FOOD STANDARDS AGENCY

PESTICIDE RESIDUE MINIMISATION

CROP GUIDE

TOMATOES

Plan Author: Nick Caspell, Dan Drakes & Dr Tim O'Neill, ADAS

Editors: Nick Bradshaw, Sue Ogilvy, ADAS and the FSA

November 2006

Contents

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 authors' 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.

The Food Standards Agency is not responsible for, and cannot guarantee the accuracy of, information on internet sites that it does not manage; nor should the inclusion of an internet link be taken to mean endorsement by the Food Standards Agency of the site to which it points.

Preface

Why choose tomatoes 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. Tomatoes form a significant part of the UK diet and UK tomato production represents a particular example of how residues can be reduced.

Much work has been done by those involved in the UK food industry to keep pesticide residues to a minimum. In UK tomato production, residue reductions have been achieved by the use of biocontrol methods, facilitated by growing in protected environments that can be finely controlled. Growing in a protected environment, such as a greenhouse, is very different from growing in an open environment. However, it is hoped that the lessons learnt by UK tomato production can be applied to other protected crops. 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 – Tomatoes

1. Introduction

1.1 Crop description

Tomatoes are the most important glasshouse salad crop grown in the UK, in terms of area cropped and value. The wild ancestors of the cultivated tomato, *Lycopersicon esculentum,* probably originated in South America as a small-fruited cherry type. The crop grows naturally as a bush, but commercially only the main shoot is retained and trained up strings. During the growing season (earliest crops are planted in November and remain in the glasshouse for almost 12 months) the tomato plant may produce up to 15 metres of stem which is layered in the growing house to reduce height.

Historically, many tomato crops were spring-planted in rotation with winter lettuce crops, and often grown with little or no heating. The unheated crop has now almost disappeared due to uneconomic returns, and most crops are fully heated, occupying the glasshouse almost continually, with no break crops.

Until the late 1970's, crops were grown in soil, but with the advent of hydroponic (substrate) growing systems, most crops are now grown in inert media such as rockwool. Crops are grown with minimal use of pesticides, making use of beneficial organisms where possible, and bumble bees for pollination. Many glasshouses are now modern, tall structures with excellent light transmission and computer controlled climate control. Energy costs to heat the greenhouses are a major factor in the production costs, with labour costs also a significant element.

1.2 Uses and markets

For many years, the standard red-fruited, round tomato was the only type grown commercially in the UK. Within the last 20 years, the market has diversified, first with cherry tomatoes, then with intermediate and beefsteak types. Now there are many types available, including vine-ripened or truss tomatoes, cocktail, plum, mini-plum and so-called 'heritage' varieties. Standard round (sometimes called "classic" tomatoes) only account for a little over half of the area grown (Table 1). Of the above categories, approximately 70% are harvested and marketed loose, and 30% on the vine. Growth in sales of organic tomatoes has now slowed, with around 7.4% of the area down to organic production.

Almost all UK-grown tomatoes are sold to the fresh market, with virtually none grown for processing. The major multiple retailers now account for around 85% of sales, with wholesale markets losing their traditional share. Many tomatoes are pre-packed, but loose sales are still important for standard round types.

Supermarkets require continuity of supply of a product, rather than seasonality. This entails sourcing products from abroad as required, to supplement the UK season, as home-grown, all-year round production is not yet an economic proposition for most producers. The multiple retailers prefer to deal with large suppliers such as producer groups or specialist packers and importers, rather than dealing with several small individual production businesses to source produce.

Table 1. Tomato types and percentage of area grown 2002-2004
(Source: © Tomato Growers Association 2004, UK and Channel Island TGA members)

				Loose Picked Fruit				
Year	**Cherry**	**Cocktail**	**Classic**		**Plum**		**Beef**	**Total**
				Mini	**Midi**	**Large**		
2002	6.3	0.7	50.0	9.9	1.3	0.9	1.5	70.6
2003	8.9	0.2	47.7	7.8	1.9	0.8	1.8	69.1
2004	10.8	0.7	45.4	9.0	1.9	1.0	2.5	71.5

				Vine Harvested Fruit				
Year	**Cherry**	**Cocktail**	**Classic**		**Plum**		**Beef**	**Total**
				Mini	**Midi**	**Large**		
2002	3.1	6.6	17.1	0.1	2.5	0.0	0.0	29.4
2003	3.5	7.9	17.0	0.2	2.2	0.0	0.0	30.9
2004	3.0	8.1	14.2	0.0	2.7	0.4	0.0	28.5

				Total Area*			
Year	**Cherry**	**Cocktail**	**Classic**		**Plum**		**Beef**
				Mini	**Midi**	**Large**	
2002	9.4	7.3	67.1	9.9	3.9	0.9	1.5
2003	12.5	8.1	64.7	8.0	4.1	0.8	1.8
2004	13.9	8.8	59.6	9.1	4.7	1.5	2.5

* Total area may differ from sum of loose picked and vine harvested fruit due to rounding of data

Quality of the fruit is paramount. Not only must the produce be grown to exacting standards, but with several UK multiple retailers, the whole production business must conform to certain environmental codes to eliminate unnecessary risks to the environment.

Currently, British tomatoes are seen as a premium product in comparison to imports. There is an ongoing tomato publicity campaign and a re-branding of British tomatoes featuring their health-giving properties, to stimulate awareness and demand.

1.3 Area grown in the UK, volume produced and value

Tomatoes were traditionally grown in areas of the country with good soil types, good natural light levels and within reach of local markets. The advent of hydroponic growing and national transport systems for produce has removed two of the requirements, but tomatoes are still mainly grown in the traditional areas of the south coast (West Sussex and Kent), the north-west (Lancashire) and the north-east (East Yorkshire).

Nurseries range in size from small traditional family-run enterprises of less than 1 hectare, to companies with large units of up to 10 ha of production. Details of UK tomato production are shown in Tables 2-4.

Table 2. Tomato Production (England & Wales) 2001-2003
(Source: Defra/January 2004 Glasshouse Survey)

Tomato type		**Area grown (ha)**	
	2001	**2002**	**2003**
Standard, round, classic, beefsteak	#	165	123
Cocktail	#	18	18
Plum	#	24	24
Cherry	34	25	32
Total tomatoes	276	231	197

data not collected. No survey was carried out in January 2005

Table 3. Tomato production (UK) 2004
(Source: Defra/Basic Horticultural Statistics)

Volume produced* (tonnes)	Value* (£m)
78,500	58.4

* includes all types of tomato

Table 4. Tomato production estimates (England & Wales) 2005
(Source: Defra/ADAS UK Ltd.)

Tomato type	Production area (ha)					Area grown (ha)	Volume produced (tonnes)
	E	SE	NW	NE	Other		
Vine	0	17	4	9	3	28	16,110
Cherry	6	18	5	5	6	40	10,270
Round, plum and others	22	33	10	30	13	108	53,310
Total	28	68	19	44	27	186	79,690

Despite a continuing fall in production areas, output has been maintained by improved yields, doubling production per unit area over the last 25 years. Prices have fallen in real terms.

1.4 Volume imported and value

The UK is a net importer of tomatoes, with home production now representing less than one fifth of the total consumption (Table 5).

Table 5. UK tomato statistics 2004
(Source – Defra/Basic Horticultural Statistics)

Volume produced in the UK (tonnes)	Volume imported (tonnes)*	% of total consumption home-grown
78,500	393,000	17

* includes Channels Islands

A small increase in the consumption of tomatoes in the UK in the last few years has been met by increases in imports. The home production proportion appears to be falling, but much of the increased import quantities are entering outside of the home production season, as the multiple retailers offer most of the range of tomato types over the whole twelve months of the year.

Spain and the Canary Islands constitute the biggest import source, mainly during the winter months in the UK, with countries such as Israel and Italy contributing cherry and plum tomatoes. Holland is still a major exporter, especially during the UK's home production season.

Table 6. Imports of tomatoes into the UK in 2003
(Source: HM Revenue and Customs)

Country	**Volume (tonnes)**	**Value (£000)**
Spain	173,723	156,781.3
Netherlands	133,503	137,848.4
Italy	9,114	9,642.9
Germany	8,205	7,369.6
France	5,369	4,143.4
Belgium	4,592	3,298.0
Irish Republic	1,614	1,464.9
Portugal	887	1,593.7
Greece	14	7.5
Denmark	6	8.0
Total EC	**337,028**	**322,158.0**
Israel	2,864	2,663.6
S. Africa	337	179.8
Turkey	334	225.2
Senegal	287	211.9
Morocco	239	85.1
Egypt	202	211.1
Poland	179	144.3
Ivory Coast	74	48.0
Iceland	27	11.5
Switzerland	22	20.6
Tunisia	21	17.0
Czech Republic	19	4.7
Saudi Arabia	6	3.2
U.S.A.	5	3.8
Argentina	1	0.6
Total other countries	**4,615**	**3,832**
All countries	**341643**	**325,990**

2. Pesticide use on tomatoes

2.1 Problems requiring the use of pesticides

The key pest and disease problems in tomatoes, which can require the use of pesticides, are listed in Table 7. The problems are rated for their importance according to their effect on crop yield and also for the occurrence of residues that might arise from the use of pesticides to control the problem.

Table 7. Key pest and disease problems in tomatoes 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**	
Foliar pests				
Spider mites	*Tetranychus urticae*	***	**	Causes severe leaf damage and loss of yield.
Glasshouse whitefly	*Trialeurodes vaporariorum*	***	*	Causes feeding damage to leaves and can give rise to sooty moulds on fruit.
Tomato leaf miner	*Liriomyza bryoniae*	**	*	Causes leaf damage.
Mealy bugs	*Pseudococcus viburni*	**	*	Cause leaf loss and sooty moulds.
Macrolophus	*Macrolophus caliginosus*	**	*	Can cause feeding damage on young fruit.
Foliar/stem/root diseases				
Grey Mould	*Botrytis cinerea*	***	**	Attacks all aerial parts of the plant and causes 'ghost-spotting' on fruit.
Powdery mildew	*Oidium neolycopersici*	**	*1	Attacks leaves, stems and calyces.
Verticillium wilt	*Verticillium albo-atrum or V. dahliae*	**	-	Causes leaf wilt and stem collapse.
Root rots	*Pythium, Phytophthora & Rhizoctonia solani*	*	-	Cause reduction in plant vigour and may cause plant collapse and death.

Note 1 – Two of the residues (azoxystrobin and bupirimate) found in PRC surveys reflect activity to control powdery mildew, but neither product is now commonly used for this purpose, as growers use mildew-tolerant varieties and sulphur sprays instead.

2.2 Pesticide use on tomatoes

Details of pesticides currently approved for use on tomatoes in the UK and biocontrol agents available in the UK can be found on the Pesticides Safety Directorate (PSD) 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 tomatoes every four years. The survey data are published in the Pesticide Usage Survey Reports, and these are available from CSL, York or on the CSL (www.csl.gov.uk/science/organ/pvm/puskm/reports.cfm). Information on the use of pesticides on tomatoes is available in Pesticide Usage Survey Reports – Protected Crops (Edible & Ornamental) in Great Britain. A summary of pesticide, soil sterilant and disinfectant use on glasshouse tomatoes in 1995, 1999 and 2003 is given in Tables 8 and 9. When making comparisons between years, it should be noted that the total areas of tomatoes grown in the UK in these years were 347 ha, 295 ha and 203 ha respectively. The reduction in area grown was mainly due to a loss in the area of unheated crops grown.

Table 8. Estimated area of crop treated and the number of applications of pesticides on tomatoes in Great Britain 1995, 1999, 2003.
(Source: Garthwaite & Thomas, 2005, Garthwaite & Thomas, 2000 and Thomas & Garthwaite, 1996)

Type of pesticide	Area of crop treated (%)			No. of applications		
	1995	**1999**	**2003**	**1995**	**1999**	**2003**
Insecticides & nematicides	35.4	26.4	10.1	*	1.3	1.4
Acaricides	53.1	32.5	52.2	*	1.9	2.6
Fungicides	75.5	40.3	69.4	*	1.9	3.5
Sulphur	#	41.6	38.8	*	1.6	2.1
Herbicides & desiccants	1.4	1.1	0.3	*	0.1	1
Growth regulators	6.8	-	-	*	0	-
Molluscicides & repellents	3.5	1.1	1.5	*	0.1	1
Biological control agents	77.2	75.2	80.6	*	23.9	25.8
Soil sterilants **	8.5	1.9	4.7	*	*	*
Disinfectants	57.9	14.2	16.2	*	*	*
Not treated	7.1	25.5	7.8	*	-	-
Other pesticides	-	-	-	*	0.7	1.1
Pesticides (excl. biocontrol agents)	-	-	-	*	7.4	5.3

sulphur was included in fungicides category in 1995 Survey
** mainly methyl bromide
* data not available

Table 9. Pesticide usage on tomatoes in GB, 1995, 1999, 2003 (treated ha and kg active substance used). (Source: Garthwaite & Thomas, 2005, Garthwaite & Thomas, 2000 and Thomas & Garthwaite, 1996)

	Treated ha			Total active substance used kg		
	1995	**1999**	**2003**	**1995**	**1999**	**2003**
Insecticides/Nematicides	400.9	264.5	25.4	1,929.0	578.0	127.0
Fatty acids	2.5	30.9	11.8	26.0	299.0	119.0
Acaricides	378.0	218.5	209.0	200.	91.0	60.0
Fungicides (total)	1,231.7	705.5	570.9	4,332	1,902	1,437
Sulphur	300.1	335.9	180.3	1,934	1,455	460
Herbicides	4.9	2.5	0.3	16	2	<1
Growth regulators	25·6	-	-	12	-	-
Molluscicides	18.1	3.1	7.7	9	-	4
Biological Control Agents & Pollinators	10,346.1	5,767.2	5,123.7	N/A	N/A	N/A
Soil sterilants	19.7	12.6	12.9	9,194	12,048*	7,789*
Disinfectants	118.8	53.5	45.9	4,376	2,669	1,627

* Includes methyl bromide which was withdrawn on 31/12/04.

These tables clearly illustrate the reliance on biological control agents for pest and disease control in commercial GB tomato production. There was also a dramatic decline in the amount of conventional insecticide use and a slight increase in the use of fatty acids as insecticides by both conventional and organic growers. Acaricides used for spider mite control have decreased since 1995. There was also a decline in the use of fungicides over the 1995-2003 period with sulphur being the predominant fungicide used. The trend towards a reduction in overall pesticide usage is driven by the use of beneficial insects as biological control agents and the need to maintain adequate predator/parasite populations. A number of pesticides can have adverse effects on beneficials. The most commonly used biological control agent is *Encarsia formosa,* a parasitic wasp which was introduced to control whitefly which is a major problem pest. Soil sterilisation declined between 1995 and 2003 with methyl bromide being withdrawn at the end of 2004.

Recent virus-related problems in tomato crops have increased hygiene measures on nurseries, particularly at the end of the season when preparing for the next crop. The threat to crops from the spread of Pepino Mosaic Virus and Potato Spindle Tuber Viroid have led to an increase in the general level of disinfectants, particularly those with claimed activity against viruses.

2.3 Grower practice

Examples of typical pesticide use by growers are detailed in Tables 10 and 11 for 2001 and 2002 (Source: British Tomato Growers Association (TGA)). The data come from six members of the TGA and whilst not representing the picture for all of the crop area for each grower, they do cover around 10% of the total tomato area in Britain and the Channel Islands.

Table 10. Pesticide use in 2001 for six TGA members (Source: TGA 2003)

	Grower No.						
	1	**2**	**3**	**4**	**5**	**6**	Total
Grower area (ha)	1.72	3.14	0.67	6.85	5.14	1.6	19.1
Fungicide (kg or l/ha)							Average
Azoxystrobin		1.59			2.14		0.84
Carbendazim				0.51			0.18
Copper oxychloride					17.52		4.71
Propamocarb hydrochloride				4.96	6.03		3.4
Iprodione						0.63	0.05
Pyrimethanil				0.31			0.11
Sulphur	4.77		2.99	12.7	11.29	5.01	8.54
Insecticide/Acaricide (kg or l/ha)							
Abamectin				0.47			0.17
Buprofezin		0.09					0.01
Fenbutatin oxide	0.03	0.46	1.01	0.29	4.87		1.53
Fatty acid - soap				0.15	5.84		1.62
Verticillium lecanii				0.18			0.07
Total (kg + litres/ha)	5	2	4	20	48	6	21

Table 11. Pesticide use in 2002 for six TGA members (Source: TGA 2003)

	Grower No.						
	1	**2**	**3**	**4**	**5**	**6**	**Total**
Grower area (ha)	1.72	2.62	0.67	6.85	7.22	1.6	20.7
Fungicide (kg or l/ha)							Average
Azoxystrobin				2.19	1.8	1.25	1.45
Carbendazim	2.33			1.31			0.63
Propamocarb hydrochloride	0.58			2.88			1.0
Fenarimol		0.25					0.03
Iprodione						0.63	0.05
Pyrimethanil		0.69		0.30	2.63		1.11
Sulphur	12.44	8.87		12.7	11.43	2.51	10.55
Insecticide/Acaricide (kg or l/ha)							
Abamectin				0.73			0.24
Deltamethrin		0.24					0.03
Fenbutatin oxide	0.13	1.59		0.04	0.48		0.39
Fatty acid – soap		11.45		20.44			8.22
Nicotine		0.23			10.25		3.58
Pirimicarb		0.17					0.02
Thiacloprid		0.20					0.03
Total (kg + l/ha)	15	24	0	41	27	4	27
Total cost pesticide (£/ha)	94	484	0	498	496	78	404
Total cost biocontrol (£/ha)	1066	3331	1004	649	3540	0	1992
Total cost bees (£/ha)	2860	2470	2870	2330	2460	2200	2443

On average, more units of pesticide (kg or litres) were used in 2002 than in 2001. This reflects an increase in the use of products containing sulphur and soap. (N.B. Costings data was not available for 2001)

There was also a marked difference in pesticide use between growers with Grower 3 being the lowest overall user, using no pesticides at all in 2002. Larger growers were using more pesticide than smaller growers. One possible explanation for this is that those growers who own and manage small nurseries may have a greater awareness of their crops and problems than managers of the larger nurseries.

Pesticide use will vary from year to year depending on which pest and disease problems occur. However, actual pesticide use is very low given that the tomato crops are grown for almost the whole year. Key components of good practice are attention to detail and nursery hygiene.

3. Pesticide residues on tomatoes

3.1 Pesticide residue survey data

Data on pesticide residues in tomatoes have been taken from the annual reports of the Working Party on Pesticide Residues (WPPR) for 1995 to 1998, and then from the quarterly Pesticide Residue Committee (PRC) survey reports from 2001 to 2004 (www.pesticides.gov.uk/prc_home.asp). Tomatoes were only sampled for routine tests in 1995, 1998, 2001 and 2004. A special survey was done in 2002 on Italian tomatoes to check for chlormequat residues. Because tomatoes are not regarded as a staple food product, sampling has been less frequent than some other commodities. Details of the pesticide residues sought and found in the surveys are given in Appendices A and B.

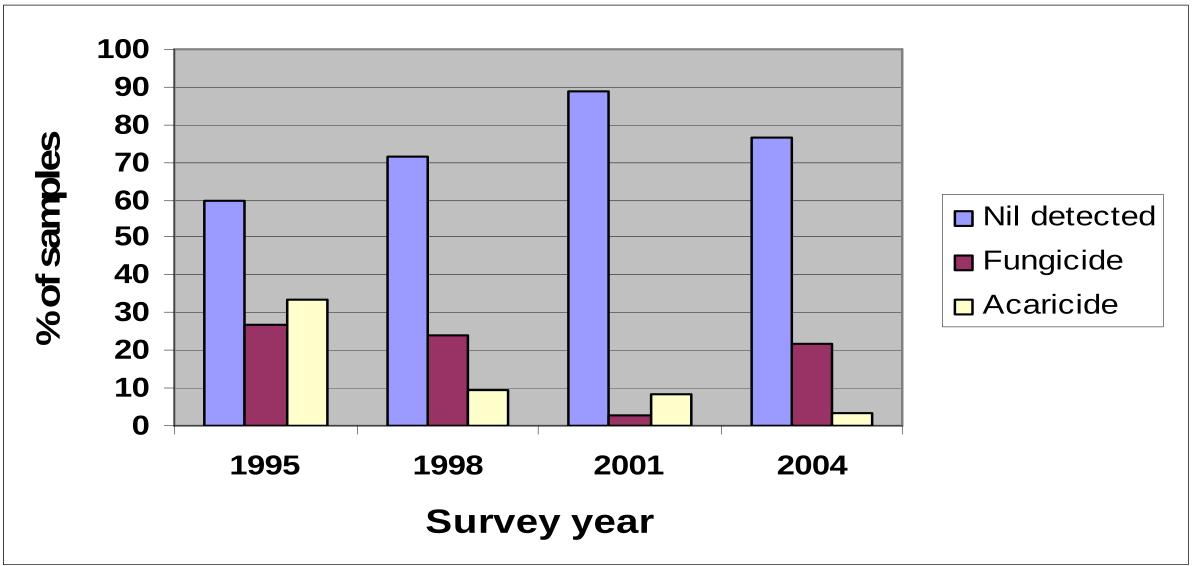
The number of pesticides sought over this period in the routine tests has varied from 36 to 112 active substances per year. The PRC choose which pesticides to test for based on information from the Pesticide Usage Surveys, the likely occurrence of a residue appearing based on degradation data and time of application, and the availability of a cost-effective analytical test.

3.2 Pesticide residue trends

3.2.1 UK produced tomatoes

A total of 131 UK tomato samples were analysed for residues over the four sampling years. Overall, there were no residues found in 77% of the UK samples from the PRC surveys. None of the residues found exceeded the available MRL.

Fig. 1. UK tomato samples analysed, percentage with no residues detected, and with fungicide or acaricide residues in 1995, 1998, 2001 & 2004 (Source: WPPR/PRC Survey data)

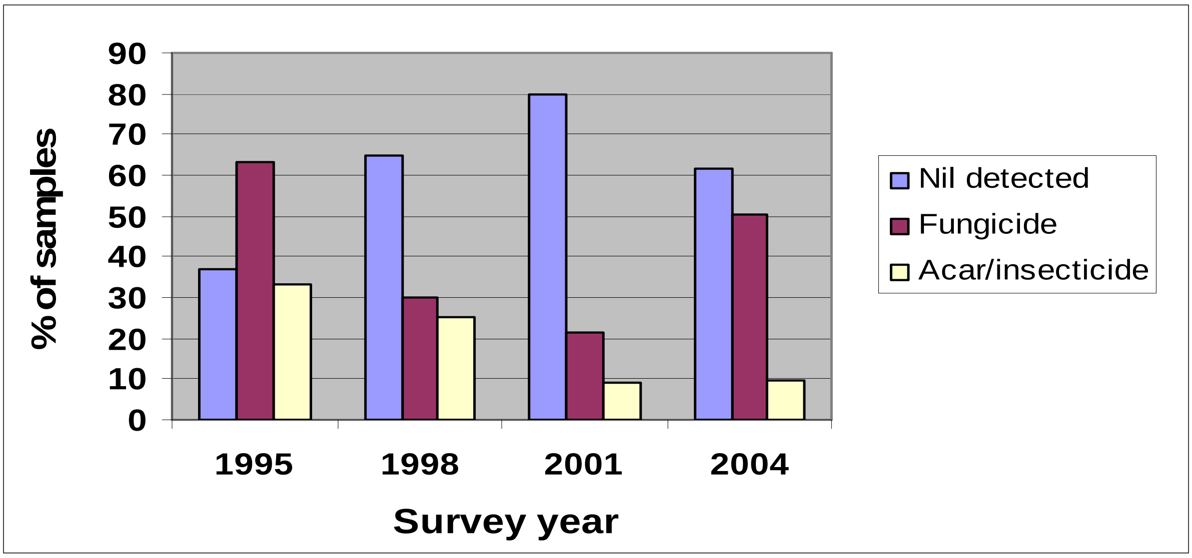


In the PRC report for 2004, a total of three residues were found on two of the 23 UK tomato samples. Two of the residues were approved (at the time of sampling) fungicides, iprodione and pyrimethanil, whereas the third sample contained a residue of the non-approved fungicide procymidone. On investigation with the brand owner, it was thought that the sample of tomatoes was probably from an imported consignment of tomatoes, which had been used to calibrate a new tomato grader (PRC Q2 2004 report, Appendix 1). The slightly higher proportion of fungicide residues found in 2004 is probably a reflection of the poor growing conditions from July onwards which resulted in increased fungicide use to control

Botrytis. Two acaricide residues of fenbutatin oxide were found on UK produce in the 2004 survey.

3.2.2 Imported tomatoes

Fig. 2. Imported tomato samples analysed, percentage with no residues detected, and with fungicide or acaricide residues in 1995, 1998, 2001 & 2004 (Source: WPPR/PRC Survey data)



More samples were taken from imported crops, a total of 407 samples for the same four years. On imported crops over the same period, 61.6 % of the 292 fresh produce samples had no detectable residues but a much wider range of residues was found compared with the UK crop samples. Two out of 12 Italian tomato samples from a special survey in 2002, contained chlormequat residues in excess of the MRL. All the other residues found were below the MRLs. Residues were found on the imported tomatoes for pesticides not approved for use in the UK (see section 5.3 for more information on imports and approved uses). Samples of tinned tomatoes taken in 2003 had no residues.

3.2.3 Producer data

Table 12. Examples of residues found on TGA members UK tomato crops

	No. of samples found	Residue (mg/kg)	MRL (mg/kg)	Year of sampling
Fungicide				
Copper oxychloride	3	0.13, 0.92, 0.98	None set	1998-2003
Iprodione	7	0.06-1.90	5.00	2003
Pyrimethanil	7	0.01-0.17	None set	2003
Acaricide				
Tetradifon	9	0.02-0.18	None set	2003

Examples of residue data from five UK nurseries are summarised in Table 12. These data do not include total numbers of samples tested or the number of negative results. The copper fungicide was used as a disinfectant to the soil surface on organic crops of tomatoes. Iprodione and pyrimethanil were used for Botrytis control, and tetradifon was used for spider mite control. Official approval for the use of tetradifon on protected tomatoes lapsed at the end of December 2003.

4. Approaches to reduce pesticide residues

4.1 General approaches/policies to reduce use and residues

Tomato growers producing conventionally grown crops follow the principles of Integrated Crop Management (ICM) to reduce the use of pesticides and minimise residues. ICM is a cropping strategy in which the growers aim to conserve and enhance the environment while producing safe and wholesome food economically. ICM recognises that profitability is vital to the success and sustainability of any farmer/grower business.

ICM is built on a combination of sound science and good agronomy practices regularly updated by research. A comprehensive knowledge of pest, disease and weed biology and epidemiology together with environmental awareness is vital. Integrated Pest Management (IPM) is a part of ICM and involves developing pest control strategies based on environmental control, biocontrol agents and the use of physical and chemical control agents. IPM relies on representative and diligent crop monitoring carried out at regular intervals. The glasshouse environment and hydroponic systems in which tomatoes are often grown is highly favourable to the use of IPM, far more than open fields.

Where possible, varieties resistant to pests and diseases are selected but this depends on customer requirements. For example, mildew-tolerant varieties are available and these are selected with the customer's agreement. Customers may however insist that more susceptible varieties are grown for quality and other characteristics and this inevitably makes pest and disease control more difficult. Plant breeding clearly offers opportunities for minimising pesticide usage.

4.2 Assurance schemes

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

The crop specific AP protocol for tomatoes gives advice on the control of pests, and diseases, advocates the use of resistant varieties where appropriate, advises on site selection, the correct use of other agronomic inputs and the use of thresholds. The protocol also gives specific advice on residue minimisation. Environmental concerns associated with pesticide use are also addressed. All British Tomato Growers Association (TGA) members are registered under Assured Produce.

4.3 Organic production

In organic tomato production systems, where tomato plants are grown in the soil, weed control is achieved through preventative measures such as rotation, soil cultivations, the use of mulches and hand weeding. Herbicides are not permitted.

Pest and disease control is achieved primarily through the use of crop hygiene, balanced crop nutrition and crop rotation, varietal selection and management to encourage pest predators. Crop covers may be used to keep out pests. Specified biological controls and non-synthetic insecticides and fungicides may be permitted for plant protection, but these are only to be used as a last resort. These include sulphur for disease control, and copper which is approved on outdoor and protected tomatoes for disease control. Fatty acids and *Bacillus thuringiensis* may be used for pest control.

The TGA estimate that 7.4% of the total production area is under organic production. There are four glasshouse producers of organic tomatoes of a significant scale, who may also be importing organic tomatoes to provide continuity of supply to their customers. There are others producing on a small scale for local sales often growing crops in small polythene tunnels.

4.4 Decision support systems

Unlike field crop vegetable and salad crop production, there are no crop models or monitoring systems to help growers make decisions on pesticide and/or BCA use for tomatoes.

Most growers use the services of experienced crop consultants to regularly monitor crops (crop walking) to look for pests, diseases and nutritional problems and advise on the appropriate husbandry decisions. The companies who supply biocontrol agents usually provide advice on IPM. There is less guidance on disease management, with most growers adopting research/advisory information in setting climate control parameters such as the use of ventilation and pipe heat to reduce glasshouse humidity.

Modern climate control computer systems are becoming more sophisticated, using weather data to determine optimum conditions and to save energy.

4.5 Industry initiatives

4.5.1 Producer initiatives

Many of the major tomato producers have their own initiatives in place to reduce pesticide use as they see the reduction of pesticide residues as a very high priority. Systems of protected tomato production are geared to the reduction of pesticide residues and crops are regularly tested for a full screen of residues.

Many growers have a general policy that pesticides likely to result in residue problems are not used and as a result, the number of pesticides used is being reduced. This does however depend on pest and disease conditions experienced in the growing season, and the use of pesticides has to be compatible with and safe to the predators/parasites used to control of insect pests.

Biological control of insect pests is a fundamental component of successful glasshouse tomato production but requires regular crop monitoring by well trained staff.

Modern glasshouses use sophisticated environmental control systems which monitor and reduce high humidity which is invariably a major factor associated with disease problems. The use of screens to reduce pest problems is effective, but reduces light levels. A 1% light loss reduces yields by 1%, and as a result, few installations are in use.

To achieve a target of nil residues is very difficult and any residues must be below the MRL and no multi-residues are wanted. Growers maintain a dialogue with their customers on the issue of pesticide residues.

4.5.2 British Tomato Growers' Association (TGA)

The TGA is the organisation that represents the British tomato industry and is the key driver of best practice in the effective use of pesticides in the industry. It was established in 1997 to represent growers' interests and now covers 95% of British tomato growers and 85% of the British (UK and Channel Islands) production area.

The TGA play a major technical role in the industry. In 1998, it developed a strategy to minimise pesticide use in tomatoes and is working towards eliminating the use of all pesticides (herbicides, insecticides and fungicides) on British tomato crops by 2009. Some growers have already achieved this target.

The TGA seeks to differentiate British tomatoes from imports and so will encourage the adoption of new technology but not genetic modification. The TGA supports the work of the Horticultural Development Council to facilitate the approval of new pesticides for use on horticultural crops, and will advocate the use pesticides if they are shown to be effective. However, the overall aim of the TGA is to achieve zero pesticide use.

The TGA Research and Development strategy is focussed on those specific pests and diseases that currently require pesticide intervention, proposing possible solutions to reduce the problem. In September 2003, the TGA Technical Committee produced a report 'Research and Development Priorities for British Tomato Growers'. The TGA recognised in this document that there were increasing demands for food safety and environmental protection and were confident that British growers could meet these demands at the highest level.

The document focussed on the principle needs and priorities of growers for research and development, and detailed four distinct objectives, whilst setting targets and possible strategies to meet those targets. Objective 3 is specifically targeted at reducing pesticide usage, and aims "*To avoid losses caused by pests and diseases, by using integrated crop management and without recourse to pesticide intervention*".

Targets

- To achieve the optimum economic level of pest and disease control.
- To have available a wide range of natural and biological solutions, including the use of predators, parasites, fungal and bacterial agents.
- To achieve zero use of pesticides.
- Monitor for new pests and diseases which may become established, especially with predicted climate change, and seek integrated solutions.

Strategies

- Develop improved control strategies and biological solutions for those pests and diseases which may currently require pesticide intervention and thus compromise the objective of zero pesticide use.
- Develop strategies for pests and diseases likely to be influenced by the more specific requirements of organic production, such as Macrolophus and Mealy Bug.
- Develop optimisation of the glasshouse environment to reduce pest and disease pressure. This includes improved humidity control and attention to risks from condensation.
- Improved hygiene measures.
- Closed glasshouse systems and investigation of the benefits of glasshouse screening.
- Maintain expertise in the UK to enable monitoring both here and overseas for new pests and diseases, or those occurring elsewhere with a potential to establish here, and act quickly where cases do occur:
  - ♦ Pests, such as Bemisia
  - ♦ Fungi, such as Leveillula
  - ♦ Bacteria, such as Clavobacter, Xanthomonas and Ralstonia
  - ♦ Other viral agents

Since the TGA document was produced some of these strategies have been and are being addressed by research funded by HDC and DEFRA (see section 6).

5. Approaches for specific problems related to residues

UK tomato growers are well informed about the use of pesticides, the need to observe good practice and follow product label recommendations at all times. They are aware of the issue of pesticide residues and will ensure that the quality standards demanded by their customers are met. Short harvest intervals (less than 3 days) are critical for growers who will at times be required to harvest fruit daily to meet retailers' demands. Growers therefore carry out a risk assessment before applying any pesticides and observe the statutory recommended harvest intervals to ensure as much as possible that residues are below the permitted MRL. This is reflected in the very low number of UK tomato samples with detectable pesticide residues in PRC surveys. Residues which have been found include the acaricides fenbutatin oxide and tetradifon, and the fungicides azoxystrobin, bupirimate, iprodione and pyrimethanil.

There are several important pest and disease problems which may require the use of pesticides. The methods used to control these problems and minimise residues are described below.

5.1 Pests

Pest problems and their importance vary from year to year in glasshouse tomato crops depending on seasonal weather conditions, the pest in question and when in the season they occur. The tomato crop is a long-term crop growing in the glasshouse for most of the year and this may allow certain pests to increase to damaging levels.

High standards of glasshouse and crop hygiene, effective crop monitoring and attention to detail are essential in achieving successful pest control and the minimal use of insecticides. Manipulation of the growing environment in the glasshouse - moisture, temperature and light, is also an important part of the pest control strategy.

As part of growers' IPM programmes, biocontrol is generally effective within the confines of the heated glasshouses in which the UK commercial tomato crop is grown. The introduction of predators or parasites is the preferred and natural method of pest control and clearly there are no residue implications. The use and development of effective biocontrol methods has been a key factor in the continuing reduction in both the use of pesticides and the minimisation of pesticide residues. It is of note that the TGA have reported that at least one grower has achieved the zero pesticide use target.

Spot spray applications of glucose polymer and polysaccharide may also be used against certain insect pests. These materials act in a physical way by suffocating the insects. Their regulation is outside the scope of the Control of Pesticides Regulations (COPR) (1986).

The one pest for which pesticide intervention is currently most likely to be required in the UK is two spotted spider mite. Other pests requiring intervention in some cases are mealy bugs, whitefly, caterpillars, leaf miners and Macrolophus. Although they may be a significant problem in some cases, they may not be a general problem for most producers and may be completely absent from some nursery sites.

5.1.1 Residues related to pest control

The PRC data for residues in UK tomatoes for 1995, 1998 and 2001 found residues of dicofol, fenbutatin oxide and tetradifon acaricides, which were used to control spider mite. These did not exceed the MRL. Dicofol and tetradifon are no longer approved for use in the UK. Two samples in the 2004 PRC survey contained the acaricide fenbutatin oxide.

Residues of bifenthrin, buprofezin, cypermethrin, dicofol, endosulfan, fenbutatin oxide, lambda cyhalothrin, oxamyl, and tetradifon have been found in imported tomatoes. None of these exceeded the MRL, and, apart from fenbutatin oxide and buprofezin, none of these pesticides were approved (at the time of testing) for use on tomato crops grown in the UK. (See Section 5.3 in relation to pesticide use on imported crops).

In this section, only key pest problems that have resulted in pesticide residues being detected in PRC surveys are discussed. They are in order of importance for the occurrence of residues, even though these are only found at very low levels.

(a) Two spotted spider mite (*Tetranychus urticae)*
Residue frequency *

Spider mites feed mainly on the underside of leaves causing a bleached speckling of the tissue. Once infestations are established a succession of generations can occur leading to extensive leaf and growing point damage which slows the growth of the plant. Hyper-toxic strains of spider mite are particularly damaging and if uncontrolled can lead very rapidly to plant and even total crop losses. Spider mite is the major tomato pest problem requiring control with pesticides, and is the most difficult pest for growers to control. Spider mite thrives in conditions of high temperature and low humidity, which are the same conditions that are ideal for controlling the disease Botrytis.

Current best practice to minimise pesticide use and residues
An IPM programme based on introductions of biocontrol predators such as *Phytoseiulus persimilis, Feltiella acarigusa* or *Macrolophus caliginosus* is adopted but with recourse to the use of acaricides within the programme. Effective control in the event of rapid infestations and hyper-toxic strains is currently not possible without the use of pesticides.

Glucose polymer can be useful on infestation hotspots but there is a need to make sure that the product comes into physical contact with the pest on the underside of the leaf. This may be difficult to achieve with spray equipment and so the treatment may not be fully effective. Regular spot treatment is costly of labour and despite using fully trained operators and the latest spray equipment to maximise coverage, the hyper-toxic strain is very resilient. It is very important that regular crop monitoring detects the early presence of this pest.

Two currently approved acaricides are used for control on conventionally grown, protected tomatoes – fenbutatin oxide, abamectin – and the very promising newly approved insecticide spiromesifen is now available. All of these products have three day harvest intervals, which is generally the longest growers can delay harvest without crop loss and causing supply problems.

Fenbutatin oxide is recommended for use in IPM programmes with the predators *Encarsia* or *Phytoseiulus* for biological control. It is used as a spot spray on infestation hot spots and as a clean up spray at the end of the cropping season. A total of seven residues of this pesticide were found on UK tomatoes in PRC surveys in 1995, 1998, 2001 and 2004.

Abamectin is known to be damaging to biocontrol predators and is also not approved on cherry tomatoes except under SOLA. It is used as a clean up spray at the end of the season. Residues of abamectin were sought in 2001 and none were found.

There is evidence that the new pesticide spiromesifen, which has dual activity against spider mite and whitefly, can give excellent control of hyper-toxic spider mite (Grower Magazine, 2004). Residues of this pesticide have not been sought yet.

Two sprays of spiromesifen are permitted a year for whitefly control. It is reported to be ideal for use in late summer and early autumn giving good control of both pests and ensuring that they do not overwinter in the glasshouse. It could lead to a reduction in regular spot treatments for hyper-necrotic spider mite with glucose polymer and fenbutatin oxide, and end of season treatments with abamectin. It does not damage pollinating bees, but there is a need for more technical information on the compatibility of spiromesifen with biocontrols. However, spiromesifen is not currently approved for use on cherry tomatoes.

Organic growers are reliant on biological control, environmental control in the glasshouse and the use of physical control agents such as glucose polymer as they are unable to use conventional pesticides even as clean up sprays at the end of the season. There is a risk of significant if not total crop loss in organic production systems if infestations get out of hand.

(b) Glasshouse whitefly (*Trialeurodes vaporariorum)*
Residue frequency *

Whitefly spend much of their time resting on the underside of leaves on the upper parts of the plant. Larvae are found on the leaves as flat almost transparent scales. Damage is caused by feeding on the leaves but more importantly by sooty moulds which grow readily on the honeydew that the insects secrete. The moulds can ruin the appearance of the fruit, and can retard growth by reducing the light to the leaves.

Current best practice to minimise pesticide use and residues
Best practice is to control the pest by following an IPM programme based on biocontrol predators (with the parasitic wasp *Encarsia formosa* being generally most effective) in combination with some intervention with physical action sprays (such as glucose polymer and fatty acids) as spot treatments on hotspots. Sticky traps may also be used to good effect to reduce pest numbers. In severe infestations, it is necessary to resort to pesticide sprays of either buprofezin and spiromesifen. Buprofezin residues have been sought but not found and spiromesifen has not been sought.

As well as *Encarsia*, the predatory bug *Macrolophus caliginosus* may be introduced, but it in turn can cause damage to leaves, flowers and fruit, especially on cherry tomatoes. The entomopathogenic fungal parasite, *Verticillium lecanii,* can also be used against whitefly larvae and is permitted for use by organic growers. It needs high humidity conditions to become established in the crop.

Buprofezin and spiromesifen insecticides are approved for use to control whitefly, as are deltamethrin, pymetrozine (on SOLA), pyrethrins and resmethrin. However, Pesticide Usage Survey data for 2003 shows that the use of insecticides has declined rapidly with a corresponding increase in the use of fatty acids, and no insecticide residues have been found in PRC surveys.

Organic growers are reliant on biological control and physical control agents.

(c) Tomato leaf miner (*Liriomyza bryoniae)*
Residue frequency *

Adult tomato leaf miners lay eggs in leaves and the resulting larvae tunnel or mine through the leaf tissues. Some miners can be tolerated but the amount of green leaf is reduced, and in serious attacks, leaves may dry out completely leading to yield losses. Fungi and bacteria can enter the damaged feeding areas and cause further damage. Fully-grown larvae cut through the leaf surface and drop to the ground to pupate just below the soil surface. Although tomato leaf miner is a serious problem, its occurrence has declined over the last two years.

Current best practice to minimise pesticide use and residues
Best practice is built around biocontrol with the parasitic wasps *Dacnusa sibirica, Diglyphus isaea* and O*pius pallipes.* They are generally effective, with insecticides used as part of an IPM programme, if required.

Abamectin can be used at the beginning of the season to get a clean start so that biocontrol is effective through the season, and at the end of season as a clean-up. It is normally not needed to control pest problems when the crop is being harvested, and thus there is a low risk of any residues being found in fruit. It is not approved for use on cherry tomatoes and the product can be damaging to beneficials. Deltamethrin, nicotine, and thiacloprid are also approved for control and no residues of these insecticides have been found.

For organic growers, biological control provides the best method of pest control. If leaf miner is present in the previous tomato crop, the soil can be steam sterilised to kill overwintering pupae. Good crop hygiene is essential.

(d) Mealy bug (*Pseudococcus & Planococcus* spp)
Residue frequency *

Infestations of mealy bugs are debilitating to host plants and may lead to premature leaf loss. Plants are contaminated with honeydew on which sooty moulds develop. Mealy bugs breed continuously in favourable hot and humid conditions. Nymphs may accumulate within curled leaves and beneath leaf sheaths.

Current best practice to minimise pesticide use and residues
Best practice is to remove colonies when found and to practice strict hygiene in the glasshouse structure and irrigation lines allied to judicious use of insecticide, petroleum oil and glucose polymer products.

Biocontrol on its own is not particularly effective. Available biocontrols include: predatory beetles (*Cryptolaemus montrouzieri)* and their larvae which can eat mealybugs, and adult parasitic wasps (*Leptomastix dactylopii)* which can parasitise citrus mealybug (P*lanococcus citri)* larvae.

Buprofezin has some effect when used for whitefly control, deltamethrin is also used; no residues of either of these pesticides have been found. Broad-spectrum insecticides can give control but if other pests are controlled by biocontrol, this pest can fill the gap.

(e) Macrolophus (*Macrolophus caliginosus)*
Residue frequency *

Macrolophus was a predator that was used in the past to control whitefly, leaf miner and some spider mites, but is now established on nurseries as a pest, and can overwinter in glasshouses. It is particularly damaging to cherry tomato crops attacking leaves and flowers and causing feeding damage to young fruit. It is a major pest for some commercial nurseries and can be a problem in some speciality varieties.

Current best practice to minimise pesticide use and residues
Best practice is to achieve control of the other pest species on which it feeds – such as whitefly, leaf miner, some spider mites and moth eggs, to slow its breeding rate.

For those growers where it is a major pest, pesticide spraying is currently required to achieve control. If cherry tomatoes are grown the pest can be controlled with pymetrozine under a SOLA or by using nicotine. Residues of pymetrozine have not been sought in PRC surveys.

5.1.2 Implications for product quality and availability

Growers following the current best practice recommendations for pest control incorporating IPM should be able to produce a marketable product with economically acceptable yields. The fear of creating residues in tomato fruit at harvesting, which will be picked up by regular residue testing by the retailers, is a strong driver preventing deliberate misuse and poor practice, for example by over application. Growers strictly observe any recommended pesticide harvest intervals. Training in sprayer calibration under the Voluntary Initiative has helped to achieve Good Agricultural Practice.

Growers face problems when pest infestations rapidly build up beyond the control of biocontrol predators, as some pests, such as spider mite, can severely damage both yield and product quality. Growers may then have no economic option but to take action with pesticides to regain control, as they are generally contracted to retailers to supply a specified quantity and quality of fruit throughout the growing season.

5.2 Diseases

As with pests, disease problems and their incidence and severity vary from year to year in glasshouse tomato crops depending on weather conditions, the disease in question and the time in the season they occur. Several potentially damaging diseases occur quite commonly, and in some seasons may become widespread in UK tomato crops. Consequently, most growers take precautions against them.

High standards of glasshouse and crop hygiene, environmental control, effective crop monitoring and attention to detail are all key factors in achieving successful disease control and ensuring minimal use of pesticides. Growers disinfect glasshouses at the end of the season to prevent disease carryover before planting of the new crop. All crop debris and the plastic sheeting that covers the floors are removed. For any conventional soil-grown crops, the soil is sterilised, ideally with steam, to control root diseases. Rockwool slabs are steam-sterilised if re-used.

Growers will only use approved fungicides, after crop monitoring and risk assessment of the disease problem has been undertaken. Where fungicides are used, early treatment is essential to achieve effective control. The main components of best practice methods used to prevent or manage problem diseases are listed below:

- An effective end-of-season glasshouse and equipment cleaning and disinfection programme, so that the risk of transferring pathogens to the new crop is minimised.
- Effective bio-security protocols during crop production (i.e. to prevent introduction of plant pathogens on any substance entering the glasshouse).
- Optimum crop nutrition and balanced crop growth.
- As far as is practical and economic, maintaining an aerial environment unfavourable to fungal pathogens (e.g. avoiding prolonged periods of high humidity in the crop canopy, avoiding low temperatures, avoiding condensation on fruit) while still maintaining conditions for good plant growth.
- An adequate heating system with a rapid response when needed, with heating pipes appropriately placed in the crop.
- Effective air movement, by use of vents and fans.
- Where considered necessary, fungicides are used early in a disease outbreak or prophylactically where there is a history of a particular disease on a nursery and other methods fail to give adequate control.

5.2.1 Residues related to disease control

The PRC survey in UK grown tomatoes for 1995, 1998, 2001 and 2004 found residues of azoxystrobin, bupirimate, carbendazim, dichlofluanid, iprodione, procymidone, pyrimethanil and vinclozolin fungicides (Appendix B). These did not exceed the MRL, not every fungicide was found in each survey year and frequencies were very low. Dichlofluanid, procymidone and vinclozolin are no longer approved for use in the UK on tomatoes.

Residues of azoxystrobin, bupirimate, carbendazim, chlorothalonil, difenoconozole, dithiocarbamates, fenhexamid, fludioxonil, furalaxyl, iprodione, kresoxim-methyl, mepanipyrim, oxadixyl, procymidone, pyrimethanil, tebuconazole, tolyfluanid, triadimenol and vinclozolin were found in imported tomatoes (Appendix B), and again, none of these exceeded MRLs. Of these fungicides, only azoxystrobin, bupirimate, carbendazim, chlorothalonil, iprodione and pyrimethanil were approved at the time of testing for use on crops in the UK. Fenhexamid gained approval (SOLA) late in 2004. Pesticides may have an acceptable use in one country but not another, because of different agricultural, climatic and pest conditions (see Section 5.3 in relation to pesticide use on imported crops).

In this section, only those disease problems that have resulted in pesticide residues being detected in PRC surveys are discussed. They are in order of importance for the occurrence of residues.

(a) Grey mould (*Botrytis cinerea)*
Residue frequency**

Botrytis attacks the stem base of young plants with infection occurring through wounds caused during planting or through senescing cotyledon leaves. Lesions develop on leaves, stems and leaf petioles of mature plants. It can attack the fruit stalk leading to rots and premature fruit fall. The fruit stalk (truss) often dies back after fruit harvest, leading to stem rot. Also, ghost-spotting on the fruit affects marketability. Botrytis is the most difficult tomato disease to control. Correct identification of the disease is vital, as it is easily confused with *Didymella* which is less damaging nowadays.

Current best practice to minimise pesticide use and residues
Best practice is to control the disease by cultural control and good crop management allied to the judicious use of fungicides. There is currently no varietal resistance to Botrytis. Best practice without the use of pesticides includes:

- Utilising heating, vents and fans so that the humidity in the crop canopy does not exceed 85% for long periods (greater than 6 hours).
- Training staff to trim, sideshoot and layer crops without causing significant crop damage, and to leave no stubs when de-leafing or side-shooting.
- Using stem support hoops to keep layered stems off the ground (out of pooled water and to allow air-circulation).
- Spacing layered stems across the hoops to prevent contact-spread of Botrytis and to allow warm air to circulate around stems.
- Removing plants with severe stem Botrytis lesions and any dead plants immediately they occur, and not leaving dead stem bases in the crop.
- Pulling off spent fruit trusses as they start to die back, especially in glasshouses where there is a history of stem Botrytis arising by fruit truss die back.

Where there is a history of Botrytis in a glasshouse and the above methods do not provide adequate control, one or more fungicide sprays are applied to stems before the disease becomes established. Approved fungicides used by growers are usually iprodione and pyrimethanil (SOLA), and residues of these two chemicals were found in 2004, on nine samples. Disease levels were high in 2004 from July onwards because of the cold and wet summer season. Carbendazim, chlorothalonil and azoxystrobin (SOLA) may also be used, two residues of azoxystrobin were found in 2004. There are problems with resistance to iprodione and carbendazim, so fungicides from different chemical groups are alternated to help avoid and delay resistance development.

Fungicides may be applied to young plants if they are damaged at planting or if soil-grown plants are planted too deeply. If the humidity in the glasshouse is high or leaves are damaged by scorch, the disease may be a problem on mature plants and fungicides may have to be used. Better crop management can control these problems. However, some growers without sophisticated climate control equipment have experienced widespread damage from Botrytis in one season and may apply a small number of preventative sprays early in the following season, or at times when the glasshouse climate favours Botrytis. Sprays applied directly to the bundle of layered stems and the lower parts of plants will minimise the risk of residues on the fruit.

In the future, there is a possibility of biocontrol with *Microdochium dimerum, Trichoderma harzianum* and other micro-organisms but products are likely to be costly, and will be subject to the approval for use in the UK. A few growers in the UK apply food-grade acetic acid (vinegar) and similar materials directly to individual Botrytis stem lesions in order to reduce sporulation and delay lesion expansion. In the Netherlands, an aerosol formulation of a Botrytis fungicide is used for localised application to stem lesions, with a consequent reduced risk of a deposit occurring on fruit, compared with a high volume spray, but this is currently not permitted in the UK.

(b) Powdery mildew *(Oidium neolycopersici)*
Residue frequency*

This disease attacks leaves and sometimes the stems of tomato plants. Mildew-tolerant varieties are available, but some ‘heritage varieties’ have no tolerance.

Current best practice to minimise pesticide use and residues
Best practice is to plant resistant varieties where available, not to plant mildew-susceptible varieties next to mildew-tolerant varieties, and to apply an approved sulphur fungicide to susceptible varieties. Crops must be sprayed immediately symptoms are seen, as sulphur is more effective as a protectant than an eradicant treatment, and the disease can spread rapidly, so regular crop monitoring is vital. Good spray penetration is also needed. Sulphur is widely used in conventional and organic crops. It occurs naturally in plants and is naturally deposited from the atmosphere. It is not usually included in residue tests as it is not possible to distinguish between applied and naturally occurring sulphur in the plant tissue.

Azoxystrobin may be applied if disease development continues despite sulphur spraying. Fenarimol is also approved for use, and chlorothalonil (approved for leaf mould control) has an effect as a broad-spectrum protectant but it is not as effective as sulphur. Residues of azoxystrobin were found in 2001 and 2004.

A possible alternative treatment is potassium bicarbonate, which has recently received Commodity Substance Approval for use on all crops but so far there is less than one season’s commercial experience of this product in this country. On some nurseries it has given reasonable control of powdery mildew on cucumbers and it is likely that growers will test its usefulness for disease control on tomatoes.

(c) Verticillium wilt *(Verticillium albo-atrum and V. dahliae)*

Verticillium wilt causes the plant to develop part-chlorotic older leaves which wilt when it is sunny, and eventually the whole plant wilts. The causal fungi can survive for long periods in soil and in plant debris. It is becoming common in crops grown in inert substrates in the UK. Previously resistant varieties are also becoming susceptible to new strains of the disease.

Current best practice to minimise pesticide use and residues
Best practice centres on grafting plants onto resistant rootstocks during the propagation stage and assiduous nursery hygiene between crops. Soil may be steam-sterilised pre-planting for soil-grown crops. Plants may be drenched with carbendazim, up to four times, if any symptoms develop, but retailers restrict its use. Only one residue of carbendazim was found in PRC surveys, in 1998. Affected plants are removed before there is opportunity for any stem lesions bearing sporulation of Verticillium to develop, in order to minimise spread of the pathogen and nursery contamination.

(d) Pythium and Phytopthora root rots

Pythium and Phytopthora root rot symptoms reduce plant vigour. Young plants may collapse and die if they suffer severe root damage. The diseases are soil-borne and Phytopthora may be present in non-mains water supplies. The problem with Pythium appears to be waning. However, these diseases can cause yield losses.

Current best practice to minimise pesticide use and residues
Best practice centres on strict hygiene and water treatment. Propamocarb hydrochloride is approved for treatment if pesticide intervention is required (SOLA for substrate use). Residues of this pesticide were sought in 1995 and 1998 but were not found.

5.2.2 Implications for product quality and availability

If uncontrolled all of the diseases outlined above can lead to premature plant death with consequent losses of yield and crop availability. In particular, as in the 2004 season, Botrytis can be very damaging, leading to widespread plant death. Botrytis also affects fruit marketability through ghost-spotting on the fruit, and powdery mildew infection on the calyx can render fruit unmarketable.

Botrytis and powdery mildew can attack the plant whilst fruit is being harvested necessitating fungicide spraying. The fear of creating residues in fruit at harvesting, which will be picked up by regular residue testing by the retailers, is a strong driver preventing deliberate misuse and poor practice. Growers strictly observe any recommended pesticide harvest intervals.

5.3 Imported Crops

The UK is a net importer of tomatoes, with home production currently representing less than one fifth of UK consumption.

Pesticide products approved for use in the overseas country of origin can be used on imported crops although they may not be approved in the UK. Imported tomatoes generally have higher levels of residues than UK produce. Imported crops may not be grown in highly controlled environments in glasshouses, as in the UK. Biocontrols are not as effective when used in structures where stable temperatures are difficult if not impossible to achieve, and overseas growers may thus have more recourse to pesticides to achieve control.

Imported and home-grown crops have to meet the same market standards. Overseas growers also have to work to retailer protocols. UK importers test for residues on a risk assessment basis. They will check harvest intervals and spray records as they do for UK grown crops. Some TGA growers supply both UK and imported tomatoes to their customers.

6. Research

6.1 Recent research

Details are given of the recent and ongoing research that may contribute to pesticide residue minimisation. In the UK, research is commissioned by the Horticultural Development Council (HDC) and Defra with research organisations including ADAS, Central Science Laboratory, Stockbridge Technology Centre and Warwick HRI (formerly Horticultural Research International).

HDC gives minimising pesticide residues high priority, as it is responsive to the growers who are its levy payers. It addresses the residue issues in its SOLA programmes as well as its research and development programmes.

Details of recent and ongoing research projects are listed in Appendix C.

6.2 Gaps in knowledge and research needs

Tomatoes have seen a dramatic reduction in pesticide use, due to the advent of hydroponic (substrate) growing systems, introduction of biological control agents and high levels of IPM. In addition, better application technology could also help to reduce variation in residues and operator exposure.

The following have been identified as specific areas of research that may lead to a reduced use of pesticides on tomatoes and reduced risk of residues occurring.

Pests

<u>Two Spot Spider Mite</u>
- Continuing research into biocontrol of spider mite especially hyper-necrotic strains.
- More information on the compatibility of spiromesifen with biocontrols.

<u>Mealy Bugs</u>
- Research into new biocontrols for mealy bugs.
- Hygiene and biocontrol may not achieve control, and pesticides or spot treatments with physical action products may be needed.

<u>Whitefly</u>
- Research into biocontrols for whitefly and the compatibility of spiromesifen with biocontrols.

<u>General</u>
- Nozzle design and application methods for pesticides and physical products.
- Research into alternative products that may not leave residues.

Diseases

<u>Botrytis</u>
- Validate the efficacy, optimise application and determine any disbenefits (e.g. safety to biological control agents; spray deposit, consistency of effect) of any suitable biological control agents that might become available in the UK for use on tomato.
- Determine the physical requirements (temperature range, humidity, wound age) necessary for *B. cinerea* spores to successfully establish on de-leafing wounds, old fruit

trusses and cracked stems; test the efficacy of control by growing a crop with treatments to reduce the occurrence of such conditions.
- Determine the occurrence and duration of latent Botrytis in tomato stems and identify factors (e.g. stem age; C/N ratio) that may trigger a transition from latent to aggressive infection. Identify the period(s) in crop production when infection is most likely to result in aggressive stem lesions before crop termination.
- Investigate the effect of increased air movement on *B. cinerea* spore germination and infection of stems; devise growing systems to permit increased air-flow around stems throughout a crop (e.g. Dutch closed-glasshouse system); improved use of fans; filters to removal fungal spores from air).
- Determine the effect of supplementary mineral nutrition (e.g. calcium, potassium) on the susceptibility of stems to Botrytis; seek to relate tissue or sap analyses to Botrytis susceptibility so that crops at risk can be identified early.
- Investigate the potential of Systemic Acquired Resistance (SAR) induced, for example, by spray application of chemical triggers or Induced Systemic Resistance (ISR) induced for example by root inoculation with microbes, to reduce occurrence of Botrytis and other pathogens.
- Determine varietal and other factors influencing fruit truss die back; investigate whether this can be delayed or prevented.
- Determine the efficacy and cost/benefit of integrating available best-practice measures for non-chemical control of stem Botrytis, compared with current industry standard production methods.

<u>Powdery mildew</u>
- Validate the efficacy, optimise application and determine any disbenefits of natural products (e.g. potassium and sodium bicarbonate, potassium metasilicate, Milsana, Orosorb) and biological control agents potentially available in the UK for control of powdery mildew
- Investigate the basis of reduced mildew development on tolerant varieties; determine if the risk of severe mildew on different varieties can be accurately predicted.

<u>Verticillium wilt</u>
- Determine the means by which Ve-resistant rootstocks are better able to tolerate infection by Ve-aggressive isolates of *V. albo-atrum* than are Ve-resistant cultivars.
- Liaise with breeding companies to determine if any source of resistance to *V. albo-atrum*, other than Ve-gene, has been identified and could potentially be used in new cultivars.

<u>General</u>
- Investigate whether the microclimates in the leaf and stem surface boundary layer can be accurately measured or calculated. Seek to relate boundary layer microclimate to disease development so that the former can be used to predict disease risk.
- Determine the potential of SAR and induced systemic resistance ISR for control of common diseases in tomato using biotic and abiotic inducers, including, if available, commercial products (e.g. Bion, Harpin).
- There is broad discussion on alternative methods for pest and disease control in an ACP final report (2003) entitled: Alternatives to conventional pest control techniques in the UK: A scoping study of the potential for their wider use. The report is available on the ACP website at: www.pesticides.gov.uk/uploadedfiles/Web_Assets/ACP/ACP_alternatives_web_subgrp_report.pdf.

7. Knowledge/Technology transfer activities

7.1 Ongoing activities

The annual TGA/HDC/HRIA Tomato Conference enables growers, consultants and researchers to share recent findings on pesticide and biocontrol developments, as well as new information on environmental control. This is a successful way of transferring information to those that attend the Conference, and through magazine articles reporting on the Conference. One or two pest and disease topics usually feature each year. However in 2004, there were no specific discussions on pesticide residues or related subjects.

TGA workshops are held on specific pest and disease topics for TGA members, e.g. Botrytis control.

Recent HDC-funded workshops targeted at tomato growers have focussed on improving growers' knowledge of environmental computer systems to improve energy management but also to control climate to minimise disease infection and spread. The HDC transfers knowledge through its Factsheets; monthly HDC News publication, which includes new SOLAs and technical articles; crop walkers' guides; videos and wallcharts, e.g on spray nozzles.

Courses for training nursery staff on pest and disease recognition and control are usually held annually on the larger nurseries, delivered by ADAS, other independent consultants and BCA suppliers.

Training in biocontrol use and application techniques is provided on a regular basis by the supplying companies, as well as crop consultants.

7.2 Required activities

The industry will need to consider how it will address the transfer of information and best practice on reducing pesticide residues, through a number of channels which could include:

1. Discussion of research findings and best practice techniques to minimise pesticide residues through the annual TGA/HDC/HRIA Tomato Conference, which also provides a forum for debate.
2. Transmission of research findings and best practice through the TGA to its members, e.g. with workshops on specific topics, and through HDC workshops and HDC News to HDC members.
3. Providing information on pesticide degradation during the harvest interval in glasshouse conditions would give growers greater understanding of the risk of residues occurring on fruit.
4. Identifying all UK tomato growers through the Defra Survey database, to ensure that growers who are not members of any Assurance Scheme, the TGA or HDC, receive technical information and best practice guidance.
5. Commissioning best practice guidelines which address specific problems – crop structure requirements, environmental control systems, pesticide application techniques, alternative products, residues, biocontrol, pests and diseases updates. The format, length and level of detail in HDC factsheets have generally proved to be very successful.
6. Commissioning training providers to prepare training programmes to improve crop management skills, including pest and disease recognition training, in a range of languages suited to the requirements of seasonal and permanent staff members, as this is seen as crucial to the successful implementation of IPM programmes. This could include the production of suitable videos, training manuals and wall charts.

7. Discussing the issue with BASIS to include current best practice methods of minimising pesticides residues in update training for agronomists and managers.

8. Conclusions

Growers have made substantial strides in recent years towards minimising pesticide usage and residues on tomatoes. Specific approaches to pest and disease control including biocontrol, the use of alternative products, environmental control and resistant varieties have been developed by growers and the industry and are identified in the plan. Growers use biocontrol and cultural methods wherever possible and apply pesticides as a last resort.

Spider mite is the most difficult pest and Botrytis the most difficult disease to control in the tomato crop. At current levels of knowledge, despite the use of biocontrol and alternative products, it is likely that pesticides will still be needed to control these and other pests and diseases in high risk seasons and situations, especially for the ‘heritage varieties’ which are more susceptible to pests and diseases. However, as advances in the understanding of pests and diseases and their control are made, then less pesticide will be used satisfying market demands. For example, automated monitoring and quantification of Botrytis spores in glasshouse air, using very specific and sensitive molecular methods, may allow critical spore thresholds to be developed, below which it is unnecessary to spray for Botrytis. A greater understanding of the effect of canopy microclimate on disease development could also allow more precise targeting of treatments, and avoidance of conducive conditions, minimising the need to apply sprays.

The TGA have published a strategy document with the aim of eliminating the use of all pesticides on tomato crops by 2009. Some growers have already achieved this difficult target. There would be benefit in sharing best practice from the growers who have succeeded in growing crops without pesticide to those who still rely on pesticides, although commercial competition may be a barrier to this approach. With further developments and research in biocontrol, alternative treatments and investment in new glasshouse technology, it is likely that in the medium to long term, zero pesticide solutions may well be available for pest and disease control in the protected tomato crop in the UK.

However, against this positive background, growers are currently struggling to remain profitable in the face of low prices, an increasing burden of costs including rapid and large increases in energy costs, increasingly difficult labour availability to manage and harvest the crop, and strong overseas competition. There is currently no premium for producing tomatoes with minimal or no pesticide residues. The primary demand from the market is still for perfect blemish free fruit available consistently all the year round, with no market for less than perfect quality produce.

The occurrence of residues in UK produced tomatoes is relatively low, reflecting a strong industry approach to the issue to meet retailer and consumer demands, and also to differentiate the UK crop from imported crop. The key aims of the Crop Guide are to build on this positive activity and to ensure that best practice in reducing residues is shared across the industry, from retailer and grower initiatives, research, crop guidelines, down to training in problem identification for labour gangs.

8.1 Key actions to minimise pesticide residues on tomatoes

Tomato variety	Varieties are selected for resistance to pests and diseases but this depends on customer requirements. Older 'Heritage' varieties have less pest and disease resistance and are more difficult to manage. Plant breeding offers opportunities for minimising pesticide use and residues.
Glasshouse environmental controls and hygiene	New glasshouses have advanced environmental controls which provide better opportunities to monitor and reduce high humidity and associated disease problems. Screening can also reduce pest problems. Crops are now grown in inert media such as rockwool within hydroponic growing systems so that soil-borne pests and diseases are minimised. Growers disinfect glasshouses at the end of the season to prevent disease carryover before planting the next crop. All crop debris and the plastic sheeting that covers the floors are removed. Rockwool slabs are steam-sterilised if re-used. Bio-security measures are put in place to prevent pathogens entering glasshouses during crop production.
Agronomic Practice	Reduction of pesticide residues is seen as very high priority, and pesticides which cause residue problems are avoided if possible. Crops are grown with minimal use of pesticides, making use of beneficial biological control organisms where possible and bumble bees for pollination. Regular crop monitoring by trained staff to make risk assessments and implement strategies is vital. Harvest intervals (HIs) are strictly adhered to, however HIs longer than 3 days can cause harvesting and supply difficulties, as crops may at times be picked on a daily basis to supply retailer contracts.
Key residues and actions (** = medium importance)	
Acaricides ** Fenbutatin oxide	**Scope for residue minimisation – short to medium term** The introduction of predators and parasites is the preferred method of pest control as there are no residue implications. Spot sprays of glucose polymer, polysaccharides or fatty acids may be used as a physical means of pest control by suffocating pests, but regular monitoring and early detection is crucial. ***Two spotted spider mite*** Current best practice is to use an IPM programme based on introductions of biocontrol predators such as *Phytoseiulus persimilis, Feltiella acarigusa* or *Macrolophus caliginosus*. Effective control in the event of rapid infestations and hyper-toxic

	strains is currently not possible without the use of pesticides. Fenbutatin oxide is an effective spot treatment that does not damage the biocontrol but low numbers of residues are found. Abamectin damages predators but does not appear to leave residues. A new pesticide spiromesifen, which also controls whitefly, can give excellent control of hyper-toxic spider mite. This pesticide is not sought yet in PRC surveys, so the implications for residues from commercial use are not known yet.
Fungicides ** Iprodione Pyrimethanil Azoxystrobin	**Scope for residue minimisation – short to medium term** High standards of glasshouse and crop hygiene, environmental control, effective crop monitoring and attention to detail are key factors in achieving successful disease control and minimal use of fungicides. ***Botrytis grey mould*** There is currently no varietal resistance to Botrytis. Best practice without the use of pesticides includes: • Utilising heating, vents and fans so that the humidity in the crop canopy does not exceed 85% for long periods (greater than 6 hours). • Training staff to trim, sideshoot and layer crops without causing significant crop damage, and to leave no stubs when de-leafing or side-shooting. • Using stem support hoops to keep layered stems off the ground (out of pooled water and to allow air-circulation), and to prevent contact-spread of Botrytis. • Removing plants with severe stem Botrytis lesions and any dead plants immediately they occur, and not leaving dead stem bases in the crop. • Pulling off spent fruit trusses as they start to die back, especially in glasshouses where there is a history of stem Botrytis arising by fruit truss die back. Where there is a history of Botrytis in a glasshouse and the above methods do not provide adequate control, one or more fungicide sprays may need to be applied to stems before the disease becomes established to prevent more frequent pesticide use later in the season. Residues of fungicides are found, especially in wet, dull summers, although at low levels. Future controls may include bio-control and localised application to stem lesions to minimise exposure of the fruit to fungicides. ***Powdery mildew*** Current best practice is to plant resistant varieties where available, not to plant mildew-susceptible varieties next to mildew-tolerant varieties, and to apply an approved sulphur fungicide to susceptible varieties. Crops must be sprayed immediately symptoms are seen, as sulphur is more effective as a protectant than an eradicant treatment, and the disease can spread rapidly, so regular crop monitoring is vital. Azoxystrobin may be applied if disease development continues despite sulphur spraying, although a very few residues have been found.

Medium to long-term proposals	There is an important role for plant breeders to continue to develop new varieties that are resistant to pests and diseases and that are attractive to the consumer. For example, varieties that have more surface hairs have been found to be beneficial in deterring spider mites. Providing information on pesticide degradation during the harvest interval in glasshouse conditions would give growers greater understanding of the risk of residues occurring on fruit. Further research and development into biocontrol, alternative treatments and environmental control of the growing environment and the transmission of findings through all available methods and joint knowledge transfer initiatives is needed. The timely registration of useful new non-pesticide products identified through research activities should be supported. There is interest in the 'closed greenhouse' project in the Netherlands that is aimed in part at zero chemical crop protection. If successful, this new technology could minimise the use of pesticides on protected tomatoes leading to minimum residues, but growers would have to be able to finance the construction of these new glasshouses at a time when profitability is very low.
Advice	Research and development findings should continue to be transmitted to growers through all available methods, including the annual TGA/HDC/HRIA Tomato Conference, the TGA, HDC, retailers and the Assured Produce tomato protocol. A longer term aim would be to produce best practice guidelines for tomato production, which address specific problems: crop structure requirements, environmental control systems, pesticides application techniques, residues, alternative products, pest biocontrol, pest and disease updates. This could be a web-based system with regular updates from research and survey information.
Training	Providing training in pest and disease recognition, application methods including sprayer calibration and nozzle selection, biocontrol and application of alternative products, and their impact on pesticide residues is of vital importance. Training programmes in a range of languages suited to the requirements of seasonal and permanent staff members is needed, which could include the provision of suitable videos, training manuals and wall charts. Researchers, consultants, agronomists, manufacturers, and suppliers will all have a role in training provision. A BASIS training pack on pesticide residues for agronomists, advisers and grower managers, and inclusion in training and continuing professional development would help raise the issue across the protected crop industry.

Acknowledgments

Thanks are given to Gerry Hayman and the tomato grower members of the TGA for provision of grower information, relating to pesticide use and residue data.

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).

References

January 2004 Glasshouse Survey – Defra
www.defra.gov.uk

Basic Horticultural Statistics for the United Kingdom – Defra
http://statistics.defra.gov.uk/esg/publications/bhs/2005/default.asp

H M Revenue and Customs – www.hmrc.gov.uk or www.uktradeinfo.com

Pesticide Usage Survey Reports 136,164, 196 – Protected Crops in Great Britain – CSL
www.csl.gov.uk/science/organ/pvm/puskm/reports.cfm

Assured Produce Ltd – Generic Crop Protocol Standards – October 2004
Assured Produce Ltd - Generic Protocol Guidance Notes 2004-2005
Assured Produce Ltd – Crop Specific Protocol – Tomatoes (Protected) – January 2004
www.assuredproduce.co.uk/Aproduce

EUREPGAP Protocol for Fresh Fruit and Vegetables – http://www.eurep.org

The British Tomato Growers Association – www.britishtomatoes.co.uk

Research and Development Priorities for British Tomato Growers September 2003 – Produced by the Tomato Growers' Association Technical Committee – tga@britishtomatoes.co.uk

"Labour saving spider mite control" – Grower magazine – 16 September 2004
editor.horticulture@nexusmedia.com

The UK Pesticide Guide 2005 – Editor: R Whitehead – BCPC and CABI Publishing – www.ukpesticideguide.co.uk

List of products approved for use on protected tomatoes in the UK – CSL/Liaison (subscription only) http://liaison.csl.gov.uk/

List of biological control agents approved for use on protected tomatoes in the UK – CSL/Liaison (subscription only) http://liaison.csl.gov.uk/

Allan AJ, Lazaraki I, Dertzakis D, Woodward S & Seddon B (2003) Integrated biological control of powdery mildew and grey mould on cucumber and tomato using *Brevibacillus brevis* combinations. Proc. BCPC International Congress – 2003, pp 469-474. www.bcpc.org

Useful Contacts

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

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

British Tomato Growers Association
Pollards Nursery, Lake Lane, Barnham, West Sussex PO22 0AD. Tel 01243 554859
www.britishtomatoes.co.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

Horticultural Development Council
Bradbourne House, East Malling, Kent ME19 6DZ. Tel 01732 848383
www.hdc.org.uk

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

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

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

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

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

APPENDIX A. Pesticide residues sought on UK and imported tomatoes in WPPR/PRC surveys between 1995 and 2004 (See footnote below table for key to abbreviations)

Pesticide active Substance	**1995**	**1998**	**2001**	**2002#**	**2004**
Abamectin	-	-	Y	-	-
Acephate	Y	Y	Y	-	Y
Aldicarb	-	-	-	-	Y
Azinphos-methyl	-	Y	Y	-	Y
Azoxystrobin	**-**	**-**	**F**	**-**	**F**
Benalaxyl	-	-	Y	-	-
Bendiocarb	-	Y	Y	-	-
Bifenthrin	Y	Y	**F**	-	**F**
Biphenyl	-	Y	Y	-	-
Bromopropylate	-	Y	Y	-	Y
Bupirimate	**F**	**F**	**F**	**-**	**F**
Buprofezin	Y	Y	Y	-	**F**
Captan	-	Y	Y	-	Y
Carbaryl	-	Y	Y	-	Y
Carbendazim	Y	**F**	**F**	-	**F**
Chlorfenvinphos	-	Y	Y	-	Y
Chlormequat	-	-	-	**F**	Y
Chlorothalonil	Y	Y	**F**	-	**F**
Chlorpyrifos	Y	Y	Y	-	Y
Chlorpyrifos-methyl	Y	Y	Y	-	Y
Chlozolinate	Y	Y	Y	-	Y
Cyfluthrin	-	Y	Y	-	Y
Cyhalothrin, lambda	-	**F**	**F**	-	Y
Cypermethrin	Y	Y	Y	-	**F**
Cyprodinil	-	-	-	-	**F**
DDT	-	Y	Y	-	Y
Deltamethrin	Y	Y	Y	-	**F**
Diazinon	-	Y	Y	-	Y
Dichlofluanid	**F**	Y	Y	-	Y
Dichlorvos	-	Y	Y	-	Y
Dichloran	Y	Y	Y	-	Y
Dicofol	**F**	Y	**F**	-	**F**
Difenoconazole	-	-	-	-	**F**
Dimethoate	Y	Y	Y	-	Y
Diphenylamine	-	Y	Y	-	Y
Dithiocarbamates	Y	**F**	**F**	-	Y
Endosulfan	**F**	**F**	**F**	-	**F**
Ethion	-	Y	Y	-	Y
Ethofumesate	-	Y	Y	-	-
Ethoprophos	-	Y	Y	-	Y
Ethoxyquin	-	Y	-	-	-
Etradiazole	Y	Y	Y	-	-
Etrimfos	-	Y	Y	-	-
Famoxadone	-	-	Y	-	-
Fenbutatin oxide	**F**	**F**	**F**	-	**F**
Fenarimol	**F**	Y	-	-	Y
Fenazaquin	-	-	-	-	Y
Fenbuconazole	-	-	-	-	Y
Fenhexamid	-	-	**F**	-	**F**
Fenitrothion	-	Y	Y	-	Y
Fenpropathrin	-	Y	Y	-	Y
Fenpropidin	-	Y	-	-	-
Fenpropimorph	-	Y	Y	-	-
Fenpyroximate	-	-	-	-	Y
Fenvalerate	-	Y	Y	-	-
Fludioxonil	-	-	-	-	**F**
Flurochloridone	-	Y	Y	-	-

Pesticide active Substance	**1995**	**1998**	**2001**	**2002#**	**2004**
Flusilazole	-	Y	Y	-	-
Folpet	-	-	Y	-	Y
Fonofos	-	Y	Y	-	-
Fosthiazate	-	-	Y	-	-
Furalaxyl	-	Y	**F**	-	-
HCH, gamma	Y	Y	Y	-	-
Heptenophos	-	Y	Y	-	Y
Hexachlorobenzene	-	Y	Y	-	-
Imazalil	-	Y	Y	-	Y
Imidacloprid	-	-	Y	-	Y
Iprodione	**F**	**F**	**F**	-	**F**
Isofenphos	-	Y	Y	-	Y
Kresoxim-methyl	-	-	Y	-	**F**
Lindane	-	-	-	-	Y
Malaoxon	-	-	-	-	Y
Malathion	Y	Y	Y	-	Y
Mecarbam	-	Y	Y	-	Y
Mepanipyram	-	-	-	-	**F**
Metalaxyl	Y	Y	Y	-	Y
Methamidophos	Y	Y	Y	-	Y
Methidathion	-	Y	Y	-	Y
Methiocarb	-	Y	Y	-	-
Methomyl	-	-	-	-	Y
Monocrotophos	-	Y	Y	-	Y
Myclobutanil	-	Y	Y	-	Y
Napropamide	-	Y	Y	-	-
Nicotine	-	Y	-	-	-
Nitrothal-isopropyl	-	Y	Y	-	-
Ofurace	-	Y	Y	-	-
Omethoate	Y	Y	Y	-	Y
Oxadixyl	-	**F**	**F**	-	**F**
Oxamyl	-	**F**	-	-	-
Oxydemeton-methyl	-	-	-	-	Y
Paclobutrazol	-	Y	Y	-	-
Parathion	-	Y	Y	-	Y
Parathion-methyl	-	Y	Y	-	Y
Penconazole	Y	Y	Y	-	-
Pendimethalin	-	Y	Y	-	Y
Permethrin	**F**	Y	Y	-	Y
Phenthoate	-	Y	Y	-	-
Phorate	-	-	-	-	Y
Phosalone	-	Y	Y	-	Y
Phosmet	-	Y	Y	-	Y
Phosphamidon	-	-	-	-	Y
Pirimicarb	Y	Y	Y	-	Y
Pirimiphos-ethyl	-	Y	Y	-	-
Pirimiphos-methyl	-	Y	Y	-	Y
Prochloraz	-	-	-	-	Y
Procymidone	**F**	**F**	**F**	-	**F**
Profenofos	-	Y	Y	-	Y
Prometryn	-	Y	Y	-	-
Propamocarb	Y	Y	-	-	-
Propanil	-	Y	Y	-	-
Propargite	-	**F**	Y	-	**F**
Propiconazole	-	Y	Y	-	Y
Propoxur	Y	Y	Y	-	Y
Propyzamide	-	Y	Y	-	Y
Prothiofos	-	Y	Y	-	Y
Pyrazophos	-	Y	Y	-	Y
Pyridaphenthion	-	Y	Y	-	Y
Pyrifenox	-	-	**F**	-	**F**
Pyrimethanil	-	-	**F**	-	**F**

Pesticide active Substance	**1995**	**1998**	**2001**	**2002#**	**2004**
Quinalphos	-	Y	Y	-	Y
Quinomethionate	-	Y	Y	-	-
Quintozene	Y	Y	Y	-	-
Simazine	-	Y	Y	-	Y
Tebuconazole	-	Y	**F**	-	**F**
Tebufenpyrad	-	-	-	-	**F**
Tecnazene	-	Y	Y	-	Y
Tetrachlorvinphos	-	Y	Y	-	Y
Tetradifon	**F**	Y	**F**	-	Y
Thiabendazole	Y	Y	Y	-	Y
Thiophanate-methyl	-	Y	Y	-	-
Tolclofos-methyl	-	Y	Y	-	Y
Tolyfluanid	-	Y	Y	-	**F**
Triadimefon	-	-	-	-	Y
Triadimenol	-	-	-	-	Y
Triazophos	-	Y	Y	-	Y
Trifloxystrobin	-	-	Y	-	Y
Trifluralin	-	Y	Y	-	-
Vinclozolin	**F**	**F**	Y	-	Y
Total residues sought	36	107	112	1	102

Key to symbols and abbreviations:

- = pesticide not sought
Y = pesticide sought but not found
F = pesticide above LOD found
# = A special survey of Italian tomatoes was done in 2002 to check for chlormequat residues. (N.B. chlormequat use in 2002 was illegal)

APPENDIX B. Pesticide residues found in UK and imported tomatoes from WPPR/PRC surveys 1995-2004, number of samples with residues (range of residues found mg/kg) – (See page 42 for the key to the abbreviations in these tables.)

UK tomatoes

Pesticide residue	1995	1998	2001	2004
Total samples	15	21	35	60
No. of samples with no residues detected	9	15	31	46
% samples with no residues detected	60	71.4	88.6	76.7
Azoxystrobin (F) (MRL=2)	-	-	1 (0.2	2 (0.08-0.1)
Bupirimate (F)	Nil	2 (0.04-0.08)	Nil	1 (0.1)
Carbendazim (F) (MRL=0.5)	Nil	1 (0.2)	Nil	Nil
Dichlofluanid (F) (MRL=5)	1 (0.02)	Nil	Nil	Nil
Dicofol (A) (MRL=1)	2 (0.02-0.07)	Nil	Nil	Nil
Fenbutatin oxide (A) (MRL=1)	1 (0.09)	2 (0.04-0.07)	2 (0.03-0.1)	2 (0.03-0.07)
Iprodione (F) (MRL=5)	3 (0.03)	1 (0.2)	Nil	7 (0.03-0.6)
Procymidone (F) (MRL=2)	Nil	Nil	Nil	1 (0.2)
Pyrimethanil (F)	-	-	Nil	2 (0.05-0.5)
Tetradifon (A)	2 (0.02-0.07)	Nil	1 (0.06)	Nil
Vinclozolin (F) (MRL=3)	Nil	1 (0.3)	Nil	Nil
MRL exceedances	0	0	0	0

Imported tomatoes

Pesticide residue	1995	1998	2001	2002#	2004
Total samples	27	20	108	12	240
No. of samples with no residues detected	10	13	86	10	148
% samples with no residues detected	37	65	79.6	83.3	61.7
Azoxystrobin (F) (MRL=2)	-	-	2 (0.06-0.09)	-	6 (0.08-0.3)
Bifenthrin (I/A)	Nil	Nil	2 (0.03-0.04)	-	5 (0.05-0.2)
Bupirimate (F)	1 (0.03)	1 (0.02)	1 (0.02)	-	Nil
Buprofezin (A) (CAC MRL=1)	Nil	Nil	Nil	-	3 (0.05-0.3)
Carbendazim (F) (MRL=0.5)	Nil	Nil	1 (0.1)	-	2 (0.05)
Chlormequat (PGR) (MRL=0.05)	-	-	-	2** (0.07-0.2)	-
Chlorothalonil (F) (MRL=2)	Nil	Nil	2 (0.2-0.4)	-	11 (0.05-0.5)
Cypermethrin (I) (MRL=0.5)	Nil	Nil	Nil	-	2 (0.07)
Dicofol (A) (MRL=1)	2 (0.06-0.1)	Nil	2 (0.03-0.09)	-	3 (0.06-0.5)

Imported tomatoes (cont'd)

Pesticide residue	1995	1998	2001	2002#	2004
Difenoconazole (F)	-	-	-	-	1 (0.05)
Dithiocarbamates (F) (MRL=3)	Nil	3 (0.05-0.06)	1 (0.2)	-	Nil
Endosulfan (I/A) (MRL=0.5)	6 (0.06-0.2)	2 (0.08-0.2)	4 (0.06-0.2)	-	9 (0.06-0.4)
Fenbutatin oxide (A) (MRL=1)	Nil	Nil	1 (0.2)	-	Nil
Fenhexamid (F)	-	-	1 (0.2)	-	2 (0.09-0.2)
Fludioxonil (F)	-	-	-	-	3 (0.05-0.1)
Furalaxyl (F)	-	Nil	1 (0.02)	-	-
Iprodione (F) (MRL=5)	1 (0.2)	Nil	1 (0.4)	-	21 (0.02-0.3)
Kresoxim-methyl (F) (MRL=0.5)	-	-	Nil	-	2 (0.1)
Lambda cyhalothrin (I) (MRL=0.5)	-	2 (0.02-0.06)	1 (0.03)	-	Nil
Mepanipyrim (F)	-	-	-	-	5 (0.06-0.1)
Oxadixyl (F)	-	Nil	3 (0.06-0.1)	-	1 (0.08)
Oxamyl (I) (CAC MRL=2)	-	1 (0.07)	-	-	-
Procymidone (F) (MRL=2)	13 (0.02-0.2)	2 (0.02-0.04)	7 (0.03-0.2)	-	39 (0.02-0.3)
Pyrimethanil (F)	-	-	2 (0.1-0.3)	-	8 (0.05-0.7)
Tebuconazole (F) (CAC MRL=0.2)	-	Nil	1 (0.1)	-	4 (0.05-0.4)
Tebufenpyrad (I)	-	-	-	-	1 (0.09)
Tetradifon (A)	1 (0.08)	Nil	Nil	-	Nil
Tolyfluanid (F) (CAC MRL=2)	-	Nil	Nil	-	2 (0.2-0.3)
Triadimenol (F) (MRL=0.3)	-	-	-	-	14 (0.07-0.2)
Vinclozolin (F) (MRL=3)	2 (0.03-0.2)	Nil	Nil	-	Nil
MRL exceedances	0	0	0	2	0

Key to symbols and abbreviations:

MRLs shown are the most recent values presented in the latest PRC survey report for tomatoes. Where an MRL exceedance is recorded it relates to the MRL which was current at the time the survey was conducted.
- = pesticide not sought
nil = residue not found
* = one MRL exceedance found
** = two MRL exceedances found (the MRL for chlormequat in tomatoes is set at the LOD)
# = A special survey of Italian tomatoes was done in 2002 to check for chlormequat residues.

Pesticide types:
A = acaricide; F = fungicide; I = insecticide; PGR = plant growth regulator;

APPENDIX C. Recent and ongoing research

Please refer to page 47 for details of websites (Defra, HDC) where further information on research can be obtained. Note that HDC funded reports are only available to levy payers.

Recent research

Pests

<u>Integrated Pest Management</u>
Protected crops: optimising the use of abamectin within IPM programmes. HDC Project PC 160.

Protected crops: a review of the potential of *Beauveria bassiana* against pests of glasshouse crops in the UK. HDC Project PC 180

Beauveria bassiana is a naturally occurring fungal pathogen of many insect species. Its efficacy against a range of glasshouse pests was investigated and reported in 2000. In terms of pests affecting tomato crops, *Beauveria* was found to be relatively ineffective against mealy bug, *Macrolophus* and spider mites. Compatibility with BCAs and crop protection products still needs more investigation, as does the method of application with adjuvants to enhance efficacy.

<u>Mealybugs</u>
Protected tomatoes: integrated control of mealybugs. HDC Project PC 161.

In this four-year project (1998-2002), the most effective and IPM compatible control of mealybug was found to be the insect growth regulator, buprofezin (Applaud). Also effective, but only to certain stages in the life cycle, were Savona and Mycotal WP applied after Savona. Peroxyacetic acid (Jet 5) and undiluted vinegar were also effective in reducing the numbers of nymphs emerging from egg sacs on concrete.

<u>Spider mites</u>
Tomato: control of spider mites with fungal pathogens. HDC Project PC 163.

Tomato: biological and behavioural variation in spider mites infesting UK crops. HDC Project PC 189.

A one-year project (January 2002 – March 2003). The three types of spider mite found on UK tomato crops were studied: green *Tetranychus urticae* (two-spotted spider mite), red *Tetranychus cinnabarinus* (carmine mite) and green *T. cinnabarinus* (until recently unknown). Both types of *T. cinnabarinus* can cause severe damage (hyper-necrosis) at low population densities. This highlights the need to identify which type is present on crops. Increasing density of certain types of trichomes (glandular hairs) on tomato leaves reduced the population growth of all three types, so there may be scope for plant breeders to influence pest populations.

A strategic framework to investigate multi-natural enemy approaches to spider mite control in protected crops. Defra Project HH1842SPC.

A one-year project (December 2000 – March 2001). This work led to the development of a revised model to simulate use of a multiple natural enemy approach to biological control.

Glasshouse whitefly and tobacco whitefly
Semiochemicals for detection, monitoring and control of the whiteflies *Trialeurodes vaporariorum* and *Bemisia tabaci.* MAFF Project HL 0130PC.

A three-year project (January 1998 – December 2000)

Tobacco whitefly
Integrated control, containment and eradication of the quarantine pest *Bemisia tabaci* in UK glasshouses. Defra (Plant Health) Project PH 0157.

A four-year project (September 1999 – March 2003). Tomatoes were among the crops studied, with the entomopathogenic nematode *Steinernema feltiae* giving some control of the pest. Various adjuvants were tested, with Codacide oil having the greatest effect in enhancing efficacy. A key factor was humidity, with an optimum of 85%RH for 6 hours after nematode application.

Macrolophus
Protected tomato: examination of *Macrolophus* damage to commercial crops. HDC Project PC 139.

A four-year project (1997 – 2000). Damage symptoms seen on cherry tomatoes were studied, including observations of the survival of *Macrolophus* in the winter on weeds in the south of England. Although several pesticides provided control, few were compatible with other BCAs in use at the time, and were not considered as long-term solutions. Chess (pymetrozine) and Eradicoat (glucose polymer) were evaluated for control, but neither reduced populations of adults significantly. Chess needed further evaluation. Prey availability (whitefly) increased the population of *Macrolophus,* as did the type of tomato cultivar (more insects on cherry tomatoes than on larger fruited varieties).

Spectral filters
Protected crops: the potential of spectral filters for pest control: HDC Project PC 170.

This project, completed in 2000, found that UV-absorbing films reduced certain insect numbers – (100x reduction of aphids and 10x reduction of whiteflies, thrips and leaf miners). Experience from Israel has shown that UV- absorbing films have little effect on insect predators, and crops of tomatoes are now grown with reduced pesticide use (25-50% lower). Further work is needed to assess effects on BCAs used in the UK.

Diseases

Grey mould (*Botrytis cinerea*)
Tomato: development of biocontrol as a component of an integrated sustainable strategy for the control of grey mould (*Botrytis cinerea*). HDC Project PC 174.

This four year project (April 2000–March 2004) investigated biocontrol products and micro-organisms, from overseas and the UK, for their potential to control stem botrytis. Several biocontrol products and micro-organisms, including an isolate of *Trichoderma harzianum* obtained from tomato during this project, gave significant reductions of tomato stem botrytis in laboratory tests and glasshouse trials. In a full-season crop trial, *Clonostachys rosea* and Gliomix applied every 14 days, were almost as effective as a six-spray fungicide programme. Potential methods for large-scale production of *T. harzianum* were evaluated.

Long season protected tomato: control of stem botrytis. HDC project PC 98c.

A trial in 1996 on a commercial nursery showed that the stem botrytis lesions commonly originated at leaf scars, on stubs left after fruit truss removal and though decaying fruit trusses. Removal of fruit trusses reduced the incidence of stem botrytis by up to 60%. The most effective treatments were to pull off trusses as they began to turn brown and to ensure that no stubs were left on the stem.

Control of tomato stem botrytis by treating small lesions. HDC project PC 98.

In addition to fungicide treatment, the effect of painting small botrytis stem lesions with vinegar was evaluated. Vinegar appeared to delay sporulation, lesion development and plant death compared with plants where lesions were left untreated.

Powdery mildew (*Oidium neolycopersici*)
Tomato: fungicide sensitivity testing and comparison of fungicides for control of powdery mildew. HDC Project PC 26a.

Sulphur (as Thiovit) applied as a high volume spray with a wetter (Agral), was included in a range of fungicides evaluated for control of this disease. Sulphur gave good control, the effect persisted for around six weeks when applied at the start of an outbreak; treatment was less effective when applied to a crop where the disease was well established (c. 10% leaf area affected). There are a few reports in the literature of powdery mildew disease being reduced simply by spraying with water. In this experiment on tomato, spraying plants twice weekly with water neither reduced nor increased mildew development, compared with untreated plants.

Control of tomato powdery mildew (*Oidium neolycopersici*) with a plant extract (France)

In France, trials over three years with an extract from giant knotweed (*Reynoutria sachalinensis*), sold in Germany as Milsana ("a plant enhancer"), showed good protection, comparable with a fungicide, when applied at 7, 14 and 21 days intervals. Protection was given for more than 30 days, which is similar to that from sulphur, the main fungicide used to control powdery mildew in UK tomato crops. Efforts are being made to register the product in France.

Ongoing research

Pests

Biological control
Combining natural enemies for more effective biological control. Defra Project HH2402SX.

A four-year project (April 2001 – March 2005). Work at Warwick-HRI will provide information required to optimise combinations of natural enemies for biocontrol, with the aim of reducing pesticide use in horticulture. Interactions between natural enemies will be tested in small-scale trials and incorporated into a model.

The movement of pests and natural enemies in biocontrol systems. Defra Project HH2401SX.

A four-year project (April 2001 – March 2005). This project will define and quantify how movement and dispersal rates of pests and biocontrol agents are affected by plant structure, substrate topography, food availability and micro-climate.

Diseases

Grey mould (*Botrytis cinerea*)
Biological control of *Botrytis cinerea* in protected tomato with *Brevibacillus subtilis*. University of Aberdeen. EU-funded project.

The bacterium *Brevibacillus subtilis* has been demonstrated to give some control of botrytis on tomato in trials in Scotland and Greece. More recently, work on integration of the bacterium with another micro-organism to provide control of both botrytis and powdery mildew was reported (Allan *et al*., 2003). http://www.abdn.ac.uk/central/research/

Biological control of *Botrytis cinerea* in protected tomato with *Microdochium dimerum*. CTIFL and INRA, France.

Work at INRA and CTIFL over the last ten years has identified the fungus *M. dimerum* (previously known as *Fusarium dimerun*) to be efficient at protecting both trimming wounds on the stem and yellowing leaves from attack by *B. cinerea*. It has no effect on powdery mildew, but does not adversely affect the control of mildew given by Milsana (see below). Recent studies show that *M. dimerum* is tolerant of many of the pesticides registered for use on tomato in France, including sulphur and pyrimethanil, and partially tolerant of iprodione. Work is planned to investigate its compatibility with bees and biocontrol agents used against whitefly and other pests. It can be produced in quantity on a solid substrate in microporous bags. *M. dimerum* is reported to be in a group of species that does not produce mycotoxins. Efforts are being made to register the product in France. (Ref: Greenhouse tomato: integrated crop protection and organic production. CTIFL, September 2003; ISBN 2-87911-217-6). www.ctifl.fr/ or www.inra.fr/ENG/

Verticillium wilt (*Verticillium albo-atrum*)
Detection, characterisation and natural suppression of *V. albo-atrum* aggressive on Ve-resistant tomato cultivars. Defra project HH3222SPC.

This three year project (July 2003 – June 2006) undertaken jointly by ADAS, University of Nottingham and Warwick HRI is investigating aspects of the epidemiology and control of this increasing problem. Studies on sources of the causal fungus and infection routes could lead to improved hygiene practices to help prevent the disease. The potential of biological control in hydroponic and soil-grown crops will also be investigated.

Epidemiology and control of Verticillium wilt in hydroponic and soil-grown crops. HDC PC 186a.
This three year project (1 October 2003 – 30 September 2006) undertaken by ADAS and University of Nottingham is being run in conjunction with and parallel to the above DEFRA project. Aspects being investigated include: the possibility of soil-borne infection and contamination; the role of insects in disease spread; the efficacy of chemical disinfectants used to clean a glasshouse and equipment at the end of a season; and the susceptibility of different varieties and rootstocks.

Novel production methods
The ‘closed’ greenhouse (The Netherlands)

Researchers and industry have developed a ‘closed’ greenhouse (ie one without ventilation openings) as a move towards sustainable horticulture, aiming at zero use of fossil fuels, zero chemical crop protection, recycling of irrigation water and improvement of working conditions. It has the potential for better climate control that could be manipulated to reduce disease risk. Forced, cool, dry air will be pumped through large air-ducts beneath suspended plants, the air being blown up around plants. Additionally, incursion of air-borne fungal pathogens (e.g.

B. cinerea, O. neolycopersici) into the crop should be significantly reduced. A 1.4 ha commercial block of 'closed-house' tomato production is due to commence in December 2003. References: www.innogrow.com/
Opdam H. (2003). The future of greenhouse design. TGA/HDC/HRI Tomato Conference, 2003, page 6.

Energy saving. HDC project PC 198.

Work led by FEC and funded by HDC is investigating energy-saving through the use of temperature integration and thermal screens. The work is being done on commercial nurseries. The effects of treatments on botrytis is being monitored.

Energy saving through an improved understanding and control of humidity and temperature. Defra funded project.

This new four year project is led by Warwick HRI with input from SRI. It is investigating energy saving by use of temperature integration, and more precise and targeted humidity control. Additionally, the use of quantitative spore traps for monitoring aerial botrytis spores, as an early indicator of botrytis risk in a crop, is being investigated.

Defra and HDC website references

Defra http://www2.defra.gov.uk/research/project_data/Default.asp

HDC www.hdc.org.uk