FOOD STANDARDS AGENCY

PESTICIDE RESIDUE MINIMISATION

CROP GUIDE

POTATOES

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Contents

Crop Guide – Potatoes

Liability Disclaimer

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 potatoes 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. Potatoes 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 - Potatoes

1. Introduction

1.1 Crop description

The potato is a member of the family *Solanaceae* and is closely related to the tomato and the nightshades. *Solanum tuberosum* is the species cultivated in Europe, and is a tuber-bearing, herbaceous plant. The so-called root system of the plant is in fact an extension of the stem. The below ground portion of the stem gives rise to stolons which carry adventitious roots and terminate with the tuber. The tuber is therefore a highly adapted part of the stem organised for food storage and vegetative reproduction. When exposed to light, they become green.

The area of potatoes grown in the UK, together with the number of producers, has declined over the last 10 years, whereas yields have increased, due largely to the adoption of irrigation, improvements in soil management, and more effective machinery for seedbed preparation. Potato production is now in the hands of fewer but more specialised growers who are having to meet ever increasing demands for high quality potatoes, especially for blemish-free, pre-pack potatoes for retail. At the same time, as with other farm enterprises, there is increasing pressure for potatoes to be grown using integrated crop management principles (ICM), and this has led to the introduction and adoption of crop protocols and quality assurance schemes.

The potato crop is largely planted in the period February to May, with the bulk of it in March and April, weather permitting. The UK potato harvest typically begins in Cornwall, Essex and south-west Wales in May and spreads to the rest of the UK thereafter. Approximately half the crop is sold 'off-the-field' as fresh produce for immediate use, whilst the rest is stored for periods ranging from a few weeks to 10 or even 11 months. If not sold 'off-the-field', crop destined for pre-pack sales, especially through the major supermarkets, tends to be cold-stored using refrigerated stores at temperatures typically within the range 2.5-3.5^{0}C. These temperatures minimise development of most skin blemish diseases as well as sprouting. Crops destined for chipping or crisping are stored at temperatures typically within the range 8-11^{0}C. These higher temperatures minimise the build-up of reducing sugars (glucose and fructose), which cause potatoes to produce excessively dark-coloured chips or crisps after frying. Crops stored at these temperatures for periods longer than a few weeks normally require chemical sprout suppression.

1.2 Uses and markets

The range of crop uses has expanded enormously in recent years. Apart from potatoes sold at retail in polythene bags (commonly called pre-pack) in supermarkets, the range includes punnets (sold as small blemish-free potatoes) and loose (where the consumer picks individual potatoes from a tray). Potatoes may be sold for specialised uses such as baking, chipping, boiling etc. Processed potato products include crisps, frozen chips and an enormous range of foods/snacks containing potato flake. In the catering trade, apart from crisps and frozen chips, there is a very large market for fresh potatoes serving fish and chip and similar outlets. Restaurants may be supplied with pre-pack potatoes, or potatoes which have been peeled, bagged and chilled. There is also a growing market for ready meals, which contain potatoes.

Information provided by the British Potato Council (BPC) (Fig. 1) shows the percentages of planted areas grown against committed contracts, as opposed to crop traded without contracts. However, even the non-contract sales nearly all go to merchants, packers, and processors i.e. wholesalers. The quantity sold directly to consumers in farm shops and local markets would probably be less than 1-2%, and there is no way of estimating the trade through these outlets (pers. comm. D Alder, BPC Statistician).

Each outlet demands specific quality criteria which must be satisfied, including some or all of the following: variety, size, appearance, dry matter, fry colour, absence of sprouting, diseases, pest damage, disorders.

Data provided by the BPC suggest there is a trend for increasing consumption of processed products rather than fresh potatoes. The various uses/consumption pattern of home produced and imported potatoes for the period June 2001 to May 2002 is shown in Figure 2. (Figures 1 & 2 are reproduced by permission of the BPC.)

Fig. 1. Planted areas 2004 by market sector

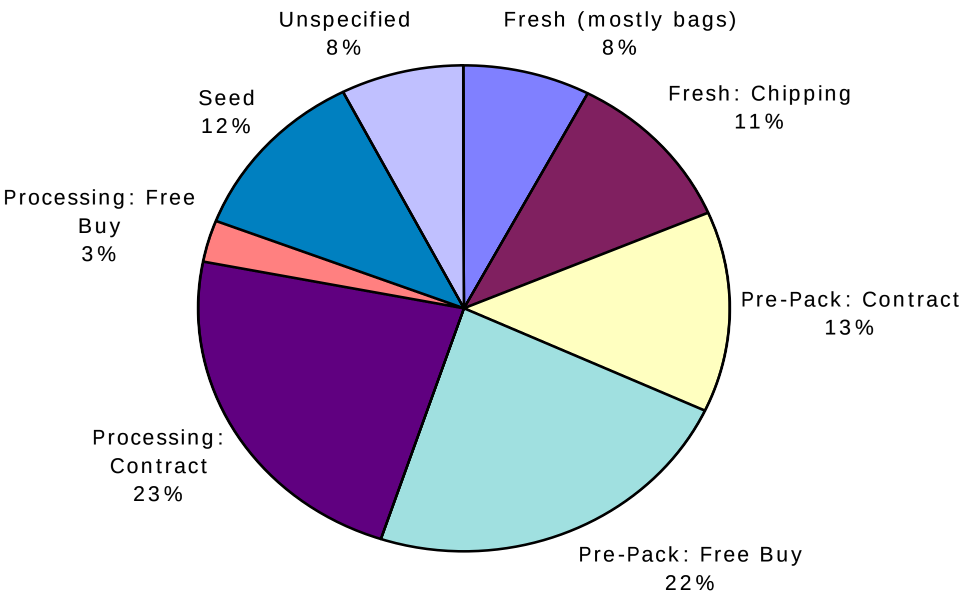
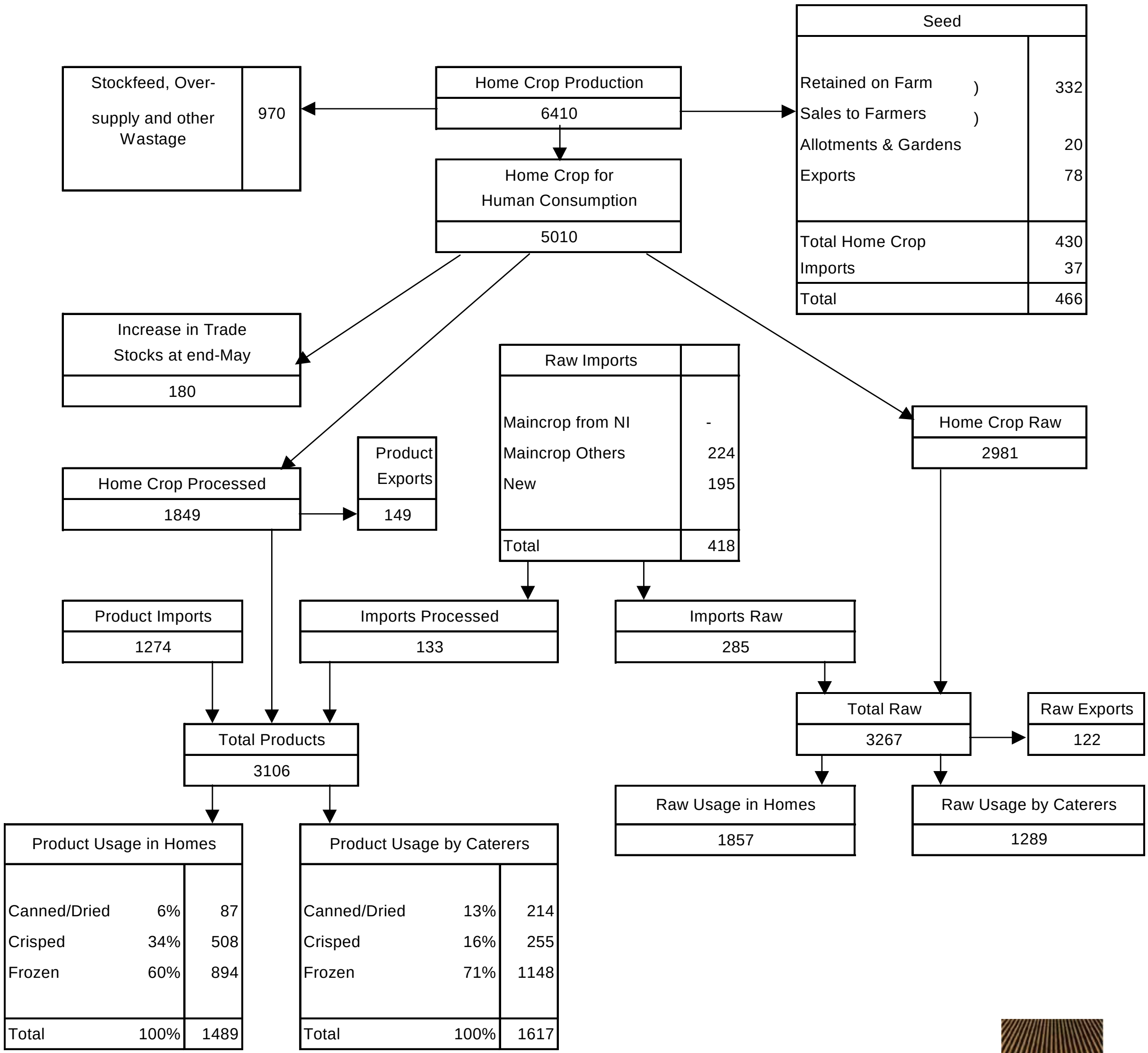


Fig. 2.

Flow Chart for Potatoes in Great Britain: June 2001 - May 2002



Figures other than percentages are in '000 tonnes raw potatoes.
Processed potato products are quoted as raw potato equivalents.
Since the individual estimates within the above data are subject to errors varying in degree, those given for a particular season should be treated with reserve.
Comparisons made over a number of seasons will indicate trends in the patterns of usage.

Sources: PPA, BPC, DEFRA

1.3 Area grown in the UK, volume produced and value

Statistics on potato production trends in Great Britain are collated by the British Potato Council (BPC) and are shown in Table 1. These and other production related statistics are available on the BPC website (www.potato.org.uk).

Table 1. Registered planting areas (ha) of first early, second early and maincrop potatoes in Great Britain, 1999-2003 (Source: BPC)

		Year				
		1999	**2000**	**2001**	**2002**	**2003**
England & Wales	First early	8,757	6,942	6,478	5,382	4,167
	Second early	33,347	32,230	34,327	30,906	25,266
	Maincrop	76,990	70,175	66,034	66,220	61,178
Total		**119,094**	**109,346**	**106,839**	**102,508**	**90,611**
Scotland	First early	1,374	1,287	1,239	1,109	829
	Second early	8,030	7,697	8,995	9,005	8,112
	Maincrop	18,584	17,324	16,099	17,142	16,008
Total		**27,988**	**26,308**	**26,333**	**27,255**	**24,950**
GB	First early	10,271	8,291	7,774	6,538	5,016
	Second early	41,523	40,036	43,400	39,962	33,413
	Maincrop	95,747	87,511	82,075	83,392	77,255
Total		**147,541**	**135,838**	**133,249**	**129,892**	**115,685**

The registered area of total potato production by crop type (first early, second early and maincrop plantings) over the period 1999 to 2003 in GB shows a decline from 147,541 ha in 1999 to 115,685 ha in 2003 (Table 1). In England and Wales, the area has fallen from 119,094 ha in 1999 to 90,611 in 2003, whereas in Scotland, the fall in total plantings has been slightly less (pro rata) from 27,988 in 1999 to 24,950 in 2003. The number of registered growers with plantings of 3 ha or more has also declined from 5,628 in 1997 to 3,374 in 2003. Approximately 77% of the UK potato area is grown in England, 17% in Scotland, 4% in Northern Ireland and 2% in Wales (www.potato.org.uk).

In England, production is concentrated largely into two broad areas, ranging from Essex to North Yorkshire in the east and Herefordshire to Lancashire in the west. In Scotland, production is concentrated in the east, and in Wales, along its south coast.

The average harvested yield of both early and maincrop production in 2001 was 48.2 t/ha. The total tonnage produced, including an adjustment of 8% to take account of unregistered production, was 6.4m tonnes. The six-year rolling average gross ‘farm gate’ value of the GB potato crop is £500m, with a range from £350 to £760m. Department for Environment, Food and Rural Affairs (Defra) statistics show that potatoes account for approximately 3.5% of the value of agricultural output.

1.4 Volume imported

Around 0.4m tonnes of potatoes were imported raw in 2001/02. This is split between new potatoes from countries around the Mediterranean (both EU and non-EU) and potatoes from the near continent (principally Holland, Belgium and France) for processing into frozen chips and crisps. In addition, around 1.3m tonnes of already processed potatoes are imported, largely from Holland and Belgium. Imports of processed potatoes have been a growing trend in recent years and have taken market share from UK producers.

2. Pesticide use on potatoes

2.1 Problems requiring the use of pesticides

An overview of pest and disease problems affecting potatoes in the UK is summarised by Lane *et al*., (2000) in the BCPC Pest and Disease Management Handbook.

Table 2. Key pest, disease and other problems in potatoes 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	
Soil pests				
Potato Cyst Nematodes (PCN)	*Globodera rostochiensis* & *Globodera pallida*	***	**	Soil-borne pests which stunt plant growth and tuber development and can seriously reduce yield
Spraing vector nematodes	*Trichodorus spp* & *Paratrichodorus spp*	**	**	Free-living nematodes that transmit viruses which result in internal tuber staining (spraing)
Wireworms	*Agriotes spp*	**	-	Larvae of click beetles which tunnel into potatoes affecting quality
Slugs	*Arion hortensis, Milax gigantes* & *Tandonia budapestensis*	**	-	Slugs cause irregular shaped holes on the tuber surface extending into large cavities in the tuber affecting quality
Cutworms	*Agrostis segetum*	**	-	Cutworms cause damage by gnawing roots or emerging shoots and also make holes in tubers.
Foliar pests				
Aphids	*Myzus persicae*, *Macrosiphon euphorbiae, Aulacorthum solani* & *Aphis nasturtii*	**	-	Aphids cause yield losses as a result of feeding on the foliage and also by the transmission of severe virus diseases – Potato Leaf Roll Virus & Potato Virus Y.
Foliar diseases				
Late blight	*Phytophthora infestans*	***	*	Blight can destroy the haulm extremely rapidly, leading to reduced photosynthetic area and consequent yield reduction. Blight can also infect the tubers, leading to breakdown in store as a result of secondary infection with soft rotting bacteria.
Stem canker	*Rhizoctonia solani*	**	-	In severe cases, stem canker can completely girdle the stems and cause ‘pruning’ which leads to death of the shoots resulting in delayed emergence, gappy and uneven plant stands.

Tuber blemish diseases				
Silver scurf	*Helminthosporium solani*	**	*	Reduces tuber quality
Black dot	*Colletotrichum coccodes*	**	*	Reduces tuber quality
Skin spot	*Polyscylatum pustulans*	*	-	Reduces tuber quality and can be more severe following CIPC use
Black scurf	*Rhizoctonia solani*	*	*	Reduces tuber quality but less important than the other blemish diseases
Tuber rotting diseases				
Gangrene	*Phoma exigua* var *foveata*	*	*	Less important nowadays due to better handling of tubers and improved storage conditions
Dry rot	*Fusarium solani* var *coeruleum & Fusarium sulphureum*	*	*	Less important nowadays due to better handling of tubers and improved storage conditions
Others				
Weed control		**	-	Severe weed populations can reduce yield by competing with the crop for light and nutrients.
Plant growth regulation		**	***	Used to control viability of potato tubers left in the ground post-harvest and to reduce sprouting in store.
Haulm desiccation		***	-	Desiccants are used to kill off the potato foliage (haulm) and stop further growth of the tubers when they reach their pre-determined market size. Also an important aid to disease control, and speeds up skin set.
Sprouting in store		***	***	Potato tubers will start to sprout at some point during the post-harvest storage period. Sprouting reduces tuber weight, quality and saleability in the fresh market. It results in a loss of turgidity making the tubers difficult to peel, and increases the levels of reducing sugars. The latter results in an unacceptable brown fry colour in processed potatoes, and an increase in acrylamide content upon cooking.

Further information on specific crop problems requiring the use of pesticides, which can result in residues, can be found in section 5.

2.2 Pesticide use on potatoes

Details of pesticides currently approved for use on potatoes 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 potatoes every two 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 potato crop can be found in Pesticide Usage Survey Reports – Arable Crops in Great Britain. Pesticide use in potato stores is available in Pesticide Usage Survey Reports – Potato Stores in Great Britain. A summary of the usage of pesticides on potato crops grown in Great Britain from 1992 to 2002 (spray hectares/tonnes of active substances applied) is given in Table 3.

2.2.1 Pesticide use on the growing crop

Table 3. Pesticide usage on ware potatoes 1992 – 2002. Average application rate (kg active substance (a.s.)/ha of crop grown) (Source: Garthwaite *et al*., 2003)

	1992	**1998**	**2000**	**2002**
Insecticides				
Carbamates	0.13	0.12	0.12	0.10
Organophosphates	0.71	1.33	0.67	0.31
Pyrethroids	0.02	0.02	0.01	0.02
Other insecticides	0.12	0.11	0.11	0.09
Desiccants	132.26	142.41	167.83	155.31
Fungicides*	1.18	0.87	0.93	0.91
Growth regulators*	3.98	3.31	3.09	2.96
Herbicides	0.89	0.65	0.67	0.72
Molluscicides	0.38	0.24	0.24	0.26
Nematicides*	5.48	3.29	12.11	8.18
All seed treatments	0.46	0.31	0.25	0.29

* Pesticide residues are primarily found in these groups.

The data quoted in Table 3 and in the comments below refer to pesticides used on the ware crop and no distinction is made between early and maincrop production systems. (The term 'ware crop' refers to those potatoes grown for human consumption, and generally excludes those grown for seed or industrial processing.) Ware potatoes received on average 23 applications of pesticide active substances to the growing crop in 2002, including 16.1 fungicides, 4.2 herbicides, 1.3 molluscicides, 1.2 insecticides/nematicides, 0.2 growth regulators and 0.1 desiccants.

Fungicides

The majority of fungicides were applied between June and August solely for the control of late blight disease (*Phytophthora infestans*) and mostly at the full recommended label rate. The total weight of fungicides applied to the growing crop in 2002 was 1,291 tonnes (0.91 kg a.s./ha) compared with 1,221 tonnes in 1992 (1.18 kg a.s./ha). Two proprietary formulations, cymoxanil+mancozeb and fluazinam were used on 73% and 66% of the area grown respectively in 2002. These formulations have consistently been the two principal blight fungicides used over the last 10 years. Other commonly used blight fungicides were mancozeb (29%), dimethomorph+mancozeb (36%) and fentin hydroxide (53%). The latter has now been revoked in the EU and is no longer permitted for use. Despite the high level of fungicide use on the growing crop, very few fungicide residues from these treatments are found on tubers.

Herbicides
In 2002, the major uses of herbicides were for general weed control (65% treated area) or pre-harvest haulm desiccation (25% treated area). The total quantity of herbicide used in 2002 was 271 tonnes (0.72 kg a.s./ha) compared with 286 tonnes (0.89kg a.s./ha) in 1992. Diquat+paraquat and linuron were used on 57% and 49% of the area grown respectively in 2002. Diquat was applied as a desiccant to 26% of the area grown. Residues of herbicides are generally not sought, as they are usually applied at the start of the growing season before the potato tubers are formed, whereas the herbicides used as desiccants are applied close to harvest. Residues of two desiccants, diquat and glufosinate-ammonium, have been sought but not found.

Desiccants
The relatively high rate of use of desiccants (7,151 tonnes applied in 2002) is linked to the use of sulphuric acid, a commodity substance which can be applied at rates between 250 and 500 kg/ha, whereas most pesticides are applied at rates of less than 2 kg/ha. Also, the fluctuation in the rate of use of desiccants over the 10 years reflects the seasonal weather conditions as crops are prepared for harvesting. Sulphuric acid was used on 35% of the area grown in 1992 and 33% in 2002. There are no residue implications from the use of this product, as the breakdown chemicals occur naturally in plants.

Insecticides
Most insecticide applications (57%) were for the control of aphids, with a further 26% of applications for cutworm control. There has been a dramatic decline in the quantity of total insecticide used since 1992, from 66.7 tonnes to 9.5 tonnes in 2002, with the average rate applied declining from 0.98 kg a.s./ha to 0.52 kg a.s./ha in 2002. This decline is mostly due to a reduction in the use of organophosphate and carbamate formulations. Pyrethoid use has increased over the same period, from 17% area grown in 1992 to 37% in 2002. Overall, insecticide use has declined from 157% of the area grown in 1992 to 97% in 2002. Insecticide residues have been sought but not found.

Nematicides
Nematicide use for the control of potato cyst nematode (PCN) increased from 18% of the area grown in 1992 to 27% in 2002. The main increase seemed to be associated with the use of the soil fumigant, 1,3 dichloropropene. This nematicide accounted for 60% by weight of all insecticides and nematicides applied in 2002, although the area of crop treated was low at less than 1% (Source: Pesticide Survey Usage Report 187). Residues of this nematicide have not been sought because 1,2 dichloropropene volatilizes before the crop is planted and so residues are not found in the crop. Aldicarb was applied to 15% of the area grown and residues of this nematicide are routinely found in surveys.

Growth regulators
Maleic hydrazide is the only growth regulator used on the growing crop but on a relatively small proportion of the total area (20% area grown in 2002). It is applied as a foliar treatment for the control of potato volunteers (tubers left behind in the ground after harvest, which grow as weeds in following crops), and can help to suppress sprouting in store. Maleic hydrazide is widely used on processing crops (30-40%) but less so on ware crops (<10%). Crop assurance and retailer protocols discourage the use of this pesticide. Residues of maleic hydrazide are frequently found in potatoes.

2.2.2 Pesticide use on the stored crop

The total weight of ware potatoes stored from the 2002 harvest was 4.69 million tonnes of which 59% received one or more chemical treatments, compared with 73% in 1994. The decline in chemical use in store from 1994 to 2002 reflects the increased use of refrigeration to control sprouting, the revocation of the sprout suppressant tecnazene and the reduced use of the fungicide thiabendazole. However, the use of the sprout suppressant, chlorpropham (also referred to as CIPC), increased over this period from 70% of the tonnage treated in 1994 to 94% in 2002, although the amount applied per treated tonne declined from 0.021 kg a.s./t to 0.016 kg a.s./t. The largest increase in chlorpropham use was from 2000 to 2002. Over 90% of applications were made by fumigation in 2002. Chlorpropham is the mostly commonly found pesticide residue in potatoes.

This increase in chlorpropham use may reflect the growing proportion of the crop used for processing, and the need to provide all year round supply to factories. Storage temperatures need to be higher to safeguard fry colour in processed potatoes, so sprout suppressants are generally used instead of refrigeration to prevent sprouting. The use of chlorpropham is considered in more detail in Section 5.1.1.

However, many stores used for storing other ware potatoes use refrigeration as the main means of sprout control, with relatively low or no use of supplemental chlorpropham for longer-term storage. There has been some recent interest in the use of ethylene as an alternative to chlorpropham, in such situations. There are no residue implications with ethylene, as it is a volatile gas. However, it is unsuitable for use in processing stores, because even relatively low exposure causes fry colours to deteriorate.

Stored potatoes are also occasionally treated with fungicides to prevent tuber blemish and rotting diseases. Only 3% of the total treated tonnage received an application of thiabendazole. Residues of this fungicide are found in surveys, but the frequency of occurrence has declined over the last 10 years. In 2002, less than 0.4% of the tonnage stored was treated with imazalil. Imazalil has been infrequently found in recent PRC surveys (2001 to 2004) but several samples contained low levels of residues in 1999 and 2000.

3. Pesticide residues on potatoes

3.1 Pesticide residue survey data

Data on pesticide residues in potatoes have been reviewed from the annual reports of the Working Party on Pesticide Residues (WPPR) from 1994 to 1999, and then from the Pesticide Residues Committee (PRC) quarterly survey reports from 2000 to 2004 (www.pesticides.gov.uk/prc_home.asp). The majority of samples analysed for residues were maincrop and also new and salad potatoes. Potatoes are monitored on a routine basis, as they are a major food staple. The samples taken are usually raw potatoes; processed potato products are sampled less frequently. Details of the pesticides residues sought and found in the surveys between 1994 and 2004 are detailed in Appendices A & B. Details of pesticides approved can be found on the PSD website at: www.pesticides.gov.uk/psd_databases.asp.

Where they exist, the Maximum Residue Levels (MRLs) given are those presented in the 2004 PRC Survey Report. However, a number of pesticides do not have an MRL. Where this is the case, MRLs set by CODEX are used (CAC MRL). Further details on MRLs can be found on the Pesticides Safety Directorate's website (PSD website: www.pesticides.gov.uk; MRL spreadsheet:
(www.pesticides.gov.uk/uploadedfiles/Web_Assets/PSD/MRL_spreadsheet.xls).

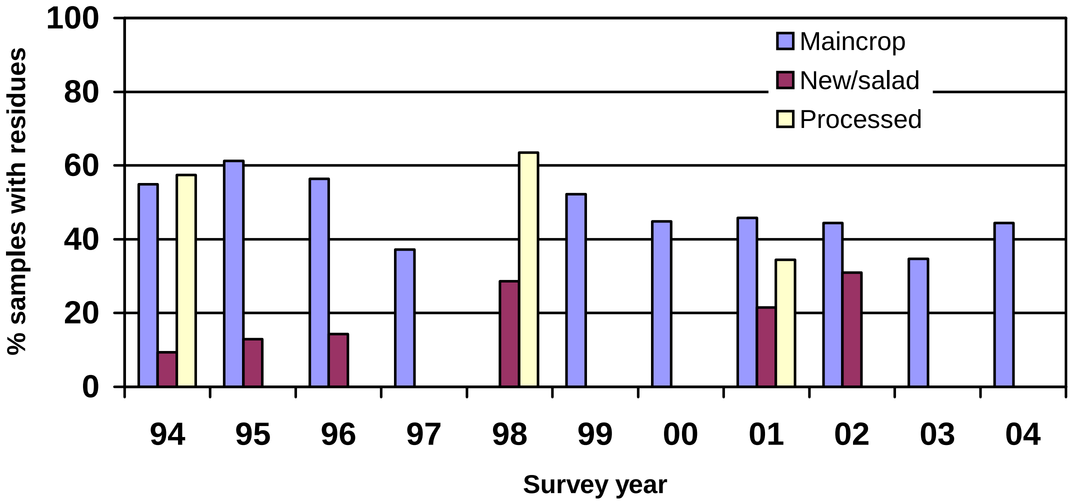
The number of pesticides on potatoes sought over this eleven year period has ranged from 10 to 93 active substances per year for the routine surveys. Only 23 pesticides were sought in 2003 and 2004. The PRC chooses which pesticides to look for based on information from the Pesticide Usage Surveys, the likely occurrence of a residue appearing based on degradation data and time of application, and the availability of a cost-effective analytical test. The proportion of the pesticides which are sought as residues and are approved for use on potatoes is low, but the key pesticides, especially the storage treatments are sought.

3.2 Pesticide residue trends

3.2.1 UK produced potatoes

In the eleven-year period from 1994 to 2004, 1290 maincrop potato samples were analysed for a range of pesticides, and residues were detected in 618 (47.9 %) of the samples. This ranged from 34.7% in 2003 to 61.2% in 1995 (Figure 3). Over the same time period but not every year, 250 new/salad and 291 processed potato samples were taken, and on average, 20.4% and 49.8% respectively contained residues. There have been questions in the past about whether new potatoes have been correctly designated in PRC sampling. This is a particular issue for interpreting residue results for products, such as maleic hydrazide, that are not recommended for use on new potatoes. However, cross-contamination, e.g. due to the use of boxes that held other treated potatoes, also needs consideration.

Fig. 3: UK maincrop, new/salad and processed potato samples containing residues of pesticides 1994-2004 (%) (Source: WPPR/PRC survey data)



Not all crop types were sampled in each year, so the gaps indicate no samples, with the exception of new/salad potato samples in 2003 and 2004 when residues were not found.

It is not possible to make year on year comparisons for all the residues which occur or to look for general trends. This is because of the targeted way the PRC selects the crop type and pesticides to be analysed, which are not always consistent between years. Also, there will be variations in pesticide use due to influence of seasonal weather changes and pest/disease pressure.

MRL exceedances

During the 11 survey years reported here, all residue levels reported for maincrop samples were below statutory limits with the exception of just four samples (only 0.31% of the total samples taken). These included an MRL exceedance for tecnazene* in 2003, two dithiocarbamate MRL exceedances in 2002 and an MRL exceedance for aldicarb in 1994. Risk assessments have shown that, with the exception of the aldicarb residue, none of the residues found were of concern for consumer health. Aldicarb has a relatively low acceptable daily intake (ADI) and acute reference dose (ARfD) of 0.003 mg/kg of bodyweight. A high consumption of potatoes containing aldicarb at the residue levels found in 1994 would result in safety limits being exceeded. No serious, irreversible effects would be expected from such an exposure but it is possible that mild transient symptoms could be produced.

Table 4. MRL exceedances in UK produced potatoes 1994-2004 (mg/kg)

Pesticide	Year	Crop type	MRL	Residue Found
Aldicarb	1994	Maincrop	0.5	2.3
Aldicarb	2001	New/salad	0.5	0.6
Maleic hydrazide	2001	New/salad	1	5.8
Dithiocarbamates	2002	Maincrop	0.05	0.06, 0.06
Tecnazene*	2003	Maincrop	0.05	1.3

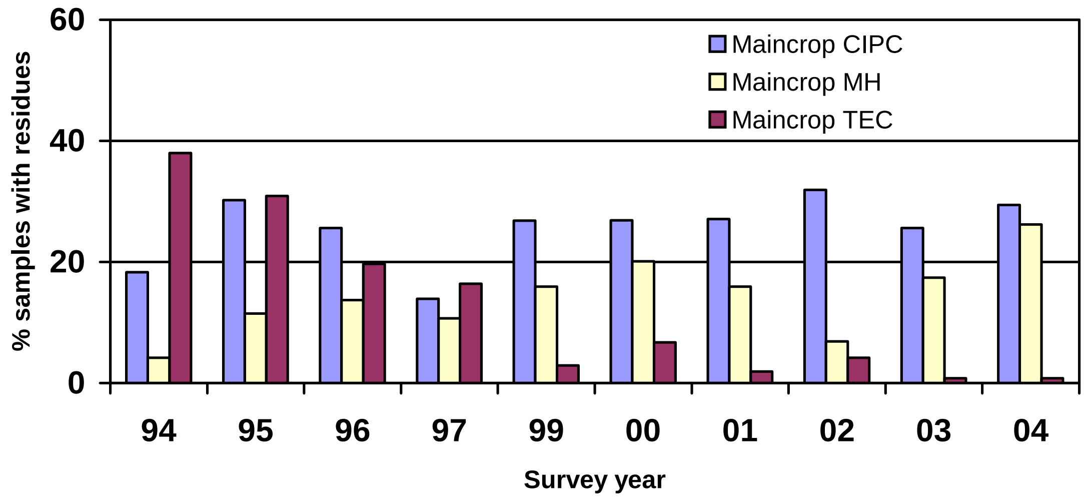
(* An advisory Codex MRL of 20 mg/kg was used for tecnazene prior to 2003, when the official MRL was set at 0.05 mg/kg.)

Residues found
The main residues found in 1994 in maincrop potatoes were from pesticides applied as sprout suppressants (tecnazene and chlorpropham) or storage fungicides (thiabendazole). In 2004, chlorpropham was the main pesticide residue found, followed by maleic hydrazide, a growth regulator applied to the crop pre-harvest which also acts as a sprout suppressant (Figure 4). Other pesticides, including nematicides and fungicides, were also found but at low frequencies.

New/salad potatoes generally contain fewer residues, probably because of the shorter growing period and the lack of storage treatments on produce which is sold fresh, shortly after harvest. The majority of residues found were from the fungicide treatments, oxadixyl and thiabendazole, with occasional residues of the sprout suppressants, chlorpropham and tecnazene, and the nematicide, aldicarb. As thiabendazole is only used in store, it is questionable whether some of the samples were actually new potatoes, although cross-contamination such as from previously treated boxes may also have occurred. One aldicarb residue sample and one maleic hydrazide residue exceeded their MRLs in 2001 although subsequent risk assessments have shown that none of the residues found were of significant concern for consumer health.

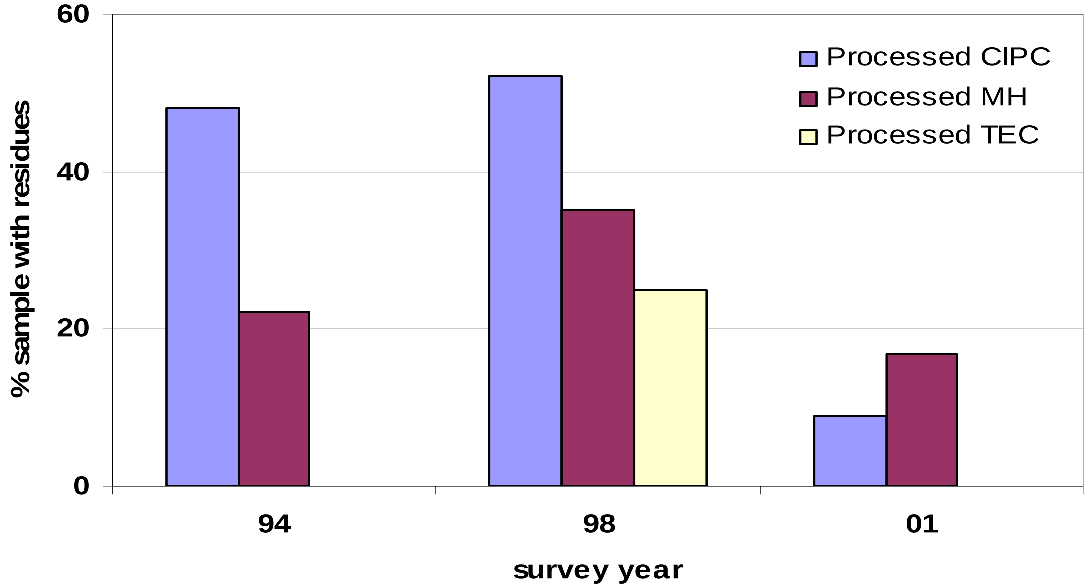
The main residues found on the processed potato samples were the sprout suppressants, chlorpropham and tecnazene, the growth regulator maleic hydrazide and the fungicide thiabendazole (Figure 5). This reflects the higher use of these chemicals in the storage of processing crops than in fresh produce crops, as refrigeration to prevent sprouting affects the quality of the processed product. No MRL exceedances were detected in the processed samples in the PRC survey, as the samples were taken up to 2001 before the new MRL for tecnazene was set.

Fig. 4: UK maincrop potato samples containing residues of chlorpropham (CIPC), maleic hydrazide (MH) and tecnazene (TEC) 1994-2004 (%) (Source: WPPR/PRC survey data)



Both chlorpropham and maleic hydrazide are used to control sprouting, with chlorpropham applied in store and maleic hydrazide applied to the growing crop before harvest. As both chemicals appear as residues, there is no opportunity to switch chemicals to prevent residues occurring. Tecnazene was also used as a sprout suppressant but it is no longer approved for use on UK potatoes and the frequent occurrence of residues has declined since 1998. However, this pesticide is particularly persistent and is likely to occur as a contaminant in the fabric and dust in potato stores for several years, so that low levels of residues may occur for some time, even with routine store cleaning.

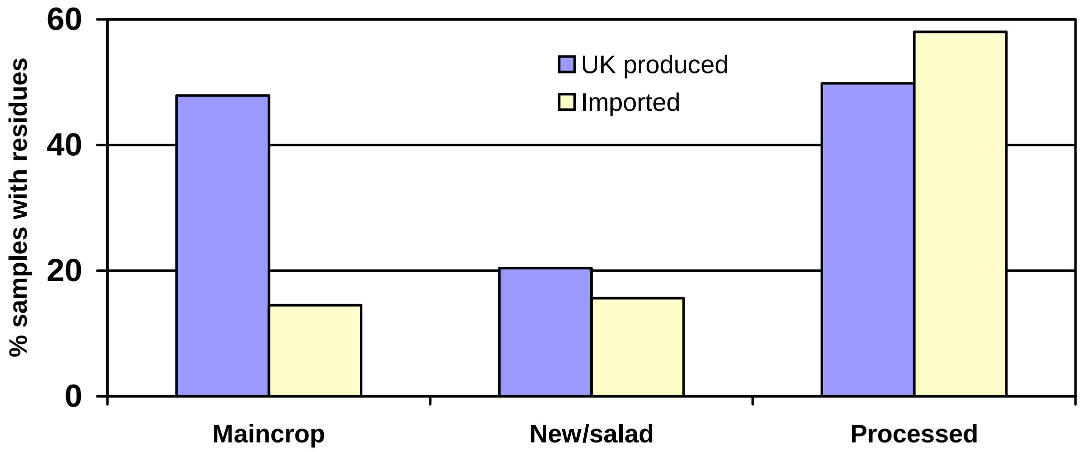
Fig. 5: UK processed potato samples containing residues of chlorpropham (CIPC), maleic hydrazide (MH) and tecnazene (TEC) 1994, 1998 and 2001 (%) (Source: WPPR/PRC survey data)



3.2.2 Imported potatoes

The numbers of samples of imported potatoes tested in the WPPR/PRC surveys between 1994 and 2004 were lower than from UK produce, and only totalled 55 maincrop, 147 new/salad and 43 processed samples, and of these 14.5, 15.6 and 58% contained pesticide residues respectively (Figure 6). Fewer residues were found on imported maincrop compared with UK produce, suggesting that the imported potatoes were not stored for long periods or were refrigerated, as the incidence of chlorpropham residues was very low. The processed potato samples had higher residues of sprout suppressants than imported maincrop. Generally, residues on imported new/salad potatoes were very low, although the MRL for maleic hydrazide was exceeded on one new/salad potato sample from France in 2001 (MRL 1mg/kg and 25mg/kg was found). A risk assessment has shown that the residue found was not of concern for consumer health. Overall, the profile of residues found on imported produce, reflected the profile in the UK samples, with chlorpropham occurring most frequently, especially in the processed potatoes.

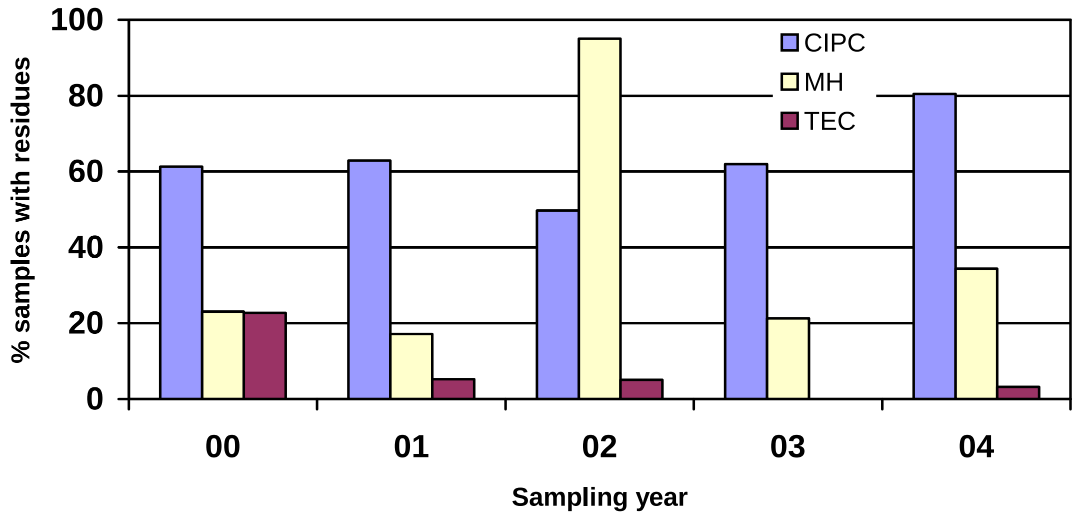
Fig. 6: Occurrence of residues in UK produced and imported potatoes (%) 1994-2004 (Source: WPPR/PRC survey data)



3.2.3 Producer/processor data

Residue data provided by members of the Potato Processors' Association (PPA) shows a similar picture to the WPPR/PRC survey data (Figure 7). The suite of pesticides sought was generally not as extensive as the official survey, but chlorpropham, tecnazene and imazalil were sought on most samples. The frequency of testing for maleic hydrazide was much less, so some caution is required in interpreting those data. The number of raw potato samples tested over the five years averaged 173 per year, of which an average of 45 per year were tested for maleic hydrazide.

Fig. 7: UK raw potato samples for processing containing residues of chlorpropham (CIPC), maleic hydrazide (MH) and tecnazene (TEC), 2000-2004 (%) (Source: Potato Processors' Association raw potato data)



One PPA member supplied data for residue tests on processed products for an average of 26 samples per year, over 4 years, although the data were limited and the nature of the processing not stated. They showed that the occurrence of chlorpropham residues did not appear to be reduced in the product, compared to raw potatoes, though the amount of residue fell after processing.

4. Approaches to reduce pesticide use

4.1 General approaches/policies to reduce use and residues

Wherever possible, potato growers will use the principles of integrated crop management (ICM) as the starting point for crop production (Bradshaw 1996; Bradshaw *et al*., 1996; Bradshaw 2002). This involves rotation (for Potato Cyst Nematode (PCN) control), the selection of varieties for their resistance to particular pests and/or diseases (subject to market requirements) and the use of due diligence when using pesticides. The current costs of potato production, and environmental issues, are such that growers do not apply pesticides unnecessarily. Also, the nature of some of the pest and disease problems on potatoes, together with increasingly stringent quality demands by retailers, may limit the scope to reduce pesticide use. However, pre-packers and processors are aware of the need to minimise the occurrence of residues on their produce and will test high risk crops to ensure residue levels are acceptable. The key husbandry principles basic to an ICM approach are:-

a) ***Seed quality***. This is an important first consideration when growing potatoes, as seed health can have a major impact on the potential need for pesticides in the subsequent crop. High grade certified seed can be expensive but quality considerations should always be given the highest priority. There may be both financial and agronomic advantages in using 'once-grown', home-saved seed. Provided this can be effectively managed in terms of maintaining the health of seed stocks, it is an acceptable alternative option.

b) ***Variety choice*.** Most potato varieties have some level of resistance to certain pests and diseases but this varies considerably and may not be sufficiently robust to completely reduce the need for chemical intervention. No single variety is resistant to the whole spectrum of pests and diseases but if a particular problem is anticipated, the impact can be greatly reduced. Variety choice is invariably governed by market requirements but resistance to pests and diseases should be considered when making that choice (Anon., 2003).

c) ***Agronomic practices***. These include rotational planning, (for potatoes maintaining wide rotations of 4-5 years between crops), using appropriate cultivation techniques to provide good soil conditions, adopting good farm hygiene to control volunteer potatoes and haulm growth on dumps. All these can have a major impact on the need for pesticide intervention to control pests such as PCN and particularly late blight.

4.2 Assurance schemes

Assured Produce Scheme (APS) – www.assuredproduce.co.uk

The crop specific AP protocol for potatoes (Crop ID:47) gives advice on the control of pests, diseases and weeds, advocates the use of resistant varieties where appropriate, advises on site selection and the correct use of other agronomic inputs, the use of thresholds and Decision Support Systems where available. Environmental concerns associated with pesticide use are also addressed. AP has developed residue minimisation protocols for a range of crops, including potatoes.

In 2005, 1,891 potato growers were registered with the Assured Produce Scheme representing 77.3% (97,355.98 ha) of the potato area (125,911 ha). 99% of those growers farmed over 3ha of potatoes and were presumably registered with the BPC. Seed potato growers and ware growers who do not supply into the major retailer market are less likely to be registered with APS.

4.3 Decision support systems

In the UK, two warning or forecasting schemes for potato blight have been in widespread use - the Beaumont Period (since 1950), which was superseded by the Smith Period in 1975. The Smith Period model is very simple and was developed empirically. Smith Period forecasts remain the industry standard and are used as one measure of blight risk. Forecasts of blight activity are based on temperature and humidity data received from the Meteorological Office network of synoptic weather stations. Mathematical calculations known as interpolation routines are used nowadays to indicate blight favourable weather down to post code level. This information is provided as a free service called BlightWatch, which is available on the internet at www.blightwatch.co.uk .

Other Decision Support Systems, also based on temperature and humidity data, are in use in Europe although the models vary in their complexity and scope. For example, NegFry forms part of the Web-Blight service in the Scandinavian countries and Baltic States (www.web-blight.net). Milsol is the warning system operated by the French Plant Protection Service, Plant Plus is available in the Netherlands as part of the Dutch Government funded Masterplan Phytophthora and Blitecast™ which is used in parts of the United States. Plant Plus is also available as a commercial service in the UK.

Although these warning systems are Decision Support Systems, they are not designed to minimise pesticide use or pesticide residues but are aimed at providing optimum control of a potentially devastating disease. There are very few pesticide residues arising from the use of potato blight fungicides.

There are also Decision Support Systems for: monitoring aphid populations and the appropriate use of insecticides; for the control of potato cyst nematode and nematicide use; and for storage management to provide risk assessments for disease control and advice on appropriate use of fungicides, such as imazalil and thiabendazole, and the sprout suppressant CIPC. These Decision Support Systems have been developed as a result of levy funding from the BPC and complement similar stewardship initiatives sponsored by the pesticide manufacturers and others in the industry. (see section 4.4 – Industry initiatives and Appendix G).

4.4 Industry initiatives

The role of the British Potato Council (BPC)

As part of the BPC's published Corporate Plan, minimisation of pesticide residues is recognised as an important objective in achieving the quality/product specification essential to maintain a competitive British potato industry. Other issues relating to quality include tuber size and uniformity, pest and disease status, processing quality, seed health, storage, and a reduction in damage and bruising. The BPC acts to:

- Co-ordinate cross-industry approaches, which do not compromise the environment and/or consumer interests, and which will assist residue minimisation by improved agronomy and storage techniques.
- Disseminate information to the potato industry and interested parties, and to assist cross-industry initiatives to complement new opportunities for residue minimisation by provision of relevant information from research and development projects, including input to Assured Produce crop protocols.

The BPC publishes an extensive range of guidance notes promoting best practice on issues such as blight control, the use of chlorpropham, application of granular nematicide, as well as alerting the industry to the issue of residue minimisation (see Appendix F). They also undertake specific knowledge transfer activities in all sectors of the supply chain.

Crop Protection Association

The Crop Protection Association (CPA) has issued general advice on pesticide residues, on behalf of the crop protection industry. This advice is available in a leaflet from their website (www.cropprotection.org.uk/), 'Keeping residues well within the limits'.

Pesticide manufacturer initiatives

There are a number of on-going initiatives by pesticide manufacturers, some of which are detailed below.

Bayer CropScience Ltd (BCS) – Potato Cyst Nematode (PCN) control & aldicarb Stewardship

Bayer CropScience (BCS), (www.bayercropscience.co.uk/) is the manufacturer and approval holder of Temik™, which is the proprietary formulation of aldicarb, marketed for the control of PCN and the nematode transmitted tuber virus disease called spraing. BCS has developed a Stewardship programme to reduce the environmental impacts and minimise residues of aldicarb, through specialist training and machinery calibration.

As part of the stewardship programme, BCS also commissioned Cambridge University Farm (CUF) to conduct independent trials to investigate the effect of different methods of aldicarb application on residues in potatoes (Firman & Hewett, 2003). Trials were conducted in 2003 on commercial farms growing potatoes for the processing market. One objective was to provide independent data to support the manufacturer's stewardship promotion that the use of 'fish-tail' applicators should be used when the product is applied in-furrow. It was believed that delivering the product in a wider band within the furrow would minimise the potential for residues. The study consisted of six replicates in a randomised block design. Potatoes were harvested 82, 96 and 110 days after planting (DAP) and sent to an independent laboratory for aldicarb analysis. Even at the shortest harvesting interval (82 DAP), use of the 'fish-tail' applicators resulted in no detectable residues (Limit of Quantification = 0.05 mg/kg) in five of the replicates. In the sixth replicate, a residue was detected at the level of quantification (0.05 mg/kg). No residues were detected at any of the other sampling times when 'fish-tail' applicators were used (see Appendix G for further details).

Dow AgroSciences Ltd (DAS) - Volunteer potato control/plant growth regulation and maleic hydrazide

Dow AgroSciences (DAS, www.dowagro.com) is one of the companies in GB marketing a proprietary formulation of the growth regulator maleic hydrazide as Fazor™. Maleic hydrazide is used for the control of potato volunteers and sprout suppression in store. DAS has set up an interactive training page on their website for BASIS-qualified advisors and others to help optimise the use of maleic hydrazide by adopting best practice (see www.fazor.co.uk). Completion of the short training programme entitles the user to BASIS points (see www.basis-reg.com)

DAS recommends that growers should also consider cultural measures to reduce potato volunteer populations throughout a rotational sequence. By adopting this 'integrated' approach, there is a reduced reliance on chemical intervention and therefore reduced environmental impact, and a possible consequent reduction in the occurrence of maleic hydrazide residues.

Aceto Agricultural Chemicals Corporation and Luxan
– Sprout suppression and chlorpropham application

Aceto Agricultural Chemicals Corporation and Luxan BV are the main data holders and suppliers of the active substance chlorpropham. Whyte Agrochemicals Ltd and Luxan UK Ltd distribute the formulated product. The PRO-POTATO initiative recognises the importance of reliable, effective chlorpropham treatment by professional applicators for sprout suppression during long-term storage. A website has been developed, in association with the potato processing industry, the British Potato Council and Assured Produce, to encourage best practice procedures for chlorpropham application. (See www.propotato.com) Additionally, Luxan has produced a technical bulletin on minimising chlorpropham residues.

5. Approaches for specific problems related to residues

In this section of the crop guide, comments are made with regard only to those pest and disease problems and agronomic practices that have resulted in pesticide residues being detected in PRC surveys. They are discussed in order of importance for the occurrence of residues.

5.1 Potato storage

5.1.1 Chlorpropham

Potatoes are an overwintering storage organ and will break dormancy and start to sprout at some point during the post-harvest storage period, before the normal planting time in the spring. The period during which the potato is dormant will vary principally according to weather conditions during the growing period, the way the tubers are stored and the variety. Sprouting reduces tuber weight and quality, and therefore saleability in the fresh market. Excessive sprouting also increases the levels of reducing sugars. The conversion of starch to reducing sugars in sprouted tubers results in an unacceptable brown fry colour in processed potatoes. Fry colour is an important quality factor, particularly as an increasing proportion of potatoes are processed.

Use of chlorpropham
Control of sprouting in storage is heavily dependent on the use of chemicals and chlorpropham is the most widely used commercial sprout suppressant in the UK and most other parts of the world. Chlorpropham is the most frequently encountered residue in potatoes and has been regularly found in WPPR/PRC surveys since 1994. In the UK, it is applied as a fog according to strict guidelines and only by suitably qualified individuals. Other formulations are used elsewhere. There has been extensive research on 'best practice' aimed at achieving lower residues, including work, funded jointly by the PPA and the BPC, that has shown that even application is essential (www.potato.org.uk). This is influenced by factors such as particle size, temperature gradients within store and ventilation. Uneven distribution of chlorpropham affects residues on tubers and can result in 'hot spots' of residues. Chlorpropham is also likely to be a contaminant of the fabric of the store, principally because of the innate difficulty in cleaning them effectively. Residues may also arise from contaminated wooden boxes, although these are likely to be dynamic and are of lesser importance than store contamination. Contamination of potatoes in low temperature stores that are now using ethylene and where CIPC was used previously, is considered to be slight and typically less than 0.1 ppm (pers. comm. Adrian Briddon, British Potato Council, Sutton Bridge Experimental Station).

Chlorpropham has received Annex 1 listing under Directive 91/414 EEC and an MRL of 10 mg/kg has been set. The majority of the residues reported in the PRC surveys and by industry are below this proposed level, although levels on two PRC samples in 2003 reached 12 and 20 mg/kg respectively.

Approaches to minimise residues
The main approaches used to minimise residues arising from the use of chlorpropham are better and more effective application of the chemical, ensuring even distribution throughout the store. Timing and dose rates are also important to avoid residues occurring. Applications made after dormancy break are relatively ineffective and higher doses or re-applications may be required. Single high dose treatments for long-term storage are not carried out in the UK. Using chlorpropham in conjunction with other sprout suppressant chemicals can help reduce residue levels, but will not affect the frequency of residues. The companies responsible for marketing CIPC have also invested considerable resources in the dissemination of best practice information. Operator competency is now included in the

National Proficiency Testing Council schedules, and best practice guidelines were incorporated into the Assured Produce potato protocol in 2003, and were further strengthened in 2005 (www.assuredproduce.co.uk/Aproduce/). The BPC also publishes a Grower Advice sheet on best practice in the use of CIPC (www.potato.org.uk).

To reduce contamination in stores, every opportunity should be taken to increase air exchange with the environment as soon as stores are emptied, and any loose debris should be removed during cleaning. Where the contamination is occurring from potato boxes, they should be weathered outside, as volatilisation is a factor in decontamination of the wood. CIPC is also reduced by exposure to UV radiation (pers. comm. Adrian Briddon, British Potato Council, Sutton Bridge Experimental Unit).

Alternatives to chlorpropham

Sprout inhibition in potatoes has been reviewed by Kleinkopf *et al.* (2003) and the efficacy of alternatives to chlorpropham has recently been evaluated (Kalt *et al.* 1999 & Noël *et al.* (2004). Possible alternatives include napthalene-based products (DMN & DIPN), carvone and ethylene, but evaluation work is still underway. These products are unlikely to replace chlorpropham. Carvone, a natural derivative, was used in Holland and Switzerland albeit on a very small tonnage (partly because of the high cost). An extension for provisional authorisations for carvone was agreed by the Standing Committee on the Food Chain and Animal Health (SCoFCAH) in June 2004. There are no current applications for its use in the UK.

Ethylene was given commodity substance approval by the Pesticides Safety Directorate in September 2003, for use in potato stores as a sprout suppressant. It is seen as an alternative to chlorpropham and does not have a residue problem, but is unlikely to completely replace it. Effective use of ethylene requires more demanding store design and maintenance, refrigeration to achieve low holding temperatures and constant monitoring to maintain critical gas concentrations. Ethylene is therefore only suitable for ware potatoes as low temperatures affect processing quality i.e. fry colour. Commercial development of ethylene based-storage systems has only recently started but it is likely that both chlorpropham and ethylene will find their own sectors as they have features suited to specific end uses (Anon., 2004). A Growers' Advice sheet has been produced by the BPC summarising the publicly available information on the use of ethylene as a sprout suppressant in potato stores (Briddon, 2004). The current approval states a target concentration of 10ppm using (99.9%v/v) ethylene and a post-treatment withdrawal period of three days.

Non-chemical approaches

There are no 'natural' chemical methods of controlling sprouting, and refrigeration is the only 'natural' option. In these circumstances, stored potatoes may need to be consumed or processed before they break dormancy and start sprouting, generally before the end of December for UK crops. Variety selection is principally governed by market requirements, rather than the propensity to break dormancy and produce sprouts. Storing potatoes at low temperatures is an expensive option in terms of both capital and running costs. Importantly, it is only suitable for ware crops as low temperatures affect processing quality i.e. fry colour. In organic production systems, cold storage is the only long-term option, and imports will be used to supply the market, especially for processed potatoes, if refrigeration is not appropriate.

5.1.2 Tecnazene

Residues of tecnazene, which was used as a sprout suppressant and fungicide for dry rot control up to January 2002, also routinely appear in the PRC surveys. The residues reported in recent years are probably due to contamination of the fabric of potato stores or wooden storage boxes. They are likely to continue to decline with time because of the volatility of the chemical. Stringent store hygiene, to clean the fabric of the store and remove contaminated dust, will help to eliminate the residues altogether.

5.2 Control of potato volunteers – maleic hydrazide

Volunteers are potatoes left behind from a previous commercial potato crop, which subsequently grow as weeds in the rest of the rotation. They are to be found growing as weeds in other crops and are now recognised as a major problem. Shorter rotations have compounded the problem and where land is rented (to avoid PCN problems), it is important that land is returned free from volunteers. Their control often forms part of land rental agreements. Typically, over 30% of the potato crop is grown on rented land (Anon., 2004a). Undersized potatoes, which give rise to volunteers, fall through the harvester webs or become detached from the plants at lifting. Estimates indicate that there can be as many as 300,000 volunteers per hectare (30 per square metre) and they can remain viable for up to eight years. Berries produced from potato flowers contain potato seeds, which can also contribute to the volunteer loading in a field.

In other crops in a rotation, volunteer potatoes compete for light, space and nutrients and this reduces yield and quality. They can slow down the harvest of cereal crops which also increases costs and may require the use of pre-harvest glyphosate, which can then appear as a residue in the cereal crop. Potato berries are potentially an important contaminant in vining pea crops. In the context of potato production, volunteers enable PCN multiplication on land in the absence of crops. Importantly, potato volunteers may be carrying or become infected with the potato blight pathogen and become an important source of inoculum for nearby commercial crops. Potato volunteers therefore act as a means of pest and disease carryover between crops.

Use of maleic hydrazide

Maleic hydrazide is a plant growth regulator used on second early and maincrop varieties (but not seed) as part of an integrated programme for the control of volunteer potatoes in succeeding crops. It is applied as a pre-harvest foliar spray, and when used in this way also helps to suppress sprouting of potatoes in store. The degree of sprout suppression is a function of several factors including, variety, growing conditions, application conditions and accuracy, length of storage period and conditions during storage period. The pesticide is systemic and residues appear throughout the tuber. Maleic hydrazide residues have been regularly detected in PRC surveys of UK main crop and processed potatoes.

Maleic hydrazide is widely used on processed crops (30-40%) but less so on ware crops (<10%). Tesco's Nature's Choice and Sainsbury's protocols do not permit the use of maleic hydrazide on crops grown for them.

Approaches to minimise residues

Maleic hydrazide has to be present in the tubers to be effective and therefore leaves residues which are within permissible levels even when best practice is followed. The manufacturer has an interactive website (www.fazor.co.uk) which gives best practice guidelines for effective use of the product but not to minimise residues.

Alternative approaches
Volunteer control at another point in the rotation would clearly reduce maleic hydrazide residues in potatoes. However, this may require more than one treatment of different herbicides in other crops such as: chlopyralid in sugar beet, fluroxypyr in cereals or the application of a non-selective herbicide such as glyphosate used pre-harvest or in the absence of a crop (e.g. on set aside land). However, the use of glyphosate pre-harvest in a cereal crop may result in glyphosate residues in the grain. The efficacy of the alternative products should be considered in relation to the window of application in the growing crop relative to the growth stage of the volunteer potato.

Non-chemical approaches
Cultural methods of volunteer control rely mainly on minimal cultivation after harvest. This leaves tubers on or near to the soil surface where they are likely to be killed by frosts. Mechanical weeding or hand-weeding potato volunteers between potato crops is not a cost-effective option, and even in organic systems may be insufficient to reduce volunteers to levels where they do not pose a risk as a source of blight inoculum. The use of outdoor pigs to reduce volunteer populations post-harvest is being investigated in an EU-funded project on blight control in organic potato production (www.ncl.ac.uk/tcoa/producers/research/blightmop/).

5.3 Late blight - fungicides

Late blight (*Phytophthora infestans*) is the most important fungal disease affecting the growing potato crop and can destroy the haulm extremely rapidly, leading to reduced photosynthetic area and consequently a yield reduction. In untreated crops and the worst case scenario, late blight may reduce yields by more than 50% making fungicide treatment essential. Observations over many years from fungicide trials have shown just how fast a blight epidemic can develop. In untreated plots, foliage blight can increase from 5 to 75% haulm destroyed in less than 10 days. Blight can also infect the tubers and in doing so directly reduces marketable yield. Tuber infection may also lead to breakdown in store as a result of secondary infection with soft-rotting bacteria, sometimes leading to complete crop loss.

Use of pesticides
Residues of blight fungicides have been recorded sporadically in WPPR/PRC data for maincrop, salad and processed potatoes. One of the active substances detected, oxadixyl, was not supported for Annex 1 listing under EC Directive 91/414 EEC and is no longer approved for use. Detection of the dithiocarbamate fungicide, mancozeb, in 2002 has been associated with exposure to contaminated soil at lifting (pers. comm. J Sellars, Dow AgroSciences). The fungicide propamocarb was detected in PRC surveys in 1997 and 1998 but not subsequently. There are a number of fungicides reported in the Pesticide Usage Survey reports which are not tested for in the PRC surveys generally because they are not considered to be of concern. Some blight fungicides are new active substances and it may be that suitable analytical techniques have not yet been developed for use in multiple pesticide residue suite analysis. The method of analysis required for the approval and registration process may be considered expensive for routine use.

Because blight is potentially so devastating, growers apply fungicides prophylactically well before the disease becomes established in the crop or locality. This is because fungicides are most effective in the early stages of an epidemic before blight can readily be found but usually have little effect once the disease is established in a crop. The choice of fungicide and their frequency of use will depend on the cost, weather conditions and perceived risk of blight in the locality. Varietal resistance in terms of foliar and/or tuber blight will also influence the intensity of spray applications.

In organic systems, copper-based fungicides may be applied to prevent the onset of blight infection, but these treatments are not as effective as conventional fungicides. Copper residues are not sought in the PRC surveys. In 2006 the PRC will be testing samples for pesticides used in organic production, but this will not include copper because it is not possible to distinguish between pesticide residues and natural environmental residues.

Because of the lack of robustness in forecasting systems (see section 4.4), fungicides will continue to be used routinely in conventional production at least for the foreseeable future. Recent research has shown that the interval between applications is more important than product choice, and effective control of foliar blight is achievable with cheaper protectant materials. However, as the intervals become extended, the more sophisticated mixtures currently available give better control (Lane *et al*., 2000). Strategies for the control of late blight in GB have recently been reviewed by Bradshaw & Bain, (2005)

Approaches to minimise residues

In 2003, the BPC successfully launched the 'Fight against Blight' campaign which continued into 2004. As part of this campaign, blight development was monitored and outbreaks reported on the BPC website to enable farmers, their consultants or agronomists to make more effective decisions on blight risk and tailor fungicide spray programmes more effectively (Bradshaw *et al.,* 2004).

Stringent quality demands from retailers means a virtual zero tolerance for tuber infection. Consequently, growers sometimes apply fungicides close to and after haulm desiccation, particularly if a slow-acting desiccant is used and there is already blight infection in the crop. This practice is common and unlikely to change in the foreseeable future but may well be having an impact on certain residues which occur either by direct contact with the tubers or as a result of exposure to contaminated soil. Fungicides, which are mobile within the plant, are positioned by the manufacturers to be used at the start of the spray programme, and as such should not result in residues in the tubers. Tesco and Sainsbury's restrict the use of dithiocarbamates close to harvest to minimise the occurrence of residues. At the time of writing, there are very few residues of blight fungicides being detected in the PRC surveys, although not all blight fungicides are currently being sought.

Non-chemical approaches

Despite considerable research effort and breeding of varieties with improved levels of resistance to blight, the routine use of fungicides is still the most effective means of control both in the UK and in other developed countries. Varietal resistance dependant on major (R) genes was introduced commercially some years ago but the pathogen population rapidly adapted and the resistance was overcome within a few seasons. Despite this, blight resistant varieties continue to be developed with the aim of developing a more durable level of resistance.

Good hygiene practices such as reducing sources of primary inoculum by control of volunteer potatoes and haulm growth on dump-sites are essential components in managing this disease. The use of healthy disease (blight) free seed is also essential.

If blight does occur in organic systems, then green haulm has to be destroyed quickly to prevent spread of the disease and major crop loss. Organically grown crops can be a potential source of inoculum to infect conventional crops because of the problems mentioned above.

5.4 Soil borne pests – aldicarb

5.4.1 Potato cyst nematode

PCN (*Globodera rostochiensis* and *G. pallida*) is one of the most serious pests of potatoes and can cause large yield losses. It is common in many ware-producing areas and a 1992 Potato Marketing Board survey estimated that 42% of land cropped with potatoes in the UK is infested. Annual yield losses to the industry have been estimated to be in the order of £50 million. Severely affected plants are stunted and often appear in patches, although symptomless plants occur when soil infection is low. Infected crops leave cysts behind in the soil, and these are easily spread to other fields with wind-blown soil, on machinery and most importantly via seed tubers. Cysts may remain dormant for ten or more years without a potato crop.

Use of nematicides

Technical advice should be obtained before planting potatoes into nematode-infested land. The risk of PCN attack and the need for chemical control measures is based on field history, the variety grown and the level of soil infestation following laboratory tests on soil samples. Chemical control will remain dependent on pre-planting soil-applied nematicides and fumigants, and accurate application is essential to achieve adequate control. The use of a nematicide may contribute to multiplication control and will help to protect the crop from yield loss due to root invasion. One of the nematicides, aldicarb (in Temik 10G) has been detected in nine of the PRC surveys since 1994. Bayer CropScience has an extensive stewardship programme designed to minimise aldicarb residues as well as any adverse environmental impact (see also section 4.5 and Appendix G for further details).

Alternatives to aldicarb

Oxamyl is the most widely used alternative to aldicarb and residues have been sought in PRC surveys since 1998. No residues of oxamyl have been detected. Fosthiazate has been developed for PCN control in the last five years. This active substance was sought in the 2002, 2003 and 2004 PRC surveys and no residues were detected. The fumigant nematicide 1,3-dichloropropene is equally effective against both species of PCN but is only suitable for use on medium-to-light soil types that can be sealed after application. This treatment is not recommended for use on heavy clay, high organic matter soils or those with a high proportion of large stones. This pesticide has not been looked for in PRC surveys. Ethoprophos is also approved for PCN control but in practice is rarely used for this purpose – it is used at a lower rate for wireworm control. Residues of ethoprophos have been sought in surveys but not found.

Non-chemical approaches

Over the last 10 years or so, potato cropping has become more intensive resulting in closer rotations. Growing potatoes one year in four or less will not allow PCN to decline to safe levels, even with chemical control. PCN survival rates can be affected by a number of factors, which would determine the optimum length of rotation to avoid damage. As a means of assessing potential risk of PCN attack, regular and intensive soil testing is considered essential not only to track PCN population levels but also to assess species composition. Tests to determine the level of infestation can be done on soil samples taken in the year before cropping and used as a basis for rotational planning.

Many widely grown varieties e.g. Maris Piper and Cara, are fully resistant to the yellow cyst nematode *G. rostochiensis*. Varieties with partial resistance to *G. pallida* pathotype Pa 2/3 are now available e.g. Midas and Sante. It is likely that current *G. pallida* partially resistant varieties, whilst still producing less multiplication than susceptible varieties, may result in an increase in cyst numbers after cropping. This will depend on many factors, including soil type, original population levels, use of nematicide, water availability, temperature and timing of harvest. The level of tolerance to root invasion also differs with variety, but there is insufficient data to produce ratings for effective use in practice. As a general guide, those varieties exhibiting vigorous growth tend to be the most tolerant but result in the greatest nematode multiplication. Resistant varieties prevent the formation of cysts, but roots are still damaged by young nematodes, and the plant can exhibit similar yield loss to a non-resistant variety. Biological control is currently not available although research at Rothamsted has identified and investigated the use of nematophagous fungi.

An alternative non-chemical means of reducing high infestations of *G. pallida* is the use of trap cropping. The choice is between using a potato crop, or using a specific trap crop such as *Solanum sisymbriifolium* (Flier *et al*., 2003). Use of the latter is likely to be more acceptable as there is no risk of PCN being allowed to complete its development. Failure to remove or destroy the trap crop in time can result in an increase rather than a decrease in the PCN population. Both techniques stimulate juvenile PCN nematodes to 'hatch' and invade the trap crop roots. The plants are then harvested a few weeks after planting and destroyed. This prevents the nematode population from increasing and substantially reduces soil nematode infestation. Recent research has shown that trap cropping can reduce infestations by up to 80%. However, the technique is costly and requires very careful management. Estimates range from approximately £1,000/ha for a potato trap crop and £250-300/ha for *Solanum sisymbriifolium* (pers. comm. A. Barker, Rothamsted). It has also been suggested that the trap crop may be a host for the late blight pathogen and widespread use of this technique could have implications for the control of this disease. This approach is currently the subject of research both in the UK and elsewhere in Europe.

5.4.2 Spraing
Spraing is the term given to the tuber symptoms resulting from infection with either Tobacco Rattle Virus (TRV)(nematode transmitted) or, less commonly, by Potato Mop Top Virus (PMTV) (transmitted by the soil-borne powdery scab pathogen). Spraing caused by the nematode transmitted TRV is locally important as infection renders tubers unmarketable for ware. Symptoms are not usually visible until tubers are cut. The virus is transmitted by free-living nematodes (not cyst nematodes) and is found mainly on light, sandy soils, notably in Norfolk, Vale of York and parts of West Midlands.

Laboratory tests are available to assess the levels of the free living nematodes *Trichodorus spp & Paratrichodorus spp* in soils and also to determine the presence of the virus. Some varieties of potato show good levels of resistance to TRV spraing. These include; Caesar, Fianna, Hermes, Lady Rosetta, Record, Romano, and Symfonia. Fields with a history of spraing and with high nematode counts and TRV should not be cropped with a sensitive variety. Some weed species are also able to host the virus so good weed control in the rotation will reduce the virus level in the nematode population. Control on known infected sites is dependent on soil-applied nematicides and fumigants as for PCN. Best practice in relation to residues is therefore the same as for PCN i.e. soil sampling to determine nematode populations and optimum nematicide application.

5.5 Tuber diseases – thiabendazole and imazalil

5.5.1 Skin blemish diseases

Silver scurf *(Helminthosporium solani),* and **black dot** *(Colletotrichum coccodes)* are the most important tuber blemish diseases which can be treated with fungicides and result in residues. The importance of these diseases has increased dramatically in recent years because of the demand for washed, pre-pack potatoes and the more stringent quality demands from retailers for blemish-free potatoes. Whilst these diseases may be introduced into crops via infected seed, this is most important for silver scurf and together with store hygiene measures, fungicide treatments are used on the seed and/or ware tubers particularly on crops destined for long-term storage.

The development of silver scurf in store can be reduced if tubers are maintained at low temperatures (<3º C). This approach is only suitable for crops which are not to be processed, as low temperatures increase reducing sugars. Although, the disease develops at different rates on different varieties, there is currently no commercially available variety with a high level of resistance to silver scurf although differences in varietal susceptibility have been observed (Thomas *et al.,* 2005). The National Institute of Agricultural Botany (NIAB) has published some information on varietal susceptibility to silver scurf (Anon. 2006).

Black dot is both a seed and soil-borne disease and is more of a problem where potatoes are grown in close rotations. The black dot fungus survives saprophytically in soils i.e. on organic matter in the soil and in the absence of the host. This explains why black dot is more of a problem on black Fen soils in East Anglia, although the disease is not restricted solely to soils high in organic matter. The disease is more prevalent on later lifted crops – early lifting and effective curing prior to storage can reduce disease incidence. There is limited information on varietal susceptibility particularly of the more commonly grown varieties although differences in susceptibility have been observed (Thomas *et al.,* 2005). Black dot has increased in prominence in recent years as a result of better control of silver scurf, which is probably due to improved seed health and the (almost) routine use of imazalil seed treatments.

Skin spot *(Polyscylatum pustulans)* is another potentially important blemish disease of tubers in store and may not become obvious on ware tubers until February or March. It is primarily a seed-borne disease but is not a major problem nowadays as most British and Dutch seed is routinely fungicide-treated for other diseases. King Edward seed may be treated with 2-aminobutane specifically to control this disease, but there is limited general use of this treatment, and it is not sought in the PRC surveys.

Black scurf is the seed-borne phase of the black scurf/stem canker disease complex caused by the fungus *Rhizoctonia solani.* It is so named because of the conspicuous tar-like sclerotia of the fungus which appear on the tuber skin. Black scurf is not currently considered to be a major tuber blemish disease, largely because of the widespread use of fungicide seed treatments. **Stem canker** is the field phase and severe infection leads to death of shoots, resulting in delayed emergence, 'gappy' or uneven plant stands. Whilst there is little hard evidence that stem canker causes a yield reduction, there is anecdotal evidence that it affects the growth and delays the maturity of early crops. Black scurf/stem canker is both seed and soil-borne and more of a problem in close rotations. Nevertheless, clean, disease-free, certified seed is recommended and potatoes should not be grown on the same field less than every 4/5 years.

Use of fungicides

Fungicides are not applied to ware tubers prior to storage for control of black scurf. Instead, fungicide treatment of seed, with products containing pencycuron or tolclofos-methyl, has given excellent protection of developing sprouts from both seed and soil-borne inoculum. However, corresponding increases in yield are rare. Tolclofos-methyl was detected in one sample in the PRC survey of salad potatoes in 1995, but pencycuron has not been sought.

The fungicide azoxystrobin applied to the soil at planting has been shown to give effective reduction of black dot and black scurf, and it has recently been granted full approval following two seasons' commercial use under an off-label approval (SOLA). Azoxystrobin was not looked for in the 2003 and 2004 PRC surveys. However, residues are apparently being found by industry.

Approaches to minimise residues
The PRC survey reports that residues of imazalil and thiabendazole were detected most frequently (but at low levels) in maincrop ware potatoes and less frequently in processed and salad/new potatoes. These residues arise following treatment prior to storage. In practice, very little fungicide is now used on ware crops as the industry relies on healthy seed, fungicide seed treatment and effective store management for disease control. Without such an integrated approach, pre-storage fungicide treatment would be essential. Also, retailers discourage fungicide use on stored ware crops. Residues may also occur as a result of cross contamination if seed and ware are both handled in the same store. It is good practice to avoid contamination from storage of ware crops in boxes used for treated seed.

5.5.2 Tuber rotting diseases

Gangrene (*Phoma exigua* var *foveata*) and **dry rot** (*Fusarium solani* var *coeruleum* and *Fusarium sulphureum)* are historically the most important diseases of stored potatoes.

Whilst there are no varieties that are completely resistant, there are some varieties that are very susceptible to gangrene, e.g. Shepody, Ulster Sceptre. Control measures include using healthy seed, ensuring that skins have set before lifting and minimising mechanical damage (especially at low temperatures) by handling ware tubers as carefully as possible. Assisting wound healing by curing damaged tubers under humid and warm conditions, 13-16°C up to 14 days following harvesting further reduces colonisation by the gangrene pathogen. Dry rot is caused by soil-borne *Fusarium spp* which infect through wounds at lifting and grading. Warm, humid storage encourages disease development. For a long time, dry rot was considered the most important cause of storage losses but in recent years, its importance has declined. This has been attributed to better handling of tubers to avoid damage, the use of chemical treatment and cooler storage conditions. There are no varieties completely resistant but some varieties are very susceptible to dry rot e.g. Arran Comet.

Use of fungicides
Thiabendazole, imazalil and 2-aminobutane may reduce the incidence of gangrene in storage and for the best results, treatment is recommended as soon after lifting as possible. Thiabendazole and imazalil give some control of dry rot when applied soon after lifting, but 2-aminobutane does not. Approaches to minimise residues are the same as for the tuber blemish diseases above.

5.6 Pre-harvest treatments

Haulm desiccation in potatoes is used to stop the crop from growing once it has reached a pre-determined market specification (usually a combination of yield and tuber size), as a means of reducing the risk of further development of foliar and tuber blight and to allow the skins to mature on crops destined for long term storage. Mature skins (skin set) help reduce the impact of damage at harvesting and reduce losses in store caused by fungal and bacterial pathogens. Tubers with good skin set are less likely to require fungicide treatments in store, which will also reduce the risk of residues occurring. From the perspective of tuber blight control, it is essential that the desiccant programme is sufficient to prevent re-growth and where this occurs, further treatments are recommended.

Sulphuric acid currently has commodity substance approval for this use and gives the most rapid desiccation. Other desiccants, based on the active substances diquat, carfentrazone-ethyl and glufosinate-ammonium, are much slower acting and unlike sulphuric acid, may require additional fungicide protection until haulm death is complete. Other means of haulm destruction/defoliation use heat treatment or flailing in combination with a desiccant. No desiccant residues of diquat and glufosinate ammonium have been detected in PRC surveys, although testing has been limited. However, if the commodity substance approval for sulphuric acid is withdrawn, there could be an increase in the use of other chemical desiccants and this may have potential consequences for residues.

6. Research

6.1 Recent and ongoing research

Defra funded science and research projects on potatoes, which have a relevance to pesticide residues, are listed in Appendix D, and projects funded by the British Potato Council are listed in Appendix E. These include both ongoing and recently completed projects. Whilst residue reduction may not be an objective for a number of these projects, a successful outcome could result in a reduction of pesticide use either through the development of alternative control measures and/or a better understanding of pest/disease epidemiology. Other projects which might have an impact on pesticides and residues include:-

- the development of varietal resistance to diseases (late blight & tuber blemish diseases);
- Decision Support Systems (late blight & PCN);
- diagnostics and best practice in the use of chlorpropham for sprout suppression in store.

6.2 Gaps in knowledge and research needs

There is a continuing need to understand further the interactions between store layout, application method, dose, timing of chlorpropham treatments and deposition rates, with the occurrence of residues, as follows:

- Depending on the end use of the crop being stored, multiple applications of low rates of chlorpropham may be better than a single high dose, which can give high residues particularly on the first potatoes graded out of store. However, there is evidence that fry colour will be affected after multiple applications. Although early ventilation of stores after chlorpropham application overcomes much of the problem, multiple applications may not be suitable for demanding situations, for example crisping varieties at 12C (pers. comm. Adrian Briddon, British Potato Council, Sutton Bridge Experimental Station). More data is needed on deposition of chlorpropham and decline of residues when it is applied throughout the storage period.
- 3-D modelling work on the movement of chlorpropham in store (currently in progress, BPC project Code 807/258) should be used to identify the best positions in store to apply chlorpropham.
- Evaluate the use of an integrated approach to sprout suppression e.g. use of chlorpropham in conjunction with other proprietary sprout suppressants. There is a need for treatments that don't interfere with wound-healing, so they can be applied early. There is pressure not to apply chlorpropham early because of wound-healing/skin spot consequences. This could compromise efficacy in short dormant varieties, with applications made only after dormancy has broken leading to greater chlorpropham use (pers. comm. Adrian Briddon, British Potato Council, Sutton Bridge Experimental Station).

There is little in the public domain about the impact of dose and timing of maleic hydrazide on the occurrence of residues.

Research that enables pesticides to be targeted appropriately is relevant to the objective of minimising residues. This includes an investigation into the impact of application techniques on residues and the development of robust Decision Support Systems (PCN /blight control). Development of varieties that are less reliant on pesticides is also important, but market acceptability can limit the uptake of promising varieties, which has a knock-on effect on the investment made by breeders.

There is a need to examine the options for strategic research on pesticide replacements i.e. to identify and evaluate biological and other control techniques for pest, disease and sprout control in potatoes.

7. Knowledge/Technology transfer initiatives

7.1 Ongoing activities

The BPC is the main organisation involved in knowledge transfer activities to the British potato industry. Up to date information is available on the BPC website www.potato.org.uk and through publications available free to levy payers and corporate members (see Appendix F).

The BPC Knowledge Transfer initiatives focus on advising and promoting best practice in all areas of production. Specific activities include the 'Fight against Blight Campaign' which complements other web-based Decision Support Systems (see section 4.4) and provides information to better assess disease risk and pesticide use.

The main ongoing initiative relating to residues is store management and the need to ensure best practice in the use of chlorpropham treatment. Storage bulletins are produced each year in conjunction with Sutton Bridge Experimental Unit and an interactive Store Managers Guide has been produced. The Guide provides advice on best practice in the use of chlorpropham to improve effectiveness and to ensure that residues are minimised.

In conjunction with commercial sponsors, the BPC organises industry events such as 'British Potato 2003', 'Roots 2004' and 'British Potato 2005'. As well as commercial exhibits and machinery demonstrations, advice is available from BPC and industry experts supported by practical fact sheets and guides, practical workshops and keynote seminars.

Potato Review is a quarterly magazine available on subscription, which provides topical, technical and marketing features specifically for the British potato industry.

7.2 Required activities

- There is a continuing need to promote best practice in all areas of pesticide use on potatoes with emphasis on reducing residues, through the BPC, Assured Produce and retailer protocols.
- Sharing information between growers within an individual company will help raise standards even further. Inter-company sharing of information may be limited by competitive pressures, unless an anonymous database can be set up. Website links to key stakeholders, sources of information and documents could help in the exchange of information relevant to minimising residues, for example, the 'best practice guide' for the use of chlorpropham, using the available research information and best industry practices.
- Inclusion of measures to promote the awareness of residue minimisation in BASIS training for agronomists and advisers, and continuing professional development would raise the profile of the issues and their importance to the industry.

8. Conclusions

Pesticide use on potatoes is high relative to other arable crops, and is a direct reflection of the pest and disease pressures and also the stringent market quality requirements whether for pre-pack or for the stored crop. In 2002, crops grown for human consumption received on average 16.1 fungicide, 4.2 herbicide, 1.3 molluscicide, 1.2 insecticide/nematicide, 0.2 growth regulator and 0.1 desiccant active substance applications, and in addition, 51% of the stored crop received one or more chemical treatments. Residues were detected in 47.9 % of the maincrop potato samples taken between 1994 and 2004. However, residue levels were generally only a fraction of statutory levels, and only 0.31% of samples taken (4 out of 1290) exceeded the MRLs.

As might be expected, the residues most frequently found on potatoes were from treatments applied close to harvest or during the storage period. Pesticides used to suppress sprout development in store, chlorpropham and maleic hydrazide (this is also used to control potato volunteers) are the most commonly found pesticide residues in recent years. Other residues, which occur less frequently, are the nematicide aldicarb, the storage fungicides imazalil and thiabendazole, and the sprout suppressant tecnazene. The best practice recommendations for reducing these residues and the research and knowledge transfer needs are summarised in the table below.

Generally, there is a good awareness of pesticide residue issues on potatoes within the industry, especially where growers are required to meet the needs of the retailers and the processors. Potato marketing companies will selectively test produce for residues, especially on crops they consider to be high risk, to ensure that statutory and market requirements are met. Individual independent growers are less likely to have their produce tested unless they are required by their contracts to do so.

There is likely to be good uptake by the industry of any new techniques which can offer lower residues whilst maintaining crop quality, providing costs are not prohibitive. The key aims of this guide are to ensure that awareness of the issue of pesticide residues in potatoes is raised at all levels in the food chain, so that all stakeholders can work together to minimise residues as a shared objective.

8.1 Key actions to minimise pesticide residues on potatoes

Seed Quality	Ensure good quality or high-grade certified seed is used. Follow the Assured Produce Guidelines for the production and storage of home-saved seed. Follow the BPC Pre-planting Seed Health checklist to ensure the health/hygiene of 'once-grown' home-saved.
Variety	Where possible, choose varieties with resistance to key pests and diseases. Supermarkets could consider working closer with growers to achieve greater flexibility with regard to varietal choice, to help meet consumers' preferences for lower residue produce.
Agronomic Practice	Use wide rotation periods of more than 4-5 years or rent fields with a known cropping history. Regularly inspect crops and use appropriate pest/disease thresholds before pesticides are used e.g. for aphid control. Practice good farm hygiene – avoid waste heaps of potato out-grades.
Key residues and actions (*** = high, ** = medium, * = low importance)	
Chlorpropham (CIPC) *****	**Scope for residue minimisation – medium to long-term** Chlorpropham is the most frequently encountered residue in potatoes and has been regularly found in WPPR/PRC surveys since 1994. As awareness of the residue problem improves and store management and treatment are adjusted to minimise residue problems, there is likely to be a gradual reduction in the occurrence of residues and the levels found. However, residues of this chemical are unlikely to be eliminated until there is an alternative treatment to replace it, especially for the long-term storage of processing potatoes. ***Best practice to minimise residues*** The main approaches to minimise residues are better and more effective application of the chemical and appropriate dose rates and timing. Best practice guidelines are available as a Growers' Advice sheet from the British Potato Council (www.potato.org.uk) and are also contained in Assured Produce Protocols (www.assuredproduce.co.uk/Aproduce/). The guidelines are regularly updated to improve understanding of the interactions between store layout, application methods, dose, timing of chlorpropham treatments, deposition and decline rates. Ongoing BPC funded research will help improve best practice. New APS protocols provide guidance on residue minimisation, however AP recognise that chlorpropham residues are unlikely to be eliminated on processed crops until a suitable alternative treatment is found, as detailed in this Plan. Where chlorpropham is likely to be a contaminant of the fabric of the store, every opportunity should be taken to increase air exchange with the environment once stores have been cleared and any loose debris should be removed during cleaning. Residues may also arise from contaminated wooden boxes although they are considered to be of lesser importance than store contamination itself. Contaminated boxes should be weathered outside as chlorpropham is reduced by volatilisation and exposure to UV radiation. ***Alternatives to chlorpropham*** Growers might consider use of alternatives such as ethylene, which would eliminate chlorpropham residues on ware potatoes, but not on processed potatoes.

	Research needs A review of chlorpropham application procedures and the impact on residues (ongoing BPC project). A review of the use of an integrated approach to sprout suppression e.g. use of chlorpropham in conjunction with other proprietary or novel sprout suppressants may be of benefit, but consumer acceptability and concerns about multiple residues (DMN & DIPN in the future) would need to be considered. Independent research on the use of ethylene for ware potatoes. ***Knowledge transfer needs*** Clearer label information is required for CIPC users, as there is a range of products with different formulations, carriers, options for use etc. Some clarification/simplification may be possible to help reduce confusion, ensure better application practice and promote lower residues. Best practice guidelines on use of CIPC to be updated to include best practice to reduce residues.
Maleic Hydrazide *******	**Scope for residue minimisation – short to medium-term** Maleic hydrazide is a plant growth regulator used on second early and maincrop varieties (but not seed) as part of an integrated programme for the control of volunteer potatoes in succeeding crops, it also acts as a sprout suppressant which is useful for crops stored for the short/medium term. The pesticide is systemic and residues appear throughout the tuber. Maleic hydrazide residues have been regularly detected in PRC surveys of UK maincrop and processed potatoes. ***Best practice to minimise residues*** Control potato volunteers by lifting as many small potatoes as possible, avoid ploughing or at least delay ploughing to allow frosts to kill tubers, and by using appropriate herbicides in other crops in the rotation. However, pre-harvest use of glyphosate, which gives effective control of potato volunteers, can result in residues in wheat grain when used on wheat. Treatment should be applied under optimum crop and spraying conditions otherwise the product's performance is adversely affected. (See interactive website www.fazor.co.uk for best practice guidelines.) However, this is unlikely to result in minimisation of residues. Production without the use of maleic hydrazide is encouraged by assurance and retailer protocols, so growers need to consider alternative treatments. ***Research needs*** Little is known about the impact of dose and timing of maleic hydrazide on the occurrence of residues, but the systemic nature of the product means that changes are probably unlikely to lead to reductions in residues. ***Knowledge transfer needs*** A review of the information on the effectiveness of maleic hydrazide and alternative volunteer control treatments would provide potato growers, agronomists and farmers who rent land out for potato production with guidance to help them make more informed decisions about the use of maleic hydrazide.

Tecnazene *****	**Scope for residue minimisation – medium-term** Tecnazene is no longer approved for use on potatoes during storage although residues are still found, mainly on maincrop potatoes. This is thought to be as a result of previously approved uses and from contamination of the stores themselves. ***Best practice to reduce residues*** Stringent store hygiene to clean the fabric of potato stores and remove contaminated dust will help to eliminate residues.
Late blight fungicides e.g. dithiocarbamates, oxadixyl *****	**Scope for residue minimisation – short term** Routine application of fungicides is essential to prevent the late blight disease infecting crops. This is because of the enormous impact the disease can have on yield, tuber quality and storage potential. Whilst forecasting systems do have a place in blight control strategies, they are mostly used as a guide to spray frequency rather than pesticide residue minimisation. There are a number of blight fungicides available to UK growers but only mancozeb (dithiocarbamate) and oxadixyl have been recorded in the PRC surveys. The dithiocarbamate residues are thought to have occurred at lifting either due to soil contamination or from sprayed haulm. Many blight fungicides are co-formulated with mancozeb and this is an integral part of the industry's Resistance Management Strategy. Removal of mancozeb could have serious implications should the blight pathogen develop resistance to other fungicides. Oxadyxil is no longer approved in Europe for the control of potato blight. ***Best practice to minimise residues*** Timing and frequency of application will always be governed by disease risk. However, adhering to harvest intervals and using fungicides that might occur as residues early in the season, and more modern lower dose fungicides, such as fluazinam or cyazofamid, closer to harvest, may reduce the likelihood of residues occurring. ***Knowledge transfer needs*** Provision of information on the residue profiles of all blight fungicides would enable growers and agronomists to plan their blight programmes to give effective blight controland minimise the occurrence of residues.
Aldicarb ******	**Scope for residue minimisation – short to medium-term** PCN (*Globodera rostochiensis* and *G. pallida*) is one of the most serious pests of potatoes and can cause large yield losses. Chemical control is dependent on pre-planting soil-applied nematicides and fumigants, and accurate application is essential to achieve adequate control. One of the nematicides, aldicarb has been detected in nine of the PRC surveys since 1994, although at low frequencies. ***Best practice to minimise residues*** Testing soils for PCN or presence of TRV/free-living nematode vectors will determine whether treatment is required. Participating in the marketing company's stewardship scheme and in particular the operator training for aldicarb granule

	application, and the use of 'fish-tail' applicators when applying in-furrow, will help minimise the occurrence of residues. ***Knowledge transfer needs*** Provision of information on the relative efficacy of the different nematicides and their residue profiles will help growers and agronomists make informed choices on their use and help minimise the occurrence of residues.
Storage disease fungicides **e.g. thiabendazole and imazalil** *****	**Scope for residue minimisation – short to medium-term** The PRC survey reports that residues of imazalil and thiabendazole were detected most frequently (but at low levels) in maincrop ware potatoes and less frequently in processed and salad/new potatoes. These residues arise following treatment prior to storage. However, in practice, very little fungicide is used on ware crops. ***Best practice to minimise residues*** Retailers discourage fungicide use on stored ware crops because of the residue issue, so best practice relies on the use of healthy seed, fungicide seed treatment and effective store management for disease control. Without such an integrated approach, pre-storage fungicide treatment would be essential.
General knowledge transfer requirements	
Residues awareness	Continued promotion of best practice in all areas of pesticide use on potatoes with an increased emphasis on residue reduction via the BPC and Assured Produce.
Provision of advice	A working group of industry experts, which could be based on existing committees, should regularly review the available information on residue minimisation and to identify needs specific to the potato industry. This would include training needs, knowledge transfer opportunities and the identification of research to maintain the drive to reduce residues. Incorporation of information on key pesticide residues in decision support systems where appropriate would flag up potential problems when pesticide recommendations are given e.g. late use of dithiocarbamate blight sprays. Liaison with pesticide manufacturers to build on current product stewardship initiatives, to raise awareness of residue issues with distributors and agronomists when advising on pesticide use, would raise awareness in the industry as a whole.
Training needs	A BASIS training pack on pesticide residues for inclusion in training for new agronomists and continuing professional development for existing agronomists would raise the profile of the issue. This which would feed down to farmers through pesticide usage advice.
Future needs	Further evaluation of the regulation and registration process for alternative naturally occurring pesticides and sprout suppressants may provide products that do not leave residues.

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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 (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 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

Agricultural Industries Confederation (AIC)
Confederation House, East of England Showground, Peterborough, PE2 6XE.
Tel 01733 385270 www.agindustries.org.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

BlightWatch
www.potatocrop.com

British Potato Council
4300 Nash Court, John Smith Drive, Oxford Business Park South, Oxford OX4 2RT. Tel 01865 782273
www.potato.org.uk

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

National Proficiency Tests Council
Stoneleigh Park, Stoneleigh, Warwickshire CV8 2LG. Tel 024 7685 7300
www.nptc.org.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 potatoes 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
Acephate					Y				Y		
Aldicarb	**F**	**F**	**F**	Y		**F**	**F**	**F**	Y	**F**	**F**
Azinphos-methyl					Y				Y		
Azoxystrobin									Y		
Bendiocarb					Y						
Bifenthrin					Y						
Biphenyl					Y						
Bromopropylate					Y				Y		
Bupirimate					Y						
Buprofezin					Y						
Cadusofos								Y	Y	Y	Y
Captan					Y				Y		
Carbaryl	Y	Y	Y		Y	Y	Y	Y	Y	Y	Y
Carbendazim	Y	Y	Y		Y	Y	Y		Y	Y	Y
Carbofuran	Y										
Chlorfenvinphos					Y						
Chlorothalonil									Y		
Chlorpropham	**F**	**F**	**F**	**F**		**F**	**F**	**F**	**F**	**F**	**F**
Chlorpyrifos	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Chlorpyrifos-methyl					Y				Y		
Chlozolinate					Y						
Cyfluthrin					Y						
Cyhalothrin					Y				Y		
Cymoxanil				Y					Y	Y	Y
Cypermethrin					Y	Y		Y	Y	Y	Y
DDT					Y						
Deltamethrin					Y	Y		Y	Y	Y	Y
Diazinon					Y				Y		
Dichlofluanid									Y		
Dichlorophen			Y								
Dichlorvos					Y						
Dichloran					Y						
Dicofol									Y		
Dieldrin				Y		Y	Y	Y	Y		
Dimethoate					Y				Y		
Dimethomorph				Y							
Diphenylamine					Y						
Diquat	Y					Y					
Disulfoton			Y			Y		Y	Y		
Dithiocarbamates					Y				Y		
Endosulfan					Y				Y		
Ethion					Y						
Ethofumesate					Y						
Ethoprophos					Y			Y	Y		
Ethoxyquin					Y						
Etriadiazole					Y						
Etrimfos					Y						
Famoxadone									Y	Y	Y
Fenamiphos					Y						
Fenitrothion					Y						
Fenpiconil							Y				
Fenpropathrin					Y						
Fenpropidin					Y						
Fenpropimorph					Y						
Fenthion					Y						
Fenvalerate					Y						

Fipronil								Y	Y	Y	Y
Pesticide	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Fluazinam				Y							
Flurochloridone					Y						
Flusilazole					Y						
Folpet									Y		
Fonophos					Y						
Fosthiazate									Y	Y	Y
Furalaxyl					Y						
Glufosinate	Y										
Alpha HCH				Y							
Beta HCH				Y							
Gamma HCH	Y	Y	Y		Y	Y	Y	Y	Y		
Heptenophos					Y						
Hexachlorobenzene					Y						
Imazalil			**F**		Y	**F**	**F**	**F**	**F**	**F**	Y
Iprodione					Y				Y		
Isofenphos					Y						
Lindane										Y	Y
Malathion					Y				Y		
Maleic hydrazide	**F**	**F**	**F**	**F**		**F**	**F**	**F**	**F**	**F**	**F**
Mecarbam									Y		
Metalaxyl					Y	Y		Y	Y	Y	Y
Methamidophos					Y				Y		
Methidathion									Y		
Metribuzin						Y	Y	Y	Y		
Monocrotophos					Y						
Myclobutanil					Y						
Napropamide					Y						
Nicotine					Y						
Nitrophal-isopropyl					Y						
Ofurace					Y						
Omethoate					Y				Y		
Oxadixyl					**F**	**F**	**F**	**F**	**F**	Y	Y
Paclobutrazol					Y						
Parathion					Y				Y		
Parathion-methyl					Y						
Penconazole					Y						
Pendimethalin					Y						
Permethrin					Y				Y		
Phenthoate					Y						
Phorate			Y		Y	Y		Y	Y	Y	Y
Phosalone					Y						
Phosmet					Y						
Pirimicarb					Y	Y		Y	Y	Y	Y
Pirimiphos-ethyl					Y						
Pirimiphos-methyl					Y				Y		
Prochloraz	**F**			Y	Y						
Procymidone					Y				Y		
Profenofos					Y						
Prometryn					Y						
Propamocarb				**F**	Y						
Propargite					Y						
Propham		**F**	**F**	Y	**F**	Y	Y	Y	Y	Y	Y
Propiconazole					Y						
Propoxur					Y						
Propyzamide					Y				Y		
Pyrazophos					Y						
Pyridaphenthion					Y						
Quinalphos					Y						
Quinomethionate					Y						

Quintozene	**F**	Y		Y		Y					
Simazine					Y						
Tebuconazole					Y						
Pesticide	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Tecnazene	**F**	**F**	**F**	**F**		**F**	**F**	**F**	**F**	**F**	**F**
Terbutryn						Y	Y	Y	Y		
2,3,5,6 tetrachloroaniline	**F**	**F**									
2,3,5,6 tetrachloro thioanisole	**F**	**F**									
Tetrachlorvinphos					Y						
Tetradifon					Y						
Thiabendazole	**F**	**F**	**F**	**F**	Y	**F**	**F**	**F**	**F**	Y	Y
Tolclofos-methyl	Y	**F**	Y		Y	Y	Y	Y	Y	Y	Y
Tolyfluanid					Y				Y		
Triazophos		Y			Y				Y		
Trifluralin					Y						
Vinclozolin					Y				Y		
Total residues sought	15	15	15	14	93	24	17	24	55	23	23

(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 potatoes from WPPR/PRC surveys 1994-2004, number of samples with residues (range of residues found mg/kg) – (See page 50 for the key to the abbreviations in these tables.)

UK maincrop potatoes

	1994	**1994 (pre-harv.)**	**1995**	**1996**	**1997**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Total samples	142	75	139	117	122	138	134	107	144	121	126
No. samples with no residues detected	64	75	54	51	76	66	74	58	80	79	70
% samples with no residues detected	45.1	100	38.8	43.6	62.8	47.8	55.2	54.2	55.6	65.3	55.6
Aldicarb (N) (MRL=0.5)	1* (2.3)	-	5 (0.06-0.3)	6 (0.01-0.1)	Nil	6 (0.05-0.2)	1 (0.07)	4 (0.06-0.09)	2 (0.05-0.1)	2 (0.05-0.09)	2 (0.02-0.03)
Chlorpropham (SS)	26 (0.1-4.0)	-	42 (0.05-4.5)	30 (0.07-4.7)	17 (0.2-7)	37 (0.07-5.1)	36 (0.05-5.1)	29 (0.06-6.6)	46 (0.05-6.6)	31 (0.06-20)	37 (0.1-9.9)
Dithiocarbamates (F) (MRL=0.05)	-	-	-	-	-	-	-	-	4** (0.05-0.06)	-	-
Diquat (D)	-	Nil	-	-	-	Nil	-	-	-	-	-
Glufosinate (D)	-	Nil	-	-	-	-	-	-	-	-	-
Imazalil (F) (MRL=5)	-	-	-	1 (0.08)	-	9 (0.06-0.4)	11 (0.2-1)	1 (1.1)	3 (0.04-0.2)	1 (0.6)	1 (0.3)
Maleic hydrazide (PGR) (MRL=50)	6 (1.7-10.6)	-	16 (1.5-16)	16 (0.9-16)	13 (6-17)	22 (2.5-15)	27 (1.6-23)	17 (1.9-22)	10 (1.3-17)	21 (1.4-16)	33 (3.1-20)
Oxadixyl (F)	-	-	-	-	-	6 (0.02-0.05)	6 (0.02-0.04)	8 (0.02-0.04)	6 (0.03-0.06)	Nil	Nil
Propamocarb (F)	-	-	-	-	1 (0.01)	-	-	-	-	-	-
Propham (SS)	Nil	-	2 (0.07-0.3)	1 (0.2)	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Quintozene (F) (MRL=0.2)	4 (0.01-0.03)	-	Nil	-	Nil	-	-	-	-	-	-
Tecnazene (SS) (MRL=0.05)#	54 (0.01-3.1	-	43 (0.01-3.1)	23 (0.01-1.1)	20 (0.02-1.9)	4 (0.5-1.2)	9 (0.1-1.5)	2 (0.06-0.4)	6 (0.06-0.3)	1* (1.3)	1 (0.05)
2,3,5,6 tetrachloroaniline (SS)	22 (0.01-0.2)	-	15 (0.01-0.2)	-	-	-	-	-	-	-	-
2,3,5,6 tetrachloro-thioanisole (SS)	Nil	-	16 (0.01-0.08)	-	-	-	-	-	-	-	-
Thiabendazole (F) (MRL=15)	27 (0.1-3.2)	-	31 (0.1-2.1)	19 (0.2-2.2)	21 (0.1-2.3)	13 (0.07-1)	5 (0.06-0.4)	3 (0.8-2.5)	5 0.05-0.07)	Nil	Nil
MRL exceedances	1	0	0	0	0	0	0	0	2	1	0

Imported maincrop potatoes

	1994	1995	1996	1997	1999	2001	2002	2003	2004
Total samples	4	8	2	1	2	8	5	14	11
No. samples with no residues detected	3	6	2	1	2	7	4	13	9
% samples with no residues detected	75	75	100	100	100	87.5	80	92.9	81.8
Chlorpropham (SS)	1 (0.5)	2 (0.1-0.2)	Nil	Nil	Nil	Nil	1 (0.08)	1 (2.5)	1 (0.7)
Oxadixyl (F)	-	-	-	-	Nil	1 (0.02)	Nil	Nil	1 (0.03)
Tecnazene (SS) (MRL=0.05)#	1 (0.02)	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Thiabendazole (F) (MRL=15)	Nil	1 (0.3)	Nil	Nil	Nil	Nil	Nil	Nil	Nil
MRL exceedances	0	0	0	0	0	0	0	0	0

UK new/salad potatoes

	1994	1995	1996	1998	2001	2002	2003	2004
Total samples	32	31	28	28	65	58	5	3
No. samples with no residues detected	29	27	24	20	51	40	5	3
% samples with no residues detected	90.6	87.1	85.7	71.4	78.5	69	100	100
Aldicarb (N) (MRL=0.5)	Nil	1 (0.06)	1 (0.2)	Nil	4* (0.1-0.6)	Nil	Nil	Nil
Chlorpropham (SS)	2 (1.0-1.6)	1 (0.2)	1 (0.7)	Nil	2 (0.1-0.3)	5 0.06-2.2)	Nil	Nil
Imazalil (F) (MRL=5)	Nil	Nil	Nil	Nil	Nil	1 (0.07)	Nil	Nil
Maleic hydrazide (PGR) (MRL=1)	-	Nil	Nil	Nil	1* (5.8)	Nil	Nil	Nil
Oxadixyl (F)	Nil	Nil	Nil	8 (0.03-0.07)	7 (0.02-0.2)	13 (0.02-0.07)	Nil	Nil
Tecnazene (SS) (MRL=0.05)#	Nil	Nil	2 (0.04-3.2)	Nil	1 (0.9)	Nil	Nil	Nil
Thiabendazole (F) (MRL=15)	3 (0.1-1.0)	2 (0.2-0.5)	3 (0.7-1.3)	Nil	Nil	Nil	Nil	Nil
Tolclofos methyl (F)	Nil	1 (0.06)	Nil	Nil	Nil	Nil	Nil	Nil
MRL exceedances	0	0	0	0	2	0	0	0

Imported new/salad potatoes

	1994	**1995**	**1996**	**1998**	**2001**	**2002**	**2003**	**2004**
Total samples	20	20	25	19	50	8	2	3
No. samples with no residues detected	17	19	23	17	37	6	2	3
% samples with no residues detected	85	95	92	89.5	74	75	100	100
Aldicarb (N) (MRL=0.5)	Nil	Nil	Nil	Nil	1 (0.09)	Nil	Nil	Nil
Chlorpropham (SS)	1 (0.1)	1 (0.05)	1 (0.4)	Nil	6 (0.3-0.5)	2 (0.05-0.06)	Nil	Nil
Maleic hydrazide (PGR) (MRL=1)	-	Nil	Nil	Nil	1* (25)	Nil	Nil	Nil
Oxadixyl (F)	Nil	Nil	Nil	2 (0.04-0.06)	7 (0.02-0.05)	Nil	Nil	Nil
Tecnazene (SS) (MRL=0.05)#	2 (0.01)	1 (0.1)	Nil	Nil	Nil	Nil	Nil	Nil
Thiabendazole (F) (MRL=15)	1 (0.2)	Nil	2 (0.1-0.4)	Nil	Nil	Nil	Nil	Nil
MRL exceedances	0	0	0	0	1	0	0	0

UK processed potatoes

	1994	1998	2001	2001
Potato product	Crisps	General	General	Crisps
Total samples	47	52	78	114
No. samples with no residues detected	20	19	57	69
% samples with no residues detected	42.6	36.5	73.1	60.5
Chlorpropham (SS)	22 (0.1-2.5)	27 (0.06-0.5)	7 (0.1-1.5)	45 (0.05-5.1)
Imazalil (F) (MRL=5)	Nil	1 (1.1)	Nil	Nil
Maleic hydrazide (PGR) (MRL=50)	10 (4.2-42)	18 (0.7-11)	13 (1.3-8.4)	Nil
Oxadixyl (F)	-	Nil	4 (0.02-0.03)	Nil
Propham (SS)	Nil	1 (0.1)	Nil	Nil
Tecnazene (SS) (MRL=0.05)#	Nil	13 (0.01-0.1)	Nil	2 (0.07-0.3)
Thiabendazole (F) (MRL=15)	-	Nil	3 (0.07-0.4)	3 (0.08-0.3)
MRL exceedances	0	0	0	0

Imported potatoes for processing

	1994	1998	2001	2001
Potato product	Crisps	General	General	Crisps
Total samples	1	13	16	13
No. samples with no residues detected	1	4	12	1
% samples with no residues detected	100	30.8	75	7.7
Chlorpropham (SS)	Nil	9 (0.06-1.2)	4 (0.1-0.4)	12 (0.05-4)
Imazalil (F) (MRL=5)	Nil	Nil	Nil	Nil
Maleic hydrazide (PGR) (MRL=50)	Nil	Nil	Nil	Nil
Oxadixyl (F)	Nil	Nil	Nil	Nil
Propham (SS)	Nil	Nil	Nil	Nil
Tecnazene (SS) (MRL=0.05)#	Nil	Nil	Nil	Nil
Thiabendazole (F) (MRL=15)	-	Nil	Nil	1 (0.1)
MRL exceedances	0	0	0	0

Key to symbols and abbreviations:

MRLs shown are the most recent values presented in the 2004 PRC survey report for the potato crop. 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 = pesticide not found
* = one MRL exceedance found
** = two MRL exceedances found
# = prior to 2003, there was a CAC MRL for tecnazene of 20 mg/kg. There were no MRL exceedances at this level.

Pesticide types:
D = desiccant; F = fungicide; N = nematicide; PGR = plant growth regulator; SS = sprout suppressant.

Pre-harv. = in 1994 samples were taken specifically to look for residues of the pre-harvest desiccants, diquat and glufosinate.

APPENDIX C. Summary of pesticides approved for use on potatoes and their uses

a) Nematode & insect pests

Problem	Method of treatment	Active substance(s) approved	Comment
Potato Cyst Nematode (PCN)	soil fumigation soil applied nematicide	1,3-dichloropropene aldicarb, ethoprophos, oxamyl, fosthiazate	Used on a small minority of heavily PCN infested farms Ethoprophos rarely used for this purpose
Spraing vector nematodes	soil applied nematicide	aldicarb, oxamyl	Aldicarb dominates this market but is likely to be replaced by oxamyl
Slugs	baits	Metaldehyde, methiocarb, thiodicarb	Variety and soil type determines need for treatment.
Wireworm	soil applied insecticide	Ethoprophos, fosthiazate	This is an increasing problem affecting quality.
Cutworm	foliar insecticide	chlorpyrifos, cypermethrin	Treatment specifically for cutworm is infrequent.
Aphids	soil applied insecticide foliar insecticide	aldicarb, oxamyl lambda-cyhalothrin, nicotine, pirimicarb, pirimicarb + deltamethrin, pymetrozine	Aldicarb is often used for seed potato production. Dominated by pirimicarb, some lambda-cyhalothrin and pymetrozine also used.

b) Diseases

Problem	Method of treatment	Active substance(s) approved	Comment
Skin spot	Seed and/or treatment	2-aminobutane, imazalil, imazalil + thiabendazole, thiabendazole	GB seed normally imazalil-treated. King Edward often additionally treated with 2-aminobutane to reduce skin spot. Seed from the Netherlands is normally treated with imazalil + thiabendazole.
Gangrene	seed and/or treatment	2-aminobutane, imazalil, imazalil + thiabendazole, thiabendazole	Not a common storage rot nowadays and not a specific target for seed treatment.
Dry rot	seed and/or treatment	imazalil, imazalil + thiabendazole, thiabendazole	Not a common storage rot nowadays and not a specific target for seed treatment.
Black dot	pre-planting soil treatment	azoxystrobin	Some crops destined for high-grade pre-pack outlets are treated.
Silver scurf	seed and/or treatment	imazalil, imazalil + thiabendazole, imazalil + pencycuron, thiabendazole	
Black scurf &	seed treatment	iprodione, flutolanil,	Pencycuron is the most

stem canker		imazalil + pencycuron, pencycuron, thiabendazole, tolclofos methyl	frequently used seed treatment. Much smaller quantities are treated with tolclofos methyl or flutolanil.
	pre-planting soil treatment	azoxystrobin	Azoxystrobin is applied to the soil at planting and currently is the only fungicide with a label claim for the control of soil-borne inoculum
Late blight	foliar spray	benalaxyl + mancozeb, copper, chlorothalonil, cyazofamid, cymoxanil + famoxadone, cymoxanil + mancozeb, cymoxanil, dimethomorph+ mancozeb, fenamidone + mancozeb, fenamidone + propamocarb hydrochloride, fenamidone + mancozeb, fluazinam, metalaxyl-M + mancozeb, metalaxyl-M + fluazinam, mancozeb, maneb, mancozeb + chlorothalonil, propamocarb + chlorothalonil, propamocarb + mancozeb, zoxamide + mancozeb	Proprietary formulations are dominated by mixtures containing mancozeb. This is considered important as a resistance management strategy.

c) Herbicides

Problem	**Method of treatment**	**Active substance(s) approved**	**Comment**
General weed control	pre-emergence spray	carfentrazone-ethyl, clomazone, cyclozydim, glufosinate-ammonium (& mixtures), linuron, metribuzin +/- flufenacet, paraquat +/- diquat, pendimethalin (& mixtures)	Main active substances used are paraquat +/- diquat, linuron, metribuzin +/- flufenacet, clomazone.
	post-emergence spray	glufosinate-ammonium (& mixtures), linuron , propaquizafop, cycloxydim, rimsulfuron, bentazone.	Market is dominated by rimsulfuron, except where only grass weeds are present, when cycloxydim or propaquizafop are preferred.
Haulm desiccants	foliar spray pre-harvest	carfentrazone-ethyl, diquat, glufosinate-ammonium, sulphuric acid.	More than one active substance may be used in a sequence at reduced rates.

d) Sprout suppressants

Problem	**Method of treatment**	**Active substance(s) approved**
Volunteer potato	Foliar spray pre-harvest	maleic hydrazide

control		
Sprout suppressant	Foliar spray pre-harvest In store treatment	maleic hydrazide chlorpropham (CIPC) ethylene (commodity approval)

e) Specific Off-label approvals (SOLA)

Problem	**Method of treatment**	**Active substance(s)**	**Comment**
black dot control	pre-planting soil treatment	Azoxystrobin (SOLA expires in June 2008 but has been superseded by a full label approval)	Some crops destined for high-grade pre-pack outlets are treated.

APPENDIX D. Selected recent & ongoing research projects funded by Defra

Please refer to page 42 for details of Defra website. where further information can be obtained.

Pests

Potato Cyst Nematode (PCN)

Impact of nematophagous fungi on the regulation of potato cyst nematode populations.
Project Code HP0115

This project aims to increase understanding of the ecology of parasitic fungi that attack potato cyst nematode (PCN) females and eggs and to measure the importance of these fungi in reducing the multiplication of *Globodera pallida* populations. Previous research has concentrated on the parasitic phase of the fungi and not addressed the factors that affect saprophytic growth because adequate techniques for isolating the fungi from soil and roots have not been developed. Hence, if applications of the fungi failed to control PCN populations it was not known if this was a result of the failure of the inoculum to survive or that it was present but not sufficiently active. The proposal builds on previous MAFF funded research (HP0126) that identified three species of fungus, an *Acremonium sp*., *Paecilomyces lilacinus* and *Verticillium chlamydosporium* that were found to parasitise potato cyst nematodes (PCN) and to cause significant reductions in infestations of the nematodes. The fungi were often found in the same soil. These fungi have provided control of PCN in glasshouse and plot trials that would be commercially exploitable. However, the levels of control have been inconsistent.

Nematode destroying microbes and the decline of potato cyst nematodes.
Project Code HH3110SPO

This one-year proposal assessed whether nematophagous fungi and the bacterium, *Pasteuria penetrans* were able to increase the rates of decline of potato cyst nematode (PCN) populations between potato crops. Recent research on PCN conducted within DEFRA project HP0115, indicated that PCN eggs within cysts are susceptible to fungal attack in soil. This finding suggests that PCN populations may be further reduced between potato crops and provide the potential for reducing recommended crop rotations on nematode infested land. The main nematophagous fungi affecting PCN populations are *Pochonia chlamydosporia, Plectosphaerella cucumerina* and *Paecilomyces lilacinus*, which caused significant (>40%) reductions in the number of eggs surviving in soil after potatoes were grown in laboratory experiments. If successful, this research could provide an alternative to chemical control of this increasingly important pest of potatoes in the UK.

Development of a robust assay to estimate the viability of potato cyst nematodes Globodera spp. Project Code HP0143

The potato cyst nematodes (PCN) *Globodera pallida* and *G. rostochiensis* are the most problematic pests of the UK potato crop and cause estimated annual losses of 9% of potato production. The corresponding loss at market value has been estimated at £43M, based on the mean value of the crop from 1990-1995. A 1997/98 survey showed that approximately 64% of potato growing land sampled in England and Wales was infested with PCN. Approximately 28,000 ha of potatoes are treated annually with the nematicides at a cost of £9 million to potato producers.

This research project seeks to develop an improved laboratory based method for determining the viability of potato cyst nematodes (PCN). When commercial assessments of PCN population densities are made it is assumed, in the several thousand tests made each year, that all the eggs are viable. This may not be the case and population densities may be being overestimated and in some situations nematicides used where they are not required. Accurate assessments of viable nematode populations would have important implications for the potential to reduce residues caused by certain nematicides.

Integrated control of PCN.
Project Code LK0918

The problem and the researchable constraint: Potato cyst nematodes (PCN), *Globodera pallida* and *G. rostochiensis*, cause substantial damage to the potato crop in the UK, estimated to cost the industry £50 million annually. They are persistent soil-borne pests and their incidence in potato land is increasing - a recent survey showed that 64% of potato land is now infested. Of this, some two thirds of infestations are pure *G. pallida* and 92% consist at least partly of this species. Since *G. pallida* (to which even the best resistance is only partial) is more difficult to control than *G. rostochiensis*, growers are using increasing amounts of nematicides for PCN control, sometimes using a fumigant and a granular nematicide on a single potato crop. Close to 30,000 ha are treated with granular nematicides each year, at a cost of more than £10 million. New approaches to the management of PCN population densities in soil and lessening the damage they cause are required in order to keep the UK potato industry competitive. These include the exploitation of precision agriculture technology to place nematicides only where they are required, and encouragement of growers to use procedures such as trap cropping, by identifying alternative trap crop species and providing a more scientific base for trap crop management. Enlightened management procedures are particularly important in the longer term since it must be a prime objective to protect potato land as yet uninfested with PCN.

<u>Aphids</u>

Plant nutritional quality as a determinant of the seasonal aphid population `crash` on potato.
Project Code HP0131

Aphids, principally *Myzus persicae* and *Macrosiphum euphorbiae*, are important pests of the potato crops affecting the entire UK area, reducing yield by both virus transmission and direct feeding damage. The pattern of aphid population development is characterised by mid-season population crash which can leave virtually aphid-free plants. This project is designed to develop significantly our understanding of the factors controlling aphid population dynamics on potato. The primary scientific aim is to test the hypothesis that changes in the nutritional status of the potato plant are the primary determinants of the mid-season crash in aphid populations on potato. If this is substantiated, the project will contribute to developing management strategies which should substantially reduce aphicide usage on both seed and ware (averaging 2 applications/crop) potatoes by preventing treatment of populations which are committed to decline naturally. This innovative approach to reduce pesticide application, both in the context of the principles of integrated Crop Management (ICM) and to help reduce the build-up of insecticide-resistant aphid populations, especially of *Myzus persicae*. The mid-season crash in aphid population phenomenon is also common to many aphids utilising a wide range of horticultural crops. This work may provide insight into the processes generally involved in the mid-season crash in populations of important horticultural aphid pests and help reduce pesticide input and the potentials for pesticide residues.

Tri-trophic interactions determining aphid phenology on potato.
Project code HP0141

Aphids, principally *Myzus persicae* and *Macrosiphum euphorbiae*, are important pests of potato crops affecting the entire UK crop area. They reduce yield by both virus transmission and direct feeding damage. Like many other aphid species, *M. persicae* and *M. euphorbiae* reproduce rapidly in early summer, but then populations crash from peak abundance to virtually zero within a few days, usually during July. Understanding the underlying physiological and biological processes controlling these crashes is critical to the development of environmentally beneficial and sustainable pest management practices. The aim of the proposed research is to build on project HP0131 which advanced our understanding of the relationship between crop physiology and aphid phenology. Also to test the hypothesis that the aphid population crash on potato is mediated by the interaction between key plant nutritional factors and proximal determinants (natural enemies, weather etc). Defra funding is appropriate as the work will continue to provide new insights into the generic topic of aphid population dynamics on crop plants and will therefore underpin sustainable crop production especially in low/no insecticide systems. At a strategic level, the work will help optimise 'natural' processes to enhance crop health and yield without environmental damage or financial cost to the farmer through reduced use of insecticide sprays.

Diseases

Potato Late Blight

Potatoes: field and crop-based forecasting for potato blight.
Project Code HP0110

This project compared UK, European and USA systems used to forecast outbreaks of potato blight (*Phytophthora infestans*). Over a three year period and across five sites in England & Wales, the Smith Period model proved to be one of the best in terms of warning before blight actually occurred. However, in some situations the warning was given too far in advance of blight outbreaks and would have triggered early and possibly unnecessary spraying in commercial practice. Non of the forecasting systems were consistent across all sites and all years reinforcing the need to use them as an aid to decision making on spray frequency rather than as a prescriptive tool.

Automated field detection and enumeration of fungal spores of *Phytophthora infestans* using flow cytometry:
Project Code HP0132T

Current methods for predicting the occurrence of late blight of potato rely on climatic modelling to identify conditions conducive to pathogen reproduction and thus of disease spread. However, there is currently no direct method in routine use to identify when aerial propagation of sporangia from initial disease foci begins. It is proposed to design and test an automated system for the trapping of airborne sporangia and their enumeration using a novel portable flow cytometer (Microcyte). Information on the presence of primary inoculum will better target fungicide use and intensity of treatment and reduce the potential for residues to occur.

Risk assessment of recombinant progeny of *Phytophthora infestans*: pathogenicity and fungicide sensitivity.
Project Code HP0134

Progeny from a matrix of in vitro and in vivo matings between the most common UK A1 and A2 mating type clonal phenotypes of *Phytophthora infestans* will be characterised for three epidemiologically important traits. Firstly, pathogenicity (virulence and aggressiveness) of parent and single oosporic progeny will be assessed using detached leaflets. Secondly, sensitivity to commonly used fungicides (metalaxyl, propamocarb, fluazinam) in sexual progeny will be evaluated. Environmental conditions for optimal survival, germination, infection, growth and sporulation of asexually reproducing *Phytophthora infestans* will be re-evaluated by comparing 'old' displaced, 'new' migrant and sexually-recombinant isolates using controlled environmental conditions. Data will be compared with existing criteria linked to biotic/abiotic factors associated with meteorological parameters used in current (Smith Periods) and emerging late blight forecasting systems.

The proposal meets the policy objectives of:

a) underpinning the industry's competitiveness and market responsiveness by providing improved disease control through a greater understanding of host/pathogen interactions,

b) exploiting the wider benefits of developing integrated farming systems through the use of forecasts in combination with agronomic elements and

c) the need to minimise chemical and energy inputs while maintaining production and effective control of plant disease by better timing and justified application of fungicides.

Tuber Blemish & Storage Diseases

Epidemiology of the soil-borne phase of potato tuber blemish diseases.
Project Code HP0125T

The main objective of this proposal is to investigate the epidemiology of the three main potato tuber blemish diseases - common scab *(Streptomyces scabies),* silver scurf (*Helminthosporium solani*) and black dot (*Colleotrichum coccodes*) in relation to current husbandry practices of ware potato production. It is important to understand how husbandry techniques and environmental conditions interact with the different pathogens and how this knowledge can be used to reduce the overall skin blemish problem. A successful outcome of this project will greatly supplement our current knowledge on the control of these pathogens i.e. the need to ensure maximum levels of seed health, of the use of fungicide seed treatments and the need for strict hygiene in seed and ware stores. The development of an integrated approach to the control of potato tuber blemish diseases would meet the declared policy objectives by advocating a strategy of safe, cost effective production of a high quality ware potatoes with minimal reliance on the use of pesticides.

Blemish diseases of potatoes - physiology and biochemistry of skin set and skin netting.
Project Code HP0140

The appearance of the skin of potatoes is a critical factor in consumer choice. The UK industry currently losses approximately £13M p.a from poor skin quality, as a result of poor skin set and excessive skin \`netting\`. Skin formation and adhesion to the underlying tissues is clearly linked to foliage growth/senescence, but the processes are poorly understood. This lack of understanding not only impedes the development of systems of production to produce different types of skin set to meet market needs, but also the development of better-informed, environmentally-friendly approaches to current chemical methods for haulm destruction. The objectives of the work are to understand the biochemical and physiological basis of skin formation and skin set, the development of skin disorders and identifying how these can be manipulated by agronomic practices to meet market requirements more reliably. This programme links closely with a British Potato Council (BPC) funded programme on skin set and skin disorders. This proposed DEFRA-funded project underpins this BPC project and, at the same time, the BPC-funded work forms the conduit for the development and transfer of improved practices for manipulating skin quality to the industry.

The achievement of suitably set skins on tubers depends upon a strategy of haulm (foliage) destruction, in the main, by chemicals and new ways to reduce reliance on those in current use will need to be developed. This project should improve the understanding of the biochemical and physiological processes involved, in the link between skin set and senescence/maturity and how these processes and relationships are influenced by variety, agronomic factors and environmental conditions. The industry continues to rely heavily on chemical destruction and to reduce this, initially, by redirecting haulm destruction strategies, a better understanding of the mechanisms of skin formation in response to haulm destruction will be required. The proposed strategic work is vital so that the industry can develop better-informed, environmentally friendly approaches for manipulation and prediction of skin characteristics and so meet more effectively the qualities required by the consumer.

Control of potato storage diseases by laser treatment.
Project Code LK0919

There has been increasing consumer concern about chemical residues on potato tubers as well as the risk of exposure of farm staff to fungicides. Current fungicide treatments do not fully control the range of economically significant diseases such as silver scurf, black dot, soft rot, gangrene and dry rot. The aim of this project will be to research and develop a novel form of treatment for potato storage diseases, based purely on a laser energy absorption mechanism. An advantage of this technology is that it is chemical free, therefore no chemical residues remain after treatment. Evidence is now emerging of fungal infections becoming insensitive to certain fungicides, due to their extensive use. The proposed treatment offers a new mode of action and may also complement existing treatments in future treatment strategies.

Potato storage

Suppression of sprouting in stored potato tubers by molecular manipulation of abscisic acid levels. Project Code HP0212

Maintenance of high quality potato tubers in storage currently relies on a combination of low temperatures and the application of sprouting inhibiting chemicals. Low temperature storage is expensive and results in cold sweetening and poor suberization. The literature indicates that abscisic acid (ABA) has a major role in maintaining potato tuber dormancy and that falling levels of ABA allow the initiation of sprouting. If endogenous ABA levels could be raised, the period of tuber dormancy could be increased without reliance on cold storage or chemicals. Thus, this work aims to reduce chemical applications to the stored crop (farm gate value about £500 million) and improve the quality of produce from store as well as minimising the residues of the most commonly used sprout suppressant CIPC.

Organic Production

Varieties of field vegetables and potatoes for organic production and marketing.
Project Code OF0142

During organic farming of field vegetables, choice of variety is more critical than in conventional farming, where problems can be solved at a later date by application of pesticides or fertilisers; varieties are required that can respond favourably to the sometimes sub-optimal conditions imposed by organic cultivation. This study will aim to investigate the suitability of selected varieties of vegetables and potatoes for organic production. Trials will be conducted on UKROFS approved sites with early carrots (12 varieties), broccoli (var. calabrese; summer and autumn crops), lettuce (iceberg types), onions (5 set varieties and 5 module set types), novelty salads, parsnips (up to 10 varieties) and potatoes in order to generate information and advice on the most appropriate variety choice for organic producers and to assist the breeding industry in identifying important characteristics for organic production. Trials will involve measurements of a range of growth parameters and quality attributes on crops selected for study. Shelf life tests will be conducted with selected crops from trials and compared with results from conventional produce. Individual trial and crop one year results will be prepared in a form presenting data obtained with a summary of variety performance. For those crops studied, summary information and advisory guidelines for organic production will be prepared, including strategies for disease control and avoidance. Results of the study will assist in reducing the uncertainty of organic production by identifying varieties and strategies that will provide a greater possibility of producing high quality crops having high consumer appeal. Results will be widely circulated to the organic and horticultural industries via NIAB's well established results and publication schemes and will be reported to the horticultural and organic press.

In addition to relevance to the organic situation the research may identify useful variety characteristics and strategies that could be applied to conventional growing to reduce pesticide and fertiliser inputs.

Residue analysis

Investigation of glufosinate residue analysis in potatoes, soya products, legume and maize Project Code PR1153

Glufosinate is the shortened name for the glufosinate-ammonium salt and is extensively used as a non-selective contact herbicide against mono- and di-cotyledons and as pre-harvest crop desiccant. It is highly toxic and has an oral LD50 of about 300mg/kg for dogs. As a result there is a requirement for this herbicide to be included in the list of pesticides which are actively sought under the PRC (Pesticide Residues Committee) surveillance programmes. The currently available methods of analysis do not allow data to be generated which fulfil the quality requirements of the PRC. It is vital, therefore, that a suitable, and if possible efficient, validated method of analysis is developed and published widely. The analysis and results will conform to standards documented by the European Commission in the guidance document SANCO/835/00 rev 6 on residue analytical methods dated June 2000. It is planned for this method to be included in the proposed PRC methods compendium and used by laboratories for routine residue analysis.

APPENDIX E. Selected research projects funded by the British Potato Council. Project details are not currently available

Please refer to page 42 for details of BPC website where further information can be obtained. Note that BPC funded reports are only available to levy payers.

Project code	Title
R251	Integrated control for skin spot
807/245	BPC PCN Management Model
807/244	Late blight resistance in new cultivars
807/243	CIPC application and environmental issues
807/242	Blight - new active ingredients in GB
807/241	Late blight mating types
807/235	Review and development of the CIPC application process and its impact on potatoes stored for processing
807/231	Independent Variety Trials and variety selection
807/233	Wireworms - evaluation of pheromone traps
807/229	Nematicide degradation
807/217	Techniques and strategies for precise targeting and reduction of inputs for the management of PCN – SAPPIO LINK
807/213	Alternative strategies for the control of potato blight in organically grown crops
807/211	Epidemiology, autecology and control of potato powdery scab
807/208	CIPC effects on stored potatoes
807/205	Prediction and prevention of black dot
807/204	Aphid control with entomopathogenic fungi - SAPPIO LINK
807/202	Independent Variety Trials and variety selection (Project completed: Feb, 2002)
807/192	Better wireworm control to reduce waste and downgrading (Project completed: March, 2002)
807/189	Combating insecticide resistance in the peach-potato aphid (LINK)
807/188	Computer predictions of PCN for integrated control (Project completed: Sept, 2001)
807/181	Healthier seed for improved ware crop quality (Project completed: March, 2000)
807/131	Improved skin finish from resistance to blemish diseases
S178	Store disinfection (Project completed: June, 1999)
S173	Bioagents for storage disease control (Project completed: June, 1999)
S104	Optimising the use of CIPC (Project completed: June, 1999)

APPENDIX F. British Potato Council advisory literature

Grower Advice Sheets

Fight Against Blight 1 - Dump hygiene (republished 2004)
Fight Against Blight 2 - Seed health (republished 2004)
Fight Against Blight 3 - Planting (republished 2004)
Fight Against Blight 4 - Volunteer control (republished 2004)
Fight Against Blight 5 - Blight maps (updated 2004)
Fight Against Blight 6 - Spray application technique (updated 2004)
Fight Against Blight 7 - Spray programme (updated 2004)
Fight Against Blight 8 - Responding to a crop infection (republished 2004)
Fight Against Blight 9 - Irrigation (republished 2004)
Fight Against Blight 10 - Haulm destruction (republished 2004)
Fight Against Blight 11 - Harvest (republished 2004)
Fight Against Blight 12 - Store loading (updated 2004)
Fight Against Blight 13 - Storage (republished 2004)
Fight Against Blight - Advice for growers of organic crops

Potato late blight: Guidelines for managing fungicides resistance
from the Fungicide Resistance Action Group UK (FRAG-UK)

Labelling of UK and imported seed potatoes

Operator safety and crop usage

Guidelines for potato tuber application equipment

Chemical application on roller tables

Spray pattern check for tuber treatments

Rationalising the use of fungicides on seed potatoes during storage

Analysis of agrochemical products on potato tubers

Potato tuber diseases and their control

The improved targeting of sprays onto potatoes on roller tables

Effective application of granular nematicides for the control of potato cyst nematodes
Safe use of nematicides and calibration of machines (updated 2004)

New water legislation and how it will affect all potato irrigators (revised and updated December 2003)

Pre-planting seed health checklist (Republished for 2003)

Getting the best from CIPC - Optimising CIPC application and distribution in stored potatoes (October 2002)

Pre or at planting fungicide treatment for Rhizoctonia control
The move back to dry formulations

Store Hygiene Action Plan

Product Guide: Sprout Suppression (updated annually)

Product Guide: Fungicides (2002/3)

Register of (CIPC) hot-fogging contractors

APPENDIX G.

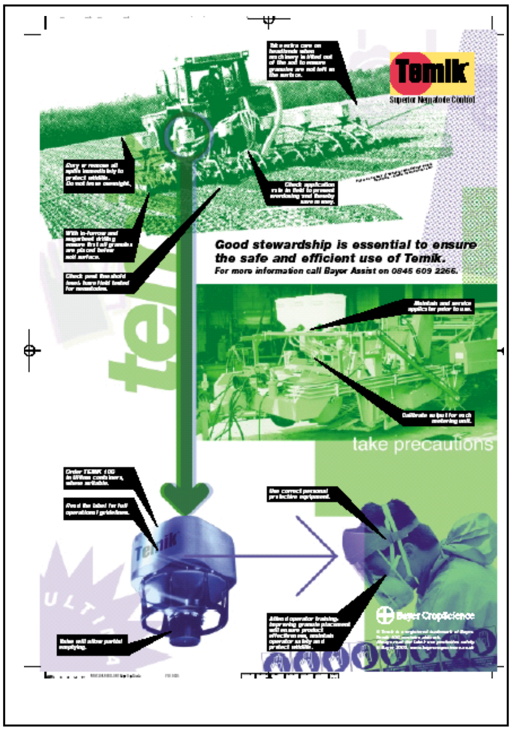
Bayer Crop Science - Nematicide Stewardship 2005

The following briefly outlines the activities carried out by Bayer CropScience for nematicide stewardship in 2005. A similar programme is planned for 2006.

1. Stewardship messages via direct mail

In 2003/4 there was an extensive postal campaign with 6000 potato, carrot and onion farmers being sent stewardship advice. This was repeated for 2005.

2. Promotion of training



- potato specialist meetings were held with agrochemical distributors, agronomists and packers - 'The Need for Stewardship'
- agrochemical distributors were trained to provide Bayer CropScience nematicide stewardship to their growers
- other players in the food supply chain (e.g. processors & supermarkets) were informed about the stewardship programme in order to ensure grower participation
- a stewardship poster (opposite) has been produced as a reminder to operators of best practice and stewardship

3. Stewardship training days for operators

Operators, advisors and distributors were trained by Bayer CropScience on operator safety, the safe use of nematicides, calibration and set up of application equipment (to ensure correct and accurate application rate) and environmental protection (e.g. immediate incorporation of granules following application). Attendees were awarded NRoSO (National Register of Spray Operators) points.
Ninety operators were trained and certificated in 2003 and 263 in 2004.

4. Applicator MOT's

Bayer CropScience provided, as in previous years, a budget to subsidise MOT and calibration services on a range of applicators.

5. Pest monitoring

Soil testing for monitoring PCN levels is encouraged (i.e. justification of use) as part of an ICM approach.

6. Promotion of stewardship in the press

In 2003/2004 stewardship training and messages were promoted heavily in the major grower journals, e.g. Farmers Weekly, The Grower etc. (see below). This was continued for 2005.

Nematicide stewardship push

By Charles Abel

A WINTER CAMPAIGN of stewardship meetings to encourage the safer use of nematicides has been launched by Bayer CropScience, in the latest part of its campaign to preserve the use of Temik (aldicarb) beyond 2007.

The goal is to train 1000 operators, through workshops run in conjunction with key distributors, packers and British Sugar. The half-day sessions will run until the end of February and score three continuing professional development points towards the National Register of Sprayer Operators.

"There is a misconception that Temik will be lost after 2007, but it will actually be subject to re-review, so it is important for us to address these issues," says Steve Higginbotham, environmental stewardship manager at Bayer CropScience's headquarters at Hauxton, Cambs.

Although the main focus is Temik, the sessions apply to all nematicides, he adds. "All nematicides are subject to similar environmental issues."

The sessions will focus on Temik use in potatoes, carrots, parsnips, onions and sugar beet, even though 2004 will be the last season Temik can be used in beet. Safe use, avoiding spills and operator exposure, calibration, correct soil incorporation and headland management will all be covered.

Bayer is also supporting distributors with funding for PCN testing, as required under the Voluntary Initiative's Crop Protection Management Plans and applicator MOTs under the National Sprayer Testing Scheme.

An on-line e-learning tool to aid the use of nematicides is also being developed at a cost of £30,000. ■

Temik has not been banned post-2007, it just faces a re-review, making stewardship all the more important, says Bayer's Steve Higginbotham.

7. Introduction of a new cartridge system

New for 2005, cartridges have been developed for Bayer CropScience nematicides that can be fitted to the rotors of applicators to help make the calibration procedure easier. The cartridges will ensure that all rotors are delivering the same dose rate and ensure the correct and even distribution of products, thereby limiting the potential for areas of higher concentration and the possibility of an incurred residue.

8. Investigation of the use of clutches

In order to ensure that granules are not left uncovered at the end of rows, Bayer CropScience will be investigating further the use of clutches. When fitted to an applicator, the clutch allows the drive shaft to be disengaged from the cab, thereby stopping the flow of granules.

9. Recommending the use of 'fish-tail' applicators

When nematicides are applied in-furrow, the use of 'fish-tail' applicators allows granules to be spread more evenly, thereby further reducing the possibility of residues occurring in the harvested crop. Field studies conducted with food chain partners in 2003 have resulted in retailers, potato processors and pre-pack suppliers supporting the use of 'fish-tail' applicators.