL=5)	7 (0.05-0.6)	3 (0.1)	-	1 (0.07)	1 (0.1)	2 (0.02-0.09)	3 (0.02-0.06)	Nil	Nil	Nil	Nil
Carbendazim (F) (MRL=2)	23 (0.2-2.7)	7 (0.5-1.1)	-	11 (0.1-0.9)	5 (0.1-0.9)	-	12 (0.1-0.7)	1 (0.5)	9 (0.09-0.3)	12 (0.05-0.3)	24 (0.06-0.8)
Chlorpyrifos (I) (MRL=0.5)	15 (0.01-0.2)	2 (0.07-0.5)	8 (0.01-0.1)	1 (0.02)	3 (0.1-0.3)	23 (0.01-0.2)	22 (0.01-0.3)	11 (0.01-0.08)	16 (0.01-0.2)	41 (0.02-0.2)	26 (0.04-0.2)
Dicofol (A) (MRL=1)	1 (0.5)	Nil	-	Nil	Nil	-	-	Nil	-	Nil	Nil
Diphenylamine (SP) (MRL=5)	20 (0.05-1.6)	Nil	-	4 (0.04-0.6)	1 (0.1)	-	-	Nil	Nil	5 (0.07-0.4)	20 (0.3-1.7)
Dithianon (F) (CAC MRL=5)	-	-	-	-	-	-	1 (0.08)	Nil	Nil	Nil	6 (0.05-0.3)
Dithiocarbamates (F) (MRL=3)	-	1 (0.1)	-	2 (0.1)	Nil	-	Nil	Nil	Nil	1 (0.4)	2 (0.06-0.1)
Ethoxyquin (F) (PL=3)	1 (0.1)	Nil	-	1 (0.03)	Nil	-	-	-	-	-	-
Fenitrothion (I) (MRL=0.5)	Nil	Nil	-	Nil	-	Nil	1 (0.01)	Nil	Nil	Nil	Nil
Iprodione (F) (MRL=10)	Nil	Nil	Nil	1 (0.5)	Nil	-	-	Nil	Nil	Nil	2 (0.04-0.5)
Metalaxyl (F) (MRL=1)	2 (0.07-0.09)	6 (0.1-0.5)	-	8 (0.03-0.2)	1 (0.2)	-	-	1 (0.2)	4 (0.06-0.1)	4 (0.06-0.2)	2 (0.09-0.2)

UK apples continued

	1994	1995	1996 EU prog.	1997	1998	1999	2000	2001	2002	2003	2004
Mycobutanil (F) (CAC MRL=0.5)	Nil	Nil	-	2 (0.01-0.04)	-	-	-	-	Nil	1 (0.6)	1 (0.09)
Paclobutrazol (PGR) (CAC MRL=0.5)	Nil	Nil	-	1 (0.08)	-	-	-	1 (0.05)	Nil	Nil	2 (0.06-0.07)
Penconazole (F) (MRL=0.2)	Nil	Nil	-	Nil	-	-	-	-	Nil	1 (0.08)	Nil
Phosalone (I) (MRL=2)	3 (0.06-0.2)	Nil	-	Nil	2 (0.3-0.7)	2 (0.02)	Nil	Nil	Nil	Nil	Nil
Pirimicarb (I) (CAC MRL=1)	Nil	Nil	-	1 (0.02)	Nil	6 (0.01-0.03)	9 (0.01-0.06)	2 (0.03-0.04)	Nil	3 (0.02-0.07)	Nil
Propargite (A) (CAC MRL=5)	Nil	Nil	-	1 (0.5)	-	-	-	Nil	Nil	Nil	Nil
Pyrimethanil (F)	-	-	-	-	-	-	-	Nil	1 (0.06)	Nil	Nil
Tecnazene (SS)	Nil	Nil	-	1 (0.1)	-	-	-	-	-	Nil	Nil
Thiabendazole (F) (MRL=5)	Nil	Nil	-	1 (0.5)	-	-	-	Nil	Nil	Nil	Nil
Tolyfluanid (F) (CAC MRL=5)	Nil	Nil	-	1 (0.06)	-	-	-	Nil	Nil	1 (0.2)	2 (0.06)
MRL exceedances	0	0	0	0	0	0	0	0	0	0	0

Imported apples

Pesticide residue	1994	1995	1996 EU prog.	1997	1998	1999	2000	2001	2002	2003	2004
Total samples	48	47	21	51	70	83	105	186	183	219	76
No. samples with no residues detected	9	9	15	5	20	50	33	129	110	64	17
% samples with no residues detected	18.8	19.1	71.4	9.8	28.6	60.2	31.4	69.4	60.1	29.2	22.4
Acephate (I) (MRL=1)	Nil	Nil	Nil	Nil	Nil	-	-	Nil	Nil	1 (0.03)	Nil
Azinphos-methyl (I) (MRL=1)	Nil	1 (0.1)	-	Nil	-	12 (0.05-0.1)	6 (0.05-0.1)	4 (0.05-0.1)	2 (0.05-0.1)	16 (0.05-0.09)	9 (0.05-0.3)
Bifenthrin (I)	4 (0.02-0.04)	Nil	-	2 (0.02-0.03)	-	-	-	-	Nil	Nil	Nil
Biphenyl (F)	1 (0.05)	Nil	-	Nil	-	-	-	-	-	Nil	Nil
Bromopropylate (A) (CAC MRL=2)	2 (0.2-0.6)	1 (0.1)	-	1 (0.1)	2 (0.06-0.08)	-	-	3 (0.1-0.4)	1 (0.1)	7 (0.07-0.5)	Nil
Buprofezin (A)	Nil	Nil	-	Nil	-	-	-	-	-	1 (0.08)	Nil
Captan (F) (MRL=3)	6 (0.1-0.9)	8 (0.05-0.7)	-	8 (0.06-0.2)	5 (0.09-0.1)	-	-	3 (0.07-0.2)	11 (0.07-0.2)	25 (0.06-0.3)	16 * (0.03-3.6)
Carbaryl (I) (MRL=5)	4 (0.2-0.6)	4 (0.1-0.7)	-	3 (0.01-0.7)	3 (0.06-0.3)	4 (0.04-0.3)	6 (0.03-0.3)	2 (0.04-0.1)	3 (0.02-0.4)	4 (0.07-0.7)	12 (0.03-0.7)
Carbendazim (F) (MRL=2)	6 (0.2-0.8)	Nil	-	16 (0.06-1.7)	14 (0.1-0.4)	-	12 (0.1-0.8)	4 (0.1-0.7)	7 (0.05-0.3)	29 (0.06-0.4)	5 (0.05-0.2)
Chlorpyrifos (I) (MRL=0.5)	6 (0.02-0.1)	Nil	6 (0.01-0.05)	4 (0.02-0.1)	3 (0.05-0.1)	14 (0.01-0.1)	28 (0.01-0.1)	6 (0.01-0.02)	12 (0.01-0.2)	21 (0.02-0.2)	5 (0.04-0.1)
Diazinon (I) (MRL=0.5)	Nil	Nil	-	1 (0.03)	-	Nil	2 (0.02-0.03)	1 (0.04)	Nil	Nil	Nil
Dicofol (A) (MRL=1)	1 (0.2)	Nil	-	Nil	1 (0.6)	-	-	Nil	-	Nil	Nil
Diethofencarb (F)	-	-	-	-	-	Nil	Nil	Nil	Nil	1 (0.09)	-
Dimethoate (I) (MRL=0.02)#	2 (0.07-0.1)	1 (0.2)	-	2 (0.02-0.06)	1 (0.07)	4 (0.02-0.09)	5 (0.02-0.04)	1 (0.02)	2 (0.03-0.04)	4 *** (0.02-0.08)	Nil
Diphenylamine (SP) (MRL=5)	24 (0.06-4.2)	14 (0.1-5)	-	27 (0.01-4.8)	25 (0.07-2.1)	-	-	29 (0.05-2.7)	21 (0.06-2.6)	66 (0.05-2.9)	21 (0.08-3.6)
Dithianon (F) (CAC MRL=5)	-	-	-	-	-	-	4 (0.07-0.1)	Nil	2 (0.06-0.2)	2 (0.05-0.1)	2 (0.06-0.1)
Dithiocarbamates (F) (MRL=3)	-	5 (0.1-0.3)	-	12 (0.1-0.3)	16 (0.1-0.5)	-	13 (0.1-0.6)	12 (0.05-0.3)	4 (0.1-0.4)	5 (0.1-0.3)	7 (0.08-0.7)

Imported apples continued

Pesticide residue	1994	1995	1996 EU prog.	1997	1998	1999	2000	2001	2002	2003	2004
Dodine (F) (CAC MRL=5)	-	-	-	-	-	-	20 (0.05-0.3)	7 (0.05-0.3)	10 (0.07-0.20)	7 (0.07-0.3)	4 (0.2-0.5)
Endosulfan (A) (MRL=0.3)	Nil	Nil	-	Nil	-	-	-	Nil	Nil	1 (0.05)	Nil
Ethoxyquin (F) (PL=3)	2 (0.06-0.1)	3 (0.07-0.3)	-	2 (0.02-0.06)	Nil	-	-	-	-	-	-
Fenazaquin (A)	-	-	-	-	-	-	-	Nil	1 (0.07)	Nil	Nil
Fenpropathrin (I) (CAC MRL=5)	-	Nil	-	Nil	-	-	-	-	-	3 (0.09-0.1)	Nil
Folpet (F)	Nil	-	-	-	-	-	-	Nil	-	6 (0.06-0.2)	2 (0.07-0.1)
Imazalil (F) (MRL=5)	Nil	Nil	-	Nil	-	-	-	Nil	-	3 (0.2-0.5)	Nil
Iprodione (F) (MRL=10)	Nil	Nil	Nil	2 (0.9-3.8)	Nil	-	-	2 (0.9-2.6)	Nil	5 (0.05-0.9)	Nil
Malathion (I) (MRL=0.5)	Nil	Nil	-	Nil	Nil	Nil	Nil	Nil	Nil	Nil	1 (0.03)
Metalaxyl (F) (MRL=1)	Nil	Nil	-	1 (0.2)	Nil	-	-	Nil	Nil	Nil	Nil
Methomyl (I/A)	-	-	-	Nil	-	-	1 (0.07)	-	-	-	Nil
Mycobutanil (F) (CAC MRL=0.5)	Nil	Nil	-	1 (0.01)	-	-	-	-	Nil	Nil	Nil
Omethoate (I) (MRL=0.2)	Nil	1 (0.05)	-	Nil	Nil	-	-	Nil	Nil	Nil	Nil
Parathion-methyl (I)	Nil	Nil	-	Nil	Nil	Nil	Nil	1 (0.05)	Nil	Nil	Nil
Phosalone (I) (MRL=2)	12 (0.05-0.6	8 (0.1-0.3)	-	6 (0.08-0.4)	Nil	8 (0.07-0.5)	14 (0.02-0.2)	4 (0.06-0.3)	4 (0.06-0.2)	13 (0.05-0.5)	4 (0.03-0.3)
Phosmet (I) (CAC MRL=10)	Nil	2 (0.06-0.7)	-	Nil	-	2 (0.07-0.1)	1 (0.2)	2 (0.08-0.1)	3 (0.05-0.2)	12 (0.02-0.3)	3 (0.03-0.08)
Pirimicarb (I) (CAC MRL=1)	Nil	Nil	-	2 (0.01-0.05)	1 (0.1)	1 (0.05)	5 (0.03-0.2)	Nil	1 (0.04)	3 (0.02-0.03)	3 (0.04-0.07)
Propargite (A) (CAC MRL=5)	13 (0.1-2.1)	9 (0.1-1.1)	-	6 (0.05-0.8)	-	-	-	7 (0.08-0.6)	12 (0.08-0.6)	31 (0.06-1.4)	5 (0.2-0.9)
Prothiofos (I)	-	-	-	-	-	Nil	Nil	Nil	Nil	1 (0.2)	Nil

Imported apples continued

Pesticide residue	1994	1995	1996 EU prog.	1997	1998	1999	2000	2001	2002	2003	2004
Tebufenpyrad (I)	-	-	-	-	-	-	1 (0.06)	Nil	Nil	1 (0.06)	Nil
Thiabendazole (F) (MRL=5)	4 (0.4-0.5)	11 (0.2-1.4)	-	11 (0.2-1.5)	-	-	-	9 (0.2-0.7)	16 (0.07-1)	34 (0.07-2.8)	16 (0.09-4.4)
Tolyfluanid (F) (CAC MRL=5)	Nil	1 (0.2)	-	Nil	-	-	-	Nil	Nil	2 (0.05-0.07)	1 (0.3)
MRL exceedances	0	0	0	0	0	0	0	0	0	3	1

Key to symbols and abbreviations:

MRLs shown are the most recent values presented in the latest PRC survey report for apples. Where an MRL exceedance is recorded it relates to the MRL which was current at the time the survey was conducted.
- = pesticide not sought
nil = residue not found
* = one MRL exceedance found
** = two MRL exceedances found
***= three MRL exceedances found
= prior to 2003, there was an MRL for dimethoate of 1 mg/kg. There were no MRL exceedances at this level.

Pesticide types:
A = acaricide; F = fungicide; I = insecticide; PGR = plant growth regulator; SP = scald prevention; SS = sprout suppressant (e.g. tecnazene used on stored potato crops and occasionally occurring as a contaminant on apples)

EU Prog.. = in 1996, the WPPR survey was part of the EU Co-ordinated residue monitoring programme.

APPENDIX C BBCH Phenological Growth Stages for Apples and Pears

(Meier *et al*.,1994)

Code	Description
Principal growth stage 0: Sprouting /Bud development	
00	Dormancy: leaf buds and the thicker inflorescence buds closed and covered by dark brown scales
01	Beginning of leaf bud swelling: buds visibly swollen, bud scales elongated, with light coloured patches
03	End of leaf bud swelling: bud scales light coloured with some parts densely covered by hairs
07	Beginning of bud break: first green leaf tips just visible
09	Green leaf tips about 5 mm above bud scales
Principal growth stage 1: Leaf development	
10	Mouse-ear stage: Green leaf tips 10 mm above the bud scales; first leaves separating
11	First leaves unfolded (others still unfolding)
15	More leaves unfolded, not yet at full size
19	First leaves fully expanded
Principal growth stage 3: Shoot development (from terminal bud)	
31	Beginning of shoot growth: axes of developing shoots visible
32	Shoots about 20% of final length
33	Shoots about 30% of final length
3.	Stages continuous till
39	Shoots about 90% of final length
Principal growth stage 5: inflorescence emergence	
51	Inflorescence buds swelling: bud scales elongated, with light coloured patches
52	End of bud swelling: light coloured bud scales visible with parts densely covered by hairs
53	Bud burst: green leaf tips enclosing flowers visible
54	Mouse-ear stage: green leaf tips 10 mm above bud scales; first leaves separating
55	Flower buds visible (still closed)
56	Green bud stage: single flowers separating (still closed)
57	Pink bud stage: flower petals elongating; sepals slightly open; petals just visible
59	Most flowers with petals forming a hollow ball

Growth Stages and Identification Keys for Apples & Pears (continued)

Code	Description
Principal growth stage 6: Flowering	
60	First flowers open
61	Beginning of flowering: about 10% of flowers open
62	About 20% of flowers open
63	About 30% of flowers open
64	About 40% of flowers open
65	Full flowering: at least 50% of flowers open, first petals failing
67	Flowers fading: majority of petals fallen
69	End of flowering: all petals fallen
Principal growth stage 7: Development of fruit	
71	Fruit size up to 10 mm; fruit fall after flowering
72	Fruit size up to 20 mm
73	Second fruit fall
74	Fruit diameter up to 40 mm; fruit erect (T-stage: underside of fruit and stalk forming a T)
75	Fruit about half final size
76	Fruit about 60% final size
77	Fruit about 70% final size
78	Fruit about 80% final size
79	Fruit about 90% final size
Principal growth stage 8: Maturity of fruit and seed	
81	Beginning of ripening: first appearance of cultivar-specific colour
85	Advanced ripening: increase in intensity of cultivar-specific colour
87	Fruit ripe for picking
89	Fruit ripe for consumption: fruit have typical taste and **firmness**
Principal growth stage 9: Senescence, beginning of dormancy	
91	Shoot growth completed; terminal bud developed; foliage still fully green
92	Leaves begin to discolour
93	Beginning of leaf fall
95	50% of leaves discoloured
97	All leaves fallen
99	Harvested Product

APPENDIX D. Pest and Disease Action Calendar for Apples

Growth stage	Check list of Integrated Pest and Disease Management tasks
Dormant period	
	Assess overwintering populations of rust mite behind growing shoot buds, fruit tree red spider mite winter eggs round spurs, aphid and sucker eggs on shoots and scale insects on bark. Earmark orchards with damaging populations of any of these pests for treatment at the appropriate time.
	Remove badly cankered branches, wood scab and mildew infected (silvered) shoots, root stock sucker growths (which may harbour capsid eggs) during winter pruning.
	Check whether any leaf litter is left in the orchard by the end of February as this may harbour perithecia of scab and act as a source of infection. Macerate thoroughly well before bud burst to aid biodegradation.
	Service and calibrate weather station. Start temperature records from 1 January.
	Stock check pesticide store.
Bud-swell	
	Start weather station records of leaf wetness, humidity and rainfall. Run disease forecasting (e.g. ADEM) and pest life cycle (e.g. PESTMAN) computer models at least weekly and before spray rounds are applied.
	Start programme of fungicide sprays for scab control promptly. Choice of fungicide and spray interval will depend on varietal susceptibility, scab levels the previous season including late season infection of leaves and the amount of leaf litter present.
Bud-burst	
	Monitor populations of apple blossom weevil adults at edges of orchards using beating method if pest was present previous season. Apply a spray of chlorpyrifos (e.g.Equity) in good conditions if threshold exceeded
	Continue sprays for scab to maintain good protection at this sensitive stage
Mouse ear	
	Monitor numbers of rust mites on outer rosette leaves. If threshold (5 mites per outer leaf) is exceeded, apply acaricide, or include sulphur at reduced (25-33%) rate in next 3-4 spray rounds
	Continue sprays for scab to maintain good protection at this sensitive stage
Green cluster	
	Conduct pre-blossom pest assessment for aphids, winter and tortrix moth caterpillars, apple sucker, capsids, rust mite and other minor pests. Apply pre-blossom insecticide spray if necessary.
	Start mildew spray programme. Choice of product, dose, volume and interval will depend on varietal susceptibility and mildew levels last year
	Continue sprays for scab to maintain good protection at this sensitive stage
Pink bud	
	Check truss leaves for scab until early June. Early detection of a potential problem is essential.
	Assess primary mildewed flower trusses. > 2% indicates a problem, > 10% a severe problem. Use eradicant mildew fungicide.
	Apply pre-blossom spray of fenoxycarb (Insegar) for summer fruit tortrix moth if required. Fenoxycarb has a high risk to bees and should not be used once blossoms are open as bees are likely to be foraging
	Put out white sticky traps for sawfly adults.
First flower	
	Continue spray programme for scab and mildew as necessary
	Apply first spray for blossom wilt if threshold exceeded. Repeat 7 days later.
Full bloom	
	Continue spray programme for scab and mildew as necessary, but try to avoid spraying fungicides at this critical time if possible
Late blossom	
	Continue spray programme for scab and mildew as necessary

	Conduct late blossom pest assessment for rosy apple aphid, sawfly, winter moth, clouded drab moth, fruit tree red spider mite, rust mite and capsid, and capped blossoms due to apple blossom weevil.
End of blossom	
	Continue spray programme for scab and mildew as necessary.
	Assess primary mildewed vegetative terminal buds. > 2% indicates a problem, > 10% a severe problem. Use good eradicant mildew fungicide, decrease spray interval and increase spray volume if a problem.
	Check for signs of wilting, dying blossoms due to blossom wilt. Cut out affected trusses now while they can be seen and before cankers form
	Check for early signs of collar rot in older orchards on susceptible rootstocks. Early detection means the tree can be saved.
	Apply post blossom insecticide spray if required for capsid, sawfly, winter moth, clouded drab moth, rosy apple aphid or other pests.
	Apply acaricide spray for rust mite or fruit tree red spider mite if necessary
	If required, apply second spray of fenoxycarb (Insegar) for summer fruit tortrix moth as soon as risk to bees has ceased.
	In orchards where leaf midge has been a severe problem and where establishment of the parasitic wasp *Platygaster demades* is to be encouraged, start monitoring numbers of leaf midge eggs in growing points twice weekly in a representative orchard until harvest. Avoid spraying broad-spectrum insecticides when midge eggs are numerous to avoid harming the adult parasite, which is active when leaf midge eggs are numerous.
	Set out pheromone traps for codling, fruit tree tortrix moth and summer fruit tortrix moth. Record the catch of moths of each species at least weekly.
Early June	
	Check orchard thoroughly for signs of scab on leaves or fruitlets and for wood scab. Continue sprays as necessary if scab is present, or it the weather is very wet or if scab problems occurred last year
	Monitor secondary mildew in shoots regularly, at least fortnightly, ideally before each spray round. Continue mildew sprays until the extension growth has ceased. Adjust rate and interval according to the levels of mildew present, the favourability of the weather for mildew and the rate of growth of the trees.
	In orchards where canker is a problem, apply a spray, e.g. dithianon, to protect leaf scars from canker during summer leaf fall.
	Conduct early June pest assessment for rosy apple aphid, woolly aphid, rosy leaf curling aphid (look out next year), sawfly damage (earmark for treatment next year), clouded drab moth, fruit tree red spider mite, rust mite.
	Continue frequent monitoring of leaf midge eggs where required. Avoid using broad-spectrum insecticide sprays when eggs are numerous to avoid harming *Platygaster demades*.
	If Blastobasis was present last year or infestation is suspected, conduct beat samples for adults at fortnightly intervals throughout June or July. Insecticidal treatment should be considered if the pest is detected.
	Calculate daily egg development amounts for summer fruit tortrix using maximum and minimum air temperatures and look up table provided. Apply egg hatch spray of suitable insecticide when sum reaches 90-100%. Repeat sprays to maintain protection through egg hatch period. This action should not be necessary if fenoxycarb (Insegar) was used just before and, if necessary, just after blossom.
	Continue weekly monitoring of pheromone traps for codling and tortrix moths. If diflubenzuron (Dimilin) is to be used for control of codling or fruit tree tortrix moth, then a spray should be applied as soon as the threshold pheromone trap catch is exceeded. If chlorpyrifos (Equity etc) is to be used, which is advisable if Blastobasis is a problem the first spray should be delayed until the start of egg hatch.
Late June	
	Continue monitoring secondary mildew in shoots regularly, at least fortnightly, ideally before each spray round. Continue mildew sprays until the extension

	growth has ceased. Adjust rate and interval according to the levels of mildew present, the favourability of the weather for mildew and the rate of growth of the trees.
	Continue sprays for scab only if necessary
	Look for signs of die back on extension growth caused by canker. Cut out and burn.
	Conduct late June pest assessment for woolly aphid, green apple aphid, fruitlet mining tortrix, fruit tree red spider mite, rust mite. Apply control treatments as necessary.
	Continue weekly monitoring of pheromone traps for codling and tortrix moths. If diflubenzuron (Dimilin) is to be used for control of codling or fruit tree tortrix moth, then a spray should be applied as soon as the threshold pheromone trap catch is exceeded. If chlorpyrifos Equity etc) is to be used, which is advisable if Blastobasis is a problem, the first spray should be delayed until the start of egg hatch.
	Continue frequent monitoring of leaf midge eggs where required. Avoid using broad-spectrum insecticide sprays when eggs are numerous to avoid harming.
	Continue regular beat sampling for Blastobasis if necessary. Apply chlorpyrifos (Equity etc) sprays if pest is detected.
July-August	
	Continue monitoring secondary mildew in shoots regularly, at least fortnightly, ideally before each spray round. Continue mildew sprays until the extension growth has ceased. Adjust rate and interval according to the levels of mildew present, the favourability of the weather for mildew and the rate of growth of the trees.
	Continue sprays for scab only if necessary
	Conduct late July-mid August pest assessment for woolly aphid, green apple aphid, fruit tree red spider mite, rust mite. Apply control treatments as necessary.
	Continue frequent monitoring of leaf midge eggs where required. Avoid using broad-spectrum insecticide sprays when eggs are numerous to avoid harming *Platygaster demades*.
	Continue regular beat sampling for Blastobasis adults throughout July if necessary. Apply chlorpyrifos (Equity etc) sprays if pest is detected.
Pre-harvest	
	Conduct rot risk assessment in each orchard. Determine best way of minimising losses due to rots with minimal use of post harvest fungicide treatments.
Harvest	
	Train pickers to be vigilant for pest and disease blemishes to fruit and record the causes of significant losses in each orchard. Be vigilant for sawfly and Blastobasis damage.
Post harvest	
	In orchards with scab, apply a spray of 5% urea post picking and before appreciable leaf fall. This will help aid microbial breakdown of the leaves bearing scab perithecia.
Leaf fall	
	To protect leaf scars from canker infection, apply a copper spray the start of leaf fall and again at 50% leaf fall.
Grading	
	Train grading staff to be vigilant for pest and disease blemishes to fruit and record the causes and extent (% incidence) of losses due to each cause in each orchard.
Dormant period	
	Go to top of table and start again. Practice makes perfect!

APPENDIX E. Rot risk assessment for apples

Research has shown that orchards vary considerably in the actual losses from rotting of fruit in store and in the main causes of these rots. Rot risk assessment has been developed by East Malling Research (with funding from Defra) to identify those orchards with fruit most likely to have significant rotting in store. Appropriate measures can then be taken to minimise these losses and to avoid unnecessary treatments to orchards where rot risk is minimal.

The risk assessment is based on the various factors experienced pre-harvest known to be related to incidence of rotting. It enables a decision to be made on the likely level of rotting and hence need for any treatment or other remedial action. It has been developed for Cox, as losses in store for other varieties are usually minimal, except for Bramley and Gala fruit from orchards with high incidence of Nectria canker.

Factors assessed pre-harvest are:

- Daily rainfall
- Fungal inoculum (brown rot and canker)
- Crop load
- Percentage bare ground
- Percentage of crop less than 0.5 metre from ground
- Orchard rot history
- Fruit storage potential (from mineral analysis of fruit and fruit firmness measurement)

Rainfall is the most significant factor influencing rots and can vary considerably from place to place with summer rainfall being particularly localised.

Rainfall and post-harvest rot risk

Fungal rot	**Rainfall criteria**
Botrytis	Rainfall from June to harvest. Scored as below average, average or above average
Nectria	Rain from blossom to harvest. Scored as below average, average or above average
Gloeosporium	Rain in the 4 weeks before harvest. Scored as below average, average or above average
Phytophthora	Rainfall in 15 days before harvest, low or no rain presents low risk, rainfall greater than 20mm presents high risk.

Orchard factors are scored as near to harvest as possible and each orchard must be assessed separately. The risk is assessed and then judged in the light or the criteria AND the level of rainfall over the risk period.

Orchard factors and post-harvest rot risk

Fungal rot	Orchard factor	Assessment	Risk criteria
Botrytis	Incidence of brown rot in orchard	20 trees at random record % of brown rot on tree and on fruit fallen to ground	High risk if > 1%
Nectria	Incidence of canker	20 trees at random assess incidence of canker on trees or shoots	Trees: >25% = high risk 5 to 25% = moderate risk <5% = low risk 0 = no risk Shoots: >0.5% shoots per tree cankered = high risk
Gloeosporium	Crop load	20 trees at random assess crop load as light, medium or heavy	Light crop = risk
Phytophthora	(i) % bare ground	Inspect orchard estimate % bare ground under trees taking account of any weed cover.	a) 100% bare ground (overall herbicide) = high risk a) Herbicide strip 20% or more bare ground = risk b) Overall grass, mulch or weed cover (i.e. 0% bare ground) = low risk
	(ii) % crop <0.5m from ground	20 trees at random and assess % crop 0.5m from ground	15 % of crop or greater = risk

Orchard history

Grower are encouraged to keep records of rotting for each orchard under their control using the information obtained during grading of fruit. Rots are taken out during grading. It is recommended that growers record the weight of rots and express this as a percentage of the total fruit graded from the orchard. Then arrange for at least 100 rot fruit, selected at random, to be inspected for each orchard and the cause of rotting recorded. This enables a simple database of information on the history of rotting to be built up and used in future decision making.

Fruit storage potential

The mineral composition of fruit is closely correlated to the level of rot found after medium or long-term storage. Increased levels of nitrogen and potassium are associated with higher levels of rots. Levels of calcium and phosphorus above established thresholds ensure a high probability of freedom from rot and physiological disorders.

Using this information, decision trees have been developed for Brown rot, *Gloeosporium*, *Nectria* and *Phytophthora* fruit rot risks.

Rainfall data and orchard history are used to assess the need for pre-harvest fungicide applications targeted at post-harvest diseases.

Fungicides for pre-harvest orchard control of post-harvest rots

Active substance	Product names	Fungicide group	Storage rots controlled
Captan	Alpha Captan 80WDG Alpha Captan 83 WP PP Captan 80WG	Phthalimide	*Nectria* *Gloeosporium* *Phytophthora*
Carbendazim	Various products including; Derosol WDG Occidor	Benzimidazole	*Nectria* *Gloeosporium* (sensitive isolates only) Brown rot
Metalaxyl-M + mancozeb	Fubol Gold (SOLA) ***	Phenylamide+ dithiocarbamate	*Phytophthora*
Thiram	Unicrop Thianosan	Dithiocarbamate	*Gloeosporium* *Botrytis*
Tolyfluanid	Elvaron Multi	Sulfamide	*Nectria* *Gloeosporium* *Phytophthora*

*** Approved for application to orchard floor SOLA 1610/2001

If rot risk assessment reveals a high risk to fruit of rotting, the only post-harvest treatment open to growers is the use of carbendazim dip or drench before storage (SOLA for Cleancrop Curve 1610/2004). This is being discouraged by marketing organisations in view of decreasing effectiveness and spectrum of control limited to *Nectria, Gloeosporium* (sensitive isolates only) and Brown rot. There are some indications that use of fungicide as dip or drench has the unwanted side effect of facilitating disease spread within consignments of fruit under some circumstances. A SOLA for metalaxyl-M (SL567A, 1514/05) exists for its use as a drench to control *Phytophthora* fruit rot.

Assured Produce has also produced a protocol for risk assessment, which can be used.

APPENDIX F. Selected recent and ongoing research projects

Further information on Defra funded projects can be found on the Defra website. It should be noted that results of HDC funded projects are available to levy payers.

Recent Research

Integrated control of new storage rot problems in apple and pears (HH2118STF) Defra.

Three year project (1998-2001) looked at rots which have become seen more frequently over recent seasons and identified the changes which had given rise to them. The key factor in the increase in levels had been the management practice of pulverising pruning in situ rather than removing them from the orchard. This had allowed these organisms to build up on rotting plant tissue.

Improving pesticide spraying techniques for tree crops. (PA1721) Defra.

One year project (2000-2001) reviewed the methods of expressing pesticide dose and discussed. This also provided the preparatory work to enable PA1732 (see below) to develop PACE.

Towards zero pesticides on apples (HH2502STF) Defra.

Three year project (2001 to 2004) which developed an integrated crop management programme that restricted the use of conventional pesticides to pre-petal fall and post harvest where possible.

Pesticide application rate adjustment to the crop environment (PACE) for fruit spraying with an axial fan sprayer. (PA1732) Defra.

This three year project ((2001 to 2004) developed an approach to assessing tree size and matching spray volume to the tree size. This methodology could when developed further help to optimise pesticide application and apply the minimum of pesticide required to achieve control of pests.

The potential for manipulating the orchard microflora to control storage rot fungi (HH2603STF) Defra.

A four year project (2001 to 2005) to understand more the orchard microflora and the scope for encouraging natural microbial antagonists and thereby reduce incidence of storage rot fungi.

A new strategy to control tortricid pests in the orchard using baculovirus and pheromones (HH3108TTF) Defra.

This three project (2002 to 2005) evaluated the use of granulovirus to control codling and summer fruit tortrix moths and the efficacy of different methods of deploying the granulovirus.

A new strategy to control tortricid pests in the orchard using baculovirus and pheromones (continuation of HH3108TTF) (HH3127STF) Defra.

A four month extension of the above project to allow further processing and analysis of data and confirm efficacy of virus formulation.

Biocontrol approaches to aphid control: chemical ecology and natural enemies (HH3103TTF) Defra

Exploring the practicability of exploiting aphid responses – and those of their natural enemies – to aphid sex pheromones and plant volatiles as a means of improving biocontrol was studied over three years (2003 to 2006).

TF108 Review of biological control of apple and pear pests in the UK. HDC.

This review, concluded in 1997 provided a basis for targeted research and development as well as areas for immediate use.

TF111 Development of a meteorological network to aid the use of HRI prediction models (ADEM and Pestman) HDC.

A three year study, ended in 1998, to assess the practicalities of using the pest and disease prediction system developed in the UK. The project followed basic research funded by MAFF and initial developments of ADEM (HDC TF68), updating Pestman (HDC TF16 and 16a) and developing their practical use as part of a network (HDC TF98). It used a number of commercial sites in the main fruit growing areas of the UK.

TF 110 Phenology of apple sawfly activity. HDC.

A two year project which was concluded in 1999 provided greater understanding of the biology of this pest of apples.

TF119 Apple: susceptibility of traditional varieties to pests and diseases.

Concluded in 2004 this study provided base information on the susceptibility of older varieties of apple to the major pests and diseases of apple. It is one of the few objective assessments of susceptibility.

Varieties and Integrated pest and disease management for organic apple production LINK (HL0150LOF) Defra.
TF121 Varieties and integrated pest and disease management for organic apple production (LINK) HDC.

A Defra 5 year (2000 to 2005) LINK project with support from HDC and number of industry partners. In addition to assessing varieties, especially newer varieties bred for pest and disease resistance, the project evaluated organically acceptable potential control options for the principal pests and diseases of apples, scab, mildew and rosy apple aphid.

Ongoing Research

Semiochemicals in the management of apple leaf midge (HH3114TTF) Defra.
TF 155 Semiochemicals in the management of apple leaf midge. HDC Project.

A three year study (2003 to 2006) supported by Defra, HDC and the East Malling Trust, seeks to identify and develop the use of the sex pheromone produced by the female apple leaf midge.

TF 156 Apple: Evaluation of surfactants for the eradication of primary mildew. HDC Project.

Three year project (2003 to 2006) evaluating dormant season application to eradicate over wintering mildew infection. This approach has previously proved successful. Could enable

TF 161 Apple: Investigation of the survival and viability of cankers of *Nectria gallinena* following removal from the tree and pulverisation on the orchard floor. HDC Project.

A short project (2005-2006) seeking to reveal more the epidemiology of the disease on pruned material to guide recommendations on orchard management and hygiene.

Integrated crop protection, apple (Residue free) (EG) (HH3122STF) Defra
TF 164 Producing apples free from residues. HDC

Development of previous work three years (2004-2007) to further evaluate the approach and assess its practicality and economic suitability for use in UK commercial orchards.

Further development of pesticide dose adjustment to crop environment (PACE) for fruit spraying with broadcast sprays. (PS2002) Defra

This three year project (2004 to 2007) develops the work carried out within project PA1732 into commercial apple orchards extending the information base looking at a wider range of tree forms and situations.

Understanding gene expression changes in rosy apple aphid on different hosts as a means to seek new control strategies (HH3125STF). Defra.

A three year project (2005 to 2008) seeking to understand more fully the genetic basis of insect physiology in order to identify novel control strategies that might be developed.

Epidemiology of apple diseases. (HH3232STF) Defra.

In order to develop further reduce fungicide programmes there is a need to fill significant gaps in knowledge of the biology, epidemiology and management of key apple diseases: apple scab, Nectria and Botrytis rots. This 4.5 year project is addressing some of these issues.