SESSION 8B

MINIMISING RESIDUES IN FOOD

Chairman: Professor Chris Payne
Assured Produce, Hampton, UK

Session Organiser: Robert J Gladwin
BASF, Cheadle Hulme, UK

Platform Papers: 8B-1 to 8B-4

An overview of the Pesticide Residues Committee's national programme of pesticide residues testing and discussion of consumer and other stakeholder interests in this area

I Brown
Chairman of the Pesticide Residues Committee, Occupational Medicine and Toxicology, Southampton University Hospitals, Southampton, SO16 6YO, UK

ABSTRACT

An extensive monitoring programme is undertaken each year in the UK for pesticide residues in food and drink. A brief overview is provided of the regulatory principles which underpin safe approval and use of pesticides. Further information about the national programme and the annual results are discussed alongside some of the issues raised by stakeholders.

INTRODUCTION

The Pesticides Residues Committee (PRC) is independent of government and was established to advise the UK government and the Food Standards Agency on the official pesticide monitoring programme. The PRC is also responsible for making public all findings and recommendations available to government, consumers and the farming industry in a way which aims to be comprehensive, understandable and timely.

Each year over £2 million is spent on the programme. Around 40 food commodities are examined, resulting in 170,000 pesticide commodity combinations.

Purpose of monitoring

There are three broad aims:

- to check that residues do not exceed permitted maximum residue levels;
- to back up the statutory approvals process for pesticides by checking that no unexpected residues are occurring;
- to check that human dietary intakes of residues are within acceptable levels.

The PRC findings are published every three months on the PRC website www.prc-uk.org

Regulatory background

The regulation and approval of pesticides is the responsibility of the Pesticides Safety Directorate in conjunction with the independent Advisory Committee on Pesticides. Regulators and those involved in submitting applications for the approval of pesticides are familiar with the process and the underlying toxicology which is required to demonstrate that the active substance can be used safely and to establish maximum residue levels which occur from those approved uses.

This is however a complex system to explain to consumers and this can lead to misunderstandings about the terminology and the relative significance of PRC findings.

Figure 1 demonstrates this relationship effectively

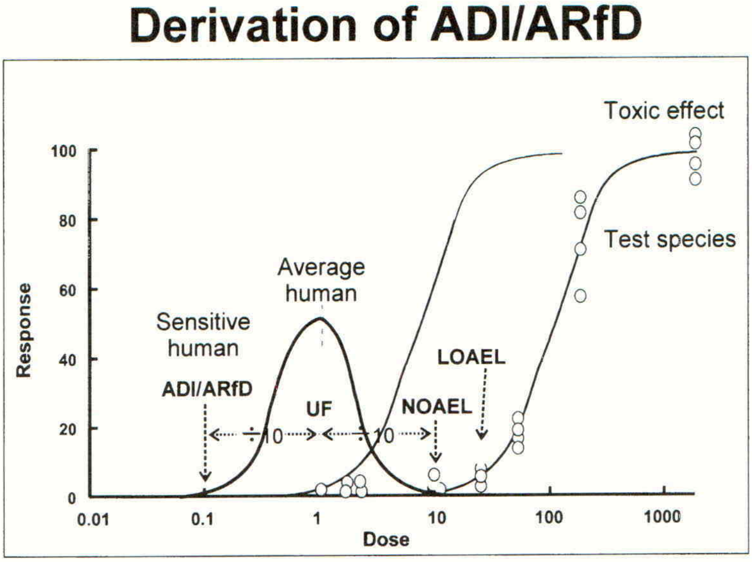

Figure 1. Derivation of ADI/ARfD

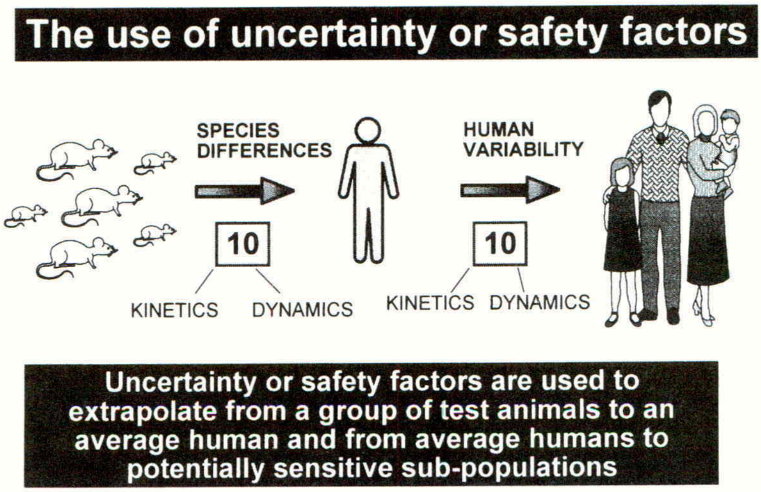

Figure 2. The use of uncertainty factors

Key issues

A large body of toxicological evidence is required to establish a **No observed adverse effect level (NOAEL)** which is the highest level of continual exposure to a chemical which causes no significant adverse effect on morphology, biochemistry, functional capacity, growth, development or life span of individuals of the target species which may be animal or human.

These data are then used to establish the **Acceptable daily intake (ADI)** and the **Acute reference dose (ARfD):** The ADI is the amount of a chemical which can be consumed every day for a lifetime in the practical certainty, on the basis of all known facts, that no harm will result. The definition of the ARfD is similar to that of the ADI, but it relates to the amount of a chemical that can be taken in at one meal or on one day without appreciable health risk to the consumer (figure 1).

Separately, field trials are conducted to determine the maximum pesticide residue which occurs in supervised field trials after normal use of the pesticide. An assessment is then made to determine the maximum amount of pesticide consumed by an extreme consumer, assuming the highest pesticide residue and taking full account of the variability of residues between individual units of a commodity. This is then compared to the relevant toxicological value, if acceptable these data are then used to help set the **Maximum residue level (MRL)** which is defined as the maximum concentration of a pesticide residue (expressed as mg/kg) legally permitted in or on food commodities and animal feeds.

MRLs are based on good agricultural practice and residues in food derived from commodities that comply with the respective MRL's are intended to be toxicologically acceptable. MRLs are not in themselves safety limits.

The PRC programme of testing

The UK has undertaken a regular monitoring programme since the 1970's. Sampling has predominated at retail level to represent the places where consumers traditionally buy their food.

Each year about 40 commodities are sampled including the fruit and vegetables listed in table 1. Samples are also taken of processed commodities including infant food, animal products and cereal based products.

Table 1. Fruit and vegetables monitored in recent PRC surveys.

2003	2004	2005
Apples	apples	apples
Aubergine	asparagus	beans
Avocado	cabbage	broccoli
carrots (fresh)	carrots	bulb onion
carrots (frozen)	chillies	carrots
cauliflower	grapes	courgette
cherries	green beans	cucumber
cucumber	kiwi fruit	exotic fruit
fennel	leeks	garlic
grapes	lettuce	grapes
lettuce	nuts	lettuce
limes	okra	mango
peaches & nectarines	parsnip	mushrooms
pears	peas (edible podded)	oranges
peas (frozen)	pears	pears
pineapple	plantain / green banana	potatoes
potatoes	potato	salad onion
pumpkin	pulses	spinach
raspberries	salad (pre-packed)	swede
spinach	soft citrus	turnip
squash	strawberries	
sweet peppers	sweetcorn	
sweet potatoes	sweet peppers	
	tomatoes	

Certain commodities are examined nearly every year such as the staples of milk, bread and potatoes. There is a rolling programme of work, which examines a wide range of fruit and vegetables on a three to four year basis. In addition several surveys are conducted which specifically target commodities where there have recent problems or which have a history of problems. In recent years this has included regular surveys of UK winter lettuce and grapes.

Brand naming

In 1998 Ministers decided that brand names should be published for most pesticide residue surveys. The PRC reports therefore include full details about the samples in the survey including where they were obtained and the identifiable brand of the product. This policy was not popular when it was first introduced but it has become an established part of the way the UK government requires surveys using public money to be presented. Because of the nature and numbers of samples analysed for different brands, the data are not representative of consistent differences between brands, however, it is probably true to say that this policy indirectly has led to a greater awareness of MRLs by those supplying retailers and may contribute to the UK's relatively low level of MRL exceedance.

RESULTS

Results have been reasonably consistent in recent years, in 2004 around 69% of samples contained no residues above reporting limits, 30% of samples contained residues at or below the MRL and 1% of samples contained residues above the MRL

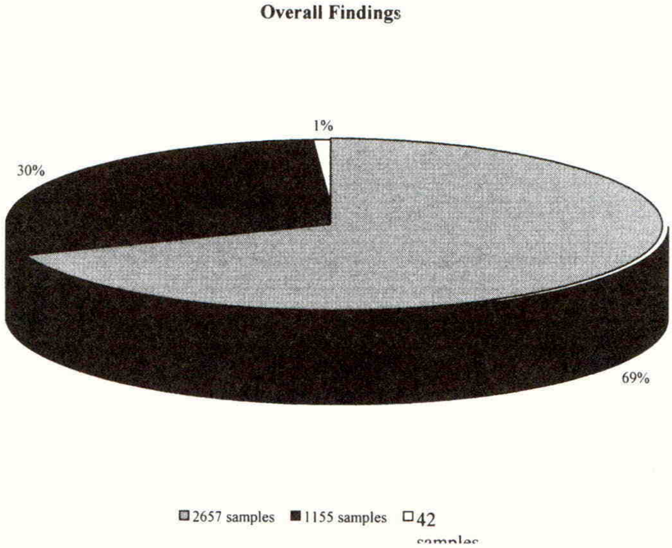

Figure 3. Overall findings for 2004.

These results can be compared to the most recently published data from the European co-ordinated programme of residue testing.

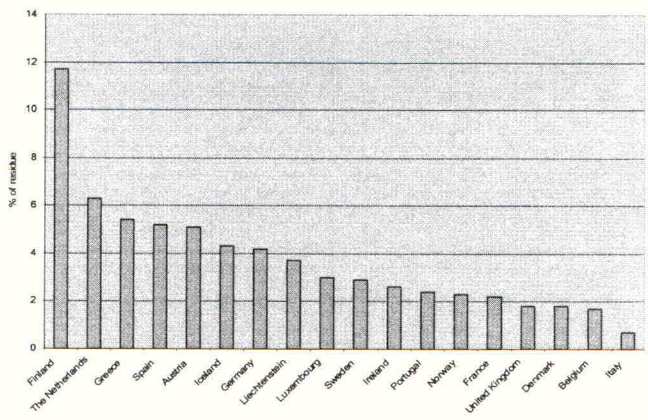

Figure 4. Findings from European monitoring: 2002 MRL exceedances

It appears that the UK has a higher level of compliance than many other member states. But caution is necessary in interpreting these figures because often they do not compare "like with like". Some other Member States have many "national" MRL's in place which will lead to more exceedances being detected and surveys can be targeted in different ways.

DISCUSSION OF STAKEHOLDER ISSUES

The PRC are not complacent about these results and are aware that these results are not always viewed as reassuring by consumers. The PRC try to keep abreast of these issues and determine an appropriate response.

Risk perception

With pesticides as with food additives and genetically modified organisms (GMO's), there is a marked gulf between the public and the expert view of risk. This is fuelled to some extent by a lack of knowledge or reduced confidence in the system. The PRC have acknowledged that the dissemination of information in this area could be improved. This is a major challenge. However, they have worked with a media consultancy organisation to produce a more user-friendly leaflet "Pesticides Facts not Fiction and to publicise the PRC's public meetings to a wider audience. A more readable version of the PRC's annual report was produced after taking on board comments from the "Plain English" organisation.

The Food Standards Agency (FSA) has a watchdog role on pesticide residue issues. They have actively sought the views of consumers to gauge opinion and consumer confidence in food safety issues. This research is useful to the PRC in helping to improve the way we communicate with the public.

Recent research has illustrated that consumers fall into four broad groups

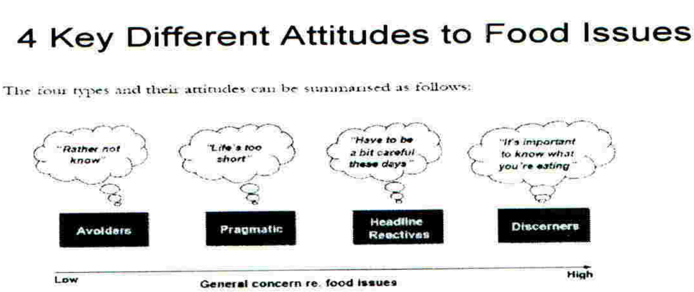

Figure 5. Overview of consumer information needs.

The main message from this research is that there are different audiences for future communications. Mainstreamers want information in the main stream press. Discerners require detailed and extensive information to educate as well as inform.

Pesticide minimisation

The FSA lead on this area, which is in direct response to consumer concerns but is acknowledged not to be driven by actual safety concerns. Since the development of this policy it is clear that initial steps to move towards "zero" pesticide residues have been modified to a reduction of pesticide residues.

The PRC have been kept fully up to date with this initiative but have made clear at all times that the presence of residues at or below the MRL is not a cause of concern. They have been pleased that the recent action plan agreed by the FSA board in 2004 has recognised the importance of working with the food production industry and other stakeholders to share best practice and ongoing minimisation initiatives.

Organic food

The authenticity of organic food is not an area within the PRC's re-mit. Organic food is surveyed routinely as part of the PRC's function and pesticides are rarely found. In recent times there have been significant changes in agricultural development which has led to significant improvements in production and yield. In real terms it is estimated that the cost of food has fallen by 75%. Providing the move to organic production does not lead to higher food prices which may limit fresh food consumption then this is not an area of health concern, but a matter of public preference.

The PRC have been keen to make sure that the permitted pesticides, which can be used in organic production, are sought in the monitoring programme. Recent research and development funded by the Pesticides Safety Directorate means that we shoud be able to look for wider list of pesticides in this area from 2006.

The "cocktail effect"

One particular area of concern is the risk from the so called "cocktail effect .The Food Standards Agency asked the Committee on Toxicity of Chemicals in Food, Consumer Products and the Environment (COT) to assess the potential for interaction between mixtures of pesticides and veterinary medicines at residue levels, and whether these combinations could result in adverse effects on human health. The Agency's request followed concerns among consumers of a potential 'cocktail effect' of exposure to several different pesticide residues in food. A Working Group on the Risk Assessment of Mixtures of Pesticides and Veterinary Medicines (WiGRAMP) was set up to take this work forward. The COT Report was published in October 2002 and its recommendations endorsed by the Agency's Board at its June 2003 meeting.

The COT concluded that the probability of any health hazard from exposures to mixtures of pesticides is likely to be small. Nonetheless, it identified areas of uncertainty in the risk assessment process and made recommendations for further work. These fell under the broad headings of regulatory, surveillance, research and public information issues. The first main step set out in the draft action plan will be to identify groups of chemicals which may act together.

An action plan to take forward the COT's recommendations has now been agreed and published. From the monitoring perspective the need for more "representative surveys" has been raised. The PRC view such surveys which involve 300 samples to be a useful component of the existing programme and have undertaken a small number of representative surveys for the last 3 years but it is acknowledged that the results need to be analysed carefully to see if there are real statistical benefits from these larger surveys.

From a risk assessment perspective the PRC have been keen to embrace the ACP's recent guidance on underlying combinative risk assessments and from the end of 2004 these have been conducted for various combination of mainly organophosphorus and carbamates pesticides.

CONCLUSION

The PRC has a clear re-mit and responsibilities and we have a good track record for meeting these aims. The food supply industry is changing and more discerning consumers want to know more about all aspects of the food that they choose to purchase and eat. The PRC is required to keep abreast of these developments both in the way it undertakes its risk assessments, communicates its results and organises its surveys.

ACKNOWLEDGEMENTS

I would like to thank Professor Andy Renwick and Professor Alan Boobis for allowing me to use presentational material that they have used at PRC events in this paper.

The Assured Produce Scheme: Developing best practice to minimise pesticide residues

C C Payne
Assured Produce, Hampton, Middlesex, TW12 2HH, UK

M Gibbard
Food chain consultant, East Dean, Chichester, West Sussex, PO18 0JB, UK

ABSTRACT

The Assured Produce Scheme (APS) is the main farm assurance scheme for fresh produce and potato production in the UK. The principal aim of the Scheme is to help maintain consumers' confidence in the safety and integrity of the produce that they eat. Growers and farmer members of the Scheme currently produce approximately 75% (c.£1 billion) of the annual farm-gate value of all fresh produce and potatoes grown in the UK. There is an increasing enthusiasm in the market place for pesticide residue free food and many stakeholder groups are now expecting that residues be kept to a minimum even if higher levels are of no concern for consumer health. The following paper describes a two stage project that was designed to review the occurrence of pesticide residues on UK sourced produce and to then provide grower members with improved good agricultural practice guidance on how residues may be minimised on a crop specific basis. Key targets for action were the late applications of fungicides and insecticides to the edible part of the crop and post harvest treatments.

INTRODUCTION

The Assured Produce Scheme (APS) was established in 1997 as a retailer-producer partnership, to deliver traceability and to set and audit good agricultural practice (GAP) production standards for fresh produce and potatoes in the UK. The Generic Protocol Standards are supplemented by Generic Protocol Guidance Notes and crop-specific protocols covering over 50 different fresh produce and potato crops produced commercially in the UK. These production protocols, which include substantial technical information and best practice guidance, are updated annually by authors who have detailed technical expertise on the individual crops. The full protocols are available on the APS website (APS, 2005).

To date, Assured Produce (AP) through its standards and crop protocols has endorsed the current regulatory risk based approach to pesticide residues in food. This continues to be the case. However, AP recognises that many stakeholder groups are now expecting that residues be kept to a minimum even if higher levels would lead to no harm. These groups span EU/UK policy makers, the food industry, non-governmental organisations (NGOs), the media and consumers.

The results of the monitoring programme conducted by the UK Pesticides Residue Committee demonstrate that pesticide residue levels above the Maximum Residue Level (MRL) trading standard are rarely exceeded on UK sourced produce and more than 70% of samples tested contain no detectable residues at all. (PRC 2003). However the presence of positive residues below the Maximum Residue Limit (MRL) trading standard but above the limit of detection (LOD), do continue to be of concern to a growing number of groups. Ideally, they would like residues to be non-detectable or if this is currently not possible, to be as low as practicable without adversely affecting the quality of their food.

Certainly the UK fresh produce industry needs to be more openly addressing these demands. AP and its grower members are well placed to develop a range of actions designed to meet the challenge. Indeed, since the start of this project, Assurance Schemes have been identified by the UK Food Standards Agency (FSA) as having a significant role to play in delivering such advancements. (Minutes of the FSA Board Meeting 13/05/04, Action Plan to Minimise Pesticide Residues in Food). AP is uniquely positioned through its crop protocol authors to deliver and regularly update any guidance to its grower members. Moreover, the annual updating and auditing of standards allows for the potential to record improvement in the implementation of best practice.

Throughout this project, AP has remained acutely aware of the delicate balance needed between maintaining produce quality and effective pest and disease control that is demanded by the retail market place, while striving to minimise residues. This balance is critical if all the fresh produce industry stakeholders and grower groups are to be engaged in support of the project.

In November 2003 at the start of the project, AP saw the benefits as being:

- a formal engagement with its membership on the issue of pesticide residues
- utilising ideas, experience and best practices of its crop authors, grower membership and their advisors to identify solutions
- to endeavour to record both changes in practice and residue levels as the project proceeds using an agreed set of change indicators
- seen to take a proactive approach by a wide range of interested stakeholders

PROCESS

The project to date has been delivered by the AP crop protocol authors and their industry stakeholder interest groups. Co-ordination and management has utilised a small project team, one of whom acted as the direct link and contact with the 31 crop authors covering over 50 crops. Approval for all activities was given by the AP Board or AP Technical Advisory Committee (TAC). Reporting was delivered in a series of comprehensive crop reports triggered by Terms of Reference for each phase. Phase 1 was completed between November 2003 and March 2004. Phase 2 was carried out between July 2004 and December 2004. Increasing stakeholder awareness (and improving the uptake) of the best practice guidance, is currently being implemented.

A number of project issues were identified at the outset that were incorporated into the planning to maximise key stakeholder awareness and support. These included-

- the need to gain understanding and support from all interested parties
- the correct positioning of the project alongside a range of other pesticide issues currently being faced by the fresh produce industry
- not being seen to be undermining the UK's effective pesticide regulatory system

- not generating advice that would contribute adversely to any pesticide efficacy, pest resistance or other issues that would compromise integrated crop management (ICM)
- choosing indicators that were able to show significant numerical or behavioural changes

PHASE 1 OBJECTIVES

The following four objectives were addressed as Phase 1 of the project.

1. To identify and confirm the key pesticide and crop residue issues in the UK. This was initially carried out as a desk evaluation by the project management team using national and industry sourced residue data. AS a consequence, thirteen crops were identified for initial investigation. They were split into three groups based on the frequency of finding positive residue data between the LOD and MRL. Group 1 (residues often found) comprised potatoes, apples, pears, protected lettuce, strawberries and raspberries. Group 2 (occasional residues) consisted of green beans, brassica, protected celery and spring onions. Group 3 included carrots, protected cucumber and protected tomato. (These were included in Phase 1, because considerable progress has already been made in these crops to minimise residues and it was felt an analysis of these crops could contribute helpful guidance for some other crops.) For each crop a draft list of target pesticides was also issued.

2. The AP crop authors were asked to confirm or amend the target pesticide list utilising the Central Science Laboratory (CSL) residue data-base RAPPORT and in consultation with an appropriate crop stakeholder group.

3. To review the target pesticide list for action (again using the expertise of the stakeholder group) under the headings- *immediate:-* where guidance could be immediately given in the crop protocol to help minimise residues; *medium-term:-* where R&D could take up to 5 years to deliver a solution and *long-term:-* where solutions might take up to 10 years to develop and implement.

4. To consider what might be suitable change indicators to measure the extent to which the project contributes to changes in the update of best practice advice, and to future pesticide residue levels.

PHASE 1 OUTPUT

1. The crop and target pesticide lists were amended as necessary and confirmed.

2. Where possible immediate guidelines were developed and included in the relevant AP crop protocol for the years 2004-5. AP were particularly pleased at the positive support that was given to it's crop authors by a wide range of interested parties, including producers.

3. Medium and long-term recommendations for future action were made in a summary form, although it was apparent from the output that more information was needed to strengthen these proposals.

4. The difficulty in identifying robust indicators of change was becoming apparent and this was an issue that still needed considerable attention to identify both the right indicators and the process for successful monitoring. While the obvious indicators of change would appear to involve pesticide residue testing, initial soundings indicated that the number of samples required (and the associated analysis costs) were likely to be prohibitive in the current situation where residue levels in UK-sourced produce are already infrequent, and at low levels.

PHASE 2 OBJECTIVES

1. Establish a common format in the protocols for delivering residue minimisation guidance to growers (and other interested parties) and ensure that this information is updated annually.

2. For the six Group 1 crops (from Phase 1), the crop authors were asked to develop their medium and long-term recommendations by expanding these to include more information on the ranking of priorities (including the future need for R&D), the likelihood of success, costings, timescales, possible funding partners and developing their ideas on change indicators. The group 2 and 3 crops were not included in this exercise as either only immediate guidance was required or residues of only a few pesticides were occasionally found.

3. Review the thirty eight remaining AP fresh produce crops (which had not been investigated fully in Phase 1) to check whether there were any significant pesticide residue issues that also required attention.

4. Develop suitable indicators of change to include both numerical changes and the adoption of best practice guidelines.

5. To report the findings to AP growers and a range of stakeholders.

PHASE 2 OUTPUTS

1. A common template has been developed for all crop authors to use when delivering pesticide minimisation guidance in their crop specific protocols. Generic guidance on residue minimisation has been included in the Generic Protocol Standards to raise awareness amongst growers.

2. Six detailed crop reports have been produced for the Group 1 crops which have identified the main priority areas for future work.

3. Of the thirty eight additional crops reviewed, twenty seven were reported to contain no, or only very occasional, residues. Of the remaining eleven, three were considered worthy of additional input to minimise more regularly occurring residues.

4. It has been agreed that the six Group 1 crops will be piloted with a range of indicators to identify whether changes in residue occurrence and/or changes in GAP have been implemented during the next 5 years. Measurements will start in 2006.

5. AP has had a good response from the UK fresh produce and potato industry together with other stakeholders in its approach to this project. Our experience in AP has clearly shown that the UK industry does identify with the need for continual improvement. The need to minimise residues from the use of insecticides and fungicides applied near harvest together with the use of post harvest treatments is well understood. However, it is worth re-emphasising that the current marketplace demand for crop quality and volume does continue to dictate the judicious need for some crop protection intervention using pesticides, which on occasions will leave small residues.

DELIVERING THE INFORMATION

Delivering information to growers in a form which assists them to take action is critical to the long-term success of the project. It has been a key AP approach that its crop authors should be giving information and guidance on GAP, not firm recommendations (except in the case of Critical Failure Points, where food safety might be compromised). This is because the dynamics of growing a crop, (climate, weather, location, frequency of pest and disease attack etc) all interact and managing these decisions together with any residue minimisation advice is therefore most appropriately undertaken on farm during the pre-planning and crop growing stages. It is therefore essential that the best guidance is available in the right format, at the right time, if best use is to be made of it by growers and their advisors.

AP will endeavour to ensure that its crop guidance is freely available not only through its web-site (APS 2005) but by encouraging as many crop groups and advisors as possible to also be messengers. AP is also aware of the role the Crop Protection Association (CPA) and its member companies together with the Agricultural Industries Confederation of distributors (AIC) and it's members staff can have in supporting the project.

A list of suggested generic solutions (not crop specific) has been placed in section 8.9 of the AP Generic Protocol Guidance Notes. The text leads the grower into the objective of keeping residues as low as practicably possible and then gives some initial suggestions:

> "A range of possible options are available to the grower to minimise residues. However an assessment must be made to ensure that yield, quality, resistance management and Good Agricultural Practice (GAP) are not compromised. These will be refined as "guidelines" for individual crop protocols from the generic options given below-
>
> - assess other techniques, cultural, mechanical, physical and biological and to use a programme containing all the appropriate options for intervention
> - minimise the carry over of pests and diseases e.g. the appropriate disposal of waste vegetable material and soil
> - ensure any planting material from propagators is as clean as possible
> - ensure that any spraying operation is carried out accurately
> - ensure that the sprayer is regularly calibrated, maintained and has a National Spray Test Certificate (NSTS)

Options include the following:

- reducing application rates nearer harvest (ensure resistance management and efficacy are not compromised)
- lengthening the Pre Harvest Interval (PHI) (ensuring efficacy is not compromised)
- reducing the number of applications to the edible crop parts by using diagnostics and prediction forecasting
- using alternating chemistry in the spray programme"

MEASURING CHANGES

One of the main aims of this project is to encourage grower members to use specific crop guidelines. AP and other stakeholders would like to be able to identify whether a reduction in residues is delivered over the next five years.

Any changes are not going to be easy to assess. Where a pesticide (which has given regular residues) is replaced or no longer used, there is likely to be an immediate measurable change. More likely we will be trying to assess changes in residue levels and patterns that are already low, often infrequent and seasonally variable. Coupled to this as already indicated will be the variation of weed, pest and disease pressure and resulting variation of inputs year on year.

Ideally many stakeholders and NGO's will wish to see reduced residues expressed numerically compared to a given baseline.

- specific pesticide active ingredients being detected
- actual number of active ingredients being detected
- frequency of detection
- levels of residues being found

However, many observers are keen that AP should also include qualitative assessments to identify change. In other words changes by growers and advisers in "best practices" designed to minimise residues. These would include for example-

- changes in usage and timing of pesticides aimed at reducing residues
- adoption of non pesticide techniques (cultural, biological, mechanical)
- usage compared to incidence of pest and disease attack
- specific changes in post-harvest procedures to reduce residues
- being part of a specific residue testing programme so that the grower understands what residues a crop is generating and can then implement a remedial plan
- increased levels of crop field monitoring to investigate pest, disease and natural enemy incidence
- increased levels of hygiene practices particularly in protected crops
- increased use of decision support systems
- actual changes in growing regimes
- improvement use of sprayer technology and application techniques

It is likely that the agreed set of indicators will include some of the above from both lists. What has been decided is that the indicators will be piloted on the six Group 1 crops where a number of residue or multi-residues exist. The benefit of this list is that it contains those crops highest in the minds of several stakeholder, NGO and consumer groups, so any changes would be acknowledged. The downside of the crop list is that we know from our investigations that, in many cases, no immediate numerical solutions are likely and these may require five to ten years to monitor trends.

NEXT STEPS

Three key areas require attention during the implementation phase of the project.

- continued communication and increasing awareness of the project amongst producers, advisers and consultants and retailers
- implementing the indicator programme successfully out to 2010
- encouraging other stakeholders to support medium and long-term R&D proposals emerging from the project, particularly in relation to the 6/7 Group 1 crops

CONCLUSIONS

The authors of this paper believe Assured Produce is an excellent vehicle to help deliver change, as a large proportion of the UK fresh produce and potato industries is in membership and already following AP standards and guidance. This has been recognised by the UK Food Standards Agency.

The crop-specific protocols, written by UK technical experts and updated annually provide an ideal mechanism to deliver up-to-date crop-specific information. This is vital as residue minimisation issues are highly crop specific. Most other farm assurance schemes (e.g. EUREPGAP) do not have this advantage as they rely on generic protocols.

ACKNOWLEDGEMENTS

The authors of this paper acknowledge the support, help and interest from a wide range of stakeholders: AP crop authors, AP Technical Advisory Committee, Horticultural Development Council, Pesticides Safety Directorate, Pesticide Residue Committee, Central Science Laboratory, Fresh Produce Consortium, National Farmers Union, Crop Protection Association and member companies, British Potato Council and other crop associations, industry stakeholders who supported the crop authors and the AP secretariat.

REFERENCES

APS 2005 The Assured Produce website
Assured Produce Generic Guidance Notes 2005/6
Assured Produce Specific Crop Protocols
On-line http://www.assuredproduce.co.uk

Central Science Laboratory (CSL) http://rapport.csl.gov.uk
Food Standards Agency http://www.food.gov.uk and
www.food.gov.uk/aboutus/ourboard/boardmeetings/boardmeetbranch2004/boardmeeting051304/boardminutes130504
Pesticide Residue Committee Annual Report 2003 www.prc-uk.org

Producing apples free of pesticide residues

J V Cross, A M Berrie
East Malling Research, New Road, East Malling, Kent, ME19 6BJ, UK
Email: jerry.cross@emr.ac.uk

ABSTRACT

Apples have traditionally been treated intensively with pesticides. Pesticide residues surveillance showed that in 2003 >70% contained residues above reporting limits. Several important retailers in the UK are asking their suppliers to strive towards elimination of pesticide residues from fresh produce including apples, to maintain and improve consumer trust. General approaches to reducing the occurrence of residues are discussed, including increasing harvest intervals and alternative control approaches. A new 'zero residue' Integrated Pest and Disease Management (IPDM) programme for apple, developed at East Malling Research, where conventional pesticides are not used during fruit development, is described and results of the first four years of a six year experiment to evaluate the strategy reported. The zero residues IPDM programme has been highly successful even on the most pest and disease prone varieties.

INTRODUCTION

Apple varieties grown in the UK are highly susceptible to a wide range of damaging pests and diseases. Adequate yields of fruit of acceptable quality cannot be produced and the crops cannot be grown profitably unless these pests and diseases are efficiently controlled. Efficient weed control is also vital. The UK apple industry relies on pesticides for these purposes. With current methods of crop protection for apples, foliar pesticide applications for pest and disease control are often made in summer during fruit development and sometimes close to harvest. Furthermore, in the past it has been common practice to drench apple fruits in fungicides and/or an antioxidant post harvest to control post harvest rots and the physiological disorder superficial scald. Use of pesticides in this way inevitably gives rise to detectable levels of pesticide residues in a high proportion of fruit. Residue levels do not exceed Maximum Residue Levels (MRLs) if Good Agricultural Practice (GAP) is adhered to. Many samples contain multiple residues.

Unfortunately, pesticides are widely regarded as highly undesirable by consumers and hence the market and there is an ongoing negative media campaign against them, fuelled by Non Government Organisations. The media firmly have pesticides in their sights. The government's policy of 'naming and shaming' has significantly raised the temperature. The concept of Maximum Residue Levels is often misunderstood. They are generally regarded as safety limits whereas in fact they are the maximum levels likely if Good Agricultural Practice is adhered to. Though public opinion is often poorly informed and the adverse consequences of pesticide use in fruit often unfounded or exaggerated, it is difficult to change public opinion against such media campaigns. However, market and consumer concerns do need to be addressed. Multiple retailers have identified the occurrence of pesticide residues as being one of the prime concerns of consumers about fresh produce. For them, consumer trust is of prime importance and pesticide residues are considered to undermine that trust. Leading multiple retailers have decided to pursue a policy of eliminating residues from their produce. They are challenging the UK apple industry to meet these concerns and develop production protocols which will greatly reduce, ideally eliminate, the occurrence of residues above reporting limits.

Thus, pesticides present a difficult dilemma to the UK apple industry. They are essential to production but using them is against the wishes of the market and consumers. They want it both ways, the very best quality at the low prices but without pesticide use and do not understand the complex issues involved. The pressure is all passed back down to the producer. This problem is not unique to top fruit production, but it is a difficult problem in top fruit requiring radical change. Fortunately, it is not as challenging as eliminating residues from other produce where alternatives to pesticides for major pest and disease problems do not exist and where not using pesticides would result in a major loss in quality. In this paper, firstly we report on which pesticide residues occur in harvested fruit giving the reasons they are used. Then we list the generic approaches to reducing the incidence of pesticide residues, then we briefly outline the East Malling zero residues apple production strategy and results of the first 4 years of a 6 year research project funded by Defra and HDC to evaluate and refine the strategy both experimentally and in commercial practice.

The occurrence of pesticide residues in apples

UK government agencies (PSD, CSL) conduct regular retail surveillance of pesticide residues in samples of fresh produce. The results are published quarterly on the web. Apples, an important dietary constituent, are surveyed every year. In 2003, 301 apple samples, 82 UK produced and 219 imported, were taken from retail outlets and analysed for residues of 109 pesticides. 71% of UK produced and 71% of imported samples contained residues above the reporting limits (5.3% had two residues, 5.0% had 3 residues, 3% had 4 residues and 1% had 5 residues). There were 3 MRL exceedences, all in imported produce. A number of pesticides are found at levels above the accepted reporting limits (RL) in UK produced fruit (Table 1).

Table 1. Occurrence of pesticide residues above reporting limits in 2003 government surveillance of UK produced apples in 2003.

Pesticide	Target	MRL (mg/kg)	Reporting Limit (mg/kg)	% samples > Reporting Limit
Bupirimate	mildew	no MRL	0.05	1
Captan	scab	3	0.05	12
Carbendazim	post harvest rots/canker†	2	0.05	15
Chlorpyrifos	caterpillar, aphid etc	0.5	0.02	48
Diphenylamine	scald post harvest	5	0.05	6
dithiocarbamates	post harvest rots†/canker	3	0.1	1
Metalaxyl	post harvest rots	1	0.05	5
Myclobutanil	mildew, scab	0.5	0.05	1
Penconazole	mildew, scab	0.2	0.05	1
Pirimicarb	aphids	1	0.02	4
Tolylfluanid	scab/post harvest rots†	5	0.05	1

† as pre-harvest sprays

Amounts below the reporting limit are regarded as zero, even though trace amounts might be present which could be measured by a more sensitive method of analysis than the standard methods. The results for UK produced fruit showed a substantive reduction in the incidence of residues from post harvest treatments to fruit compared to earlier surveys, but an increase in the incidence of chlorpyrifos residues.

General approaches to reducing the occurrence of pesticide residues

There are a number of well known generic approaches to reducing pesticide residues:

- Grow resistant varieties
- Use non chemical control methods, especially cultural, biological and biotechnological methods, wherever possible. More attention needs to be devoted to developing and using new biopesticide products which do not leave pesticide residues.
- Avoid use of pesticides except where absolutely necessary. This is done by frequent crop monitoring and risk forecasting
- Use products more intensively earlier or later in the season (e.g. pre-flowering or post fruiting to minimise problems during fruit development and fruiting)
- Use shorter persistence products
- Use products that have a high reporting limit relative to their dose. Reduce the dose of applications closer to harvest.
- Increase the harvest interval (see below)
- By training, improve knowledge and expertise of all those involved in decision making (see below)

Increasing harvest intervals

The mandatory harvest intervals on pesticide labels are designed to ensure that pesticide residue levels do not exceed Maximum Residue Levels. Longer harvest intervals would be required to guarantee residue levels below the reporting limits. The extent to which the harvest interval of each pesticide product needs to be increased needs to be determined scientifically if possible, based on properly conducted residue decline studies. Residue data is normally kept confidential by parent companies and was not gathered with the intention of determining zero residue intervals. One of the main difficulties with determining harvest intervals for zero residues is that due to variation in seasonal weather, harvest intervals that ensure no residues in one year may not do so in other years. As a starting point, parent agrochemical companies need to give guidance on harvest intervals that minimise the incidence of residues above reporting limits. Attendant efficacy data also needs to be considered, as substantially increasing harvest intervals may have negative consequences for the efficacy of control of the target pest or disease. Examination and statistical analysis of the data may enable the extent to which intervals can be/need to be increased. Conduct of further studies is likely to be prohibitively expensive. Another approach now being adopted by cooperatives is to try to tie in the occurrence of residues data from their routine residue monitoring programme with last application dates from their growers spray programmes to determine what harvest intervals lead to detectable residues. This is a less satisfactory approach. If the fruit industry is not given clear guidance by agrochemical companies, then there is a danger that arbitrary increases could be instigated and particular pesticides de-listed.

THE EAST MALLING RESEARCH ZERO RESIDUES IPDM PROGRAMME FOR APPLES

In 2001 a six year study, funded for the first three years by DEFRA alone and subsequently by Defra, the HDC and World Wide Fruit, was established to investigate the feasibility of developing a zero pesticide residue system for apples. A large scale randomised block field experiment was established in Wiseman orchard at East Malling Research which had 12 existing established plots, 6 of disease-susceptible apple varieties (Cox, Gala, Fiesta) and six of scab-resistant apples (Saturn, Ahra, Ecolette). The variety Discovery occurs in all plots as an internal standard. Each plot consisted of 144 trees on M9 rootstock and was separated from adjacent plots by alder windbreaks. In these plots the pest and disease control achieved following a routine conventional pesticide programme is being compared to that achieved following a 'zero residue' management system. Untreated plots of disease-susceptible and resistant varieties were included (Table 2).

Table 2. Treatments in the zero residue experiment in Wiseman orchard, East Malling Research

Treat name	Programme	Management
Susceptible variety plots: Cox, Gala, Fiesta, Discovery		
U-S	Untreated	None
C-S	Conventional	Routine pesticides. Captan (28 & 14 days pre-harvest) for storage rot control
Z-S	Zero residue	Managed pesticides early and after harvest. Biocontrol during fruit development. Rot risk, selective picking, inoculum removal for storage rot control
Resistant variety plots: Saturn, Ahra, Ecolette, Discovery		
U-R	Untreated	None
C-R	Conventional	Routine insecticides and mildewicides. Reduced scab fungicide programme. Captan (28 & 14 days pre-harvest) for storage rot control
Z-R	Zero residue	Managed pesticides early and after harvest. Biocontrol during fruit development. Rot risk, selective picking, inoculum removal for storage rot control.

The zero pesticide residue management strategy is based on the use of conventional pesticides (excluding organophosphorus (OP) insecticides) up to petal fall and after harvest, but during the fruit development period to rely on biocontrol for dealing with pests and diseases. The key features are:

- Integrated pest and disease management (IPDM) from bud burst to petal fall based on conventional pesticides (thiacloprid, fenoxycarb, diflubenzuron, methoxyfenozide) but excluding organophosphate insecticides. Management of scab and mildew using ADEM disease risk forecasting model to optimise timing and dose of fungicides (Berrie & Xu, 2003).
- Use of biocontrol agents (*Bacillus thuringiensis* (Bt) or codling moth granulovirus) for pest control from petal fall to harvest.

- No conventional fungicides for disease control post petal fall except for reduced dose sulphur for mildew control. Frequent assessment of secondary mildew to determine dose of sulphur to be applied.
- Cultural control. Removal of primary mildew, cankered shoots and brown rot.
- Rot risk assessment to determine likely rot problems in the orchard (Full details in Defra Best Practice Guide for apples (Cross & Berrie, 2001)).
- Cultural control and selective picking to reduce / control rot problems in store. Only sound fruit (to avoid brown rot) and fruit above knee height (to avoid *Phytophthora* rot) picked for storage (Berrie, 2000).
- During the post harvest / dormant period, a DMI (e.g. myclobutanil) fungicide applied for late mildew and scab control, urea for leaf rotting and scab control, copper sprays for canker control at leaf fall and copper pre budburst for overwintering scab.
- Post harvest application of an aphicide for control of rosy apple aphid.

Differences in pesticide use for the different treatments are illustrated in Tables 4 and 5 for fungicides and insecticides, respectively. In all years to date the zero residues programme has reduced fungicide costs but increased insecticide costs.

Table 4. Number of fungicide active ingredient applications for disease control in 2002 and their total cost. Note two fungicides were applied in many spray rounds.

Fungicide	**Conventional**		**Zero residues**	
	Susceptible	**Resistant**	**Susceptible**	**Resistant**
Early copper	0	0	1	1
Fungicides bud-burst-petal fall	10	6	12	8
Fungicides petal fall-harvest	16	11	0	0
Sulphur petal fall-harvest	0	0	9	9
Post harvest fungicides	0	0	2	2
Leaf fall urea	0	0	1	1
Total cost (£/ha)	384	304	262	217

Table 5. Spray programmes applied for pest control in 2003 and their total cost

Date (2003)	**Growth stage**	**Conventional**	**Zero residue**
16 Apr	Pink bud	Thiacloprid +methoxyfenozide	thiacloprid +methoxyfenozide
17 May	Petal fall	Thiacloprid +methoxyfenozide	thiacloprid +methoxyfenozide
14 Jun	Fruitlet	Chlorpyrifos	*Bacillus thuringiensis*
14 Aug	Pre-harvest	Chlorpyrifos	*Bacillus thuringiensis*
30 Sep	Post harvest	-	Pirimicarb
24 Oct	Post harvest	-	Pirimicarb
Total cost/ha		180	339

RESULTS

Scab control has been as good and often better in the zero residue plots than in the conventional plots, even on Gala, a variety which is exceptionally scab susceptible and including in 2002 and 2004, when scab risk was high (Table 6).This also demonstrates that the reduced scab programme, now used on the managed plots for four seasons, does not result in a build up of scab inoculum.

Table 6. Incidence of scab on the highly susceptible variety Gala.

Treatment	2001	2002	2003	2004
	% shoots infected in July			
Untreated	90.0	100	100	100
Conventional	2.5	7.5	0	5.0
Zero Residues	0	0	0	0
	% fruits infected at harvest			
Untreated	72	98	51	89
Conventional	0.5	5.6	0.3	2.4
Zero Residues	1.0	2.7	0.3	0.1

Mildew control in the zero residue plots was also similar to that in the routine treated plots, and did not exceed 20% of shoots mildewed (Table 7). The primary mildew in managed plots at the start of 2002, 2003 and 2004 was negligible, indicating that the system was not resulting in a build up of primary mildew. Primary mildew incidence was high at the outset of the experiment on the variety Ahra in one of the Zero residue management plots as prior to 2001 this plot had been untreated. However, the zero residue management system reduced the incidence of primary mildew sharply in 2001 and to zero by 2003 and 2004.

The incidence of rots in Cox after long-term controlled atmosphere storage is shown in Table 8. Post harvest rots can be a significant commercial problem in Cox. The rot management system applied in the zero residue programme gave satisfactory control and in most years the lowest incidence of rots was in fruit from the zero residues plots. The predominant rots were brown rot (*Monilinia fructigena*) and *Nectria galigena*.

Pest damage to fruit at harvest is shown in Table 9. A high incidence of pest damage was recorded in the untreated plots in all years and especially in 2004. In 2001 and 2002, pest damage in the zero residues plots was greater than in the conventional plots due to poorer control of rosy apple aphid, sawfly and tortrix. These problems were overcome in 2003 and 2004 by use of two early season thiacloprid sprays, one just before blossom and one at petal fall, by the use of fenoxycarb pre-blossom against tortrix moth caterpillars and by post harvest spraying of pirimicarb against rosy apple aphid. Codling moth incidence was low and it was not necessary to apply sprays of codling moth granulovirus for control.

Table 7. Incidence of mildew on the highly mildew susceptible varieties Cox and Ahra.

Treatment	Variety	2001	2002	2003	2004
% Blossoms infected with primary mildew					
Untreat-Suscept	Cox	2.3	0	3.5	1.8
Untreat-Resist	Ahra	8.4	3.3	13.5	26.9
Conv-Suscept	Cox	0	0	0	0
Conv-Resist	Ahra	0.4	0.1	0	0
Zero Res-Suscept	Cox	0	0	0	0
Zero Res-Resist	Ahra	14.5	0.8	0	0
% shoots with secondary mildew in Jun-July					
Untreat-Suscept	Cox	53	78	75	88
Untreat-Resist	Ahra	68	75	100	100
Conv-Suscept	Cox	5	5	10	10
Conv-Resist	Ahra	0	0	2.5	0
Zero Res-Suscept	Cox	13	5	15	13
Zero Res-Resist	Ahra	13	5	10	10

Table 8. Incidence of rots in the rot susceptible variety Cox after long term CA storage (3.5 °C, 1.25% O_2, < 1% CO_2)

Treatment	2001	2002	2003	2004
Untreated	3.4	14.4	25.2	16.3
Conventional	0.9	7.2	6.2	7.8
Zero Residues	3.2	5.5	4.6	3.6

Table 9. % fruits (averaged across all varieties) damaged by rosy apple aphid (upper part of table) an by all pests (including rosy apple aphid) (lower part of table) at harvest

Treatment	2001	2002	2003	2004
% fruits damaged by rosy apple aphid at harvest				
Untreated	4.7	16.3	2.2	32.3
Conventional	0.2	0.9	0	0.7
Zero Residues	2.8	0.7	0	0
% fruits damaged by pests at harvest				
Untreated	18.5	47.0	40.6	67.5
Conventional	4.3	8.2	6.3	6.6
Zero Residues	11.2	13.4	6.5	4.9

DISCUSSION

The results indicate that the East Malling Research Zero Residues IPDM programme for apples can give satisfactory results, even on highly disease susceptible varieties in years when there is a high risk of scab. The key to success depends on dealing with disease problems during the winter dormant period and pre blossom, such that inoculum carryover from one season to the next, and into the post blossom period, is negligible. Assuming disease control pre blossom has been successful, the main disease problems post bloom are powdery mildew and storage rots. Control of mildew during the summer in this experiment has relied on the use of sulphur, the dose applied and spray interval being determined by mildew risk identified by ADEM. Studies are ongoing at East Malling Research to investigate alternative methods of mildew control, such as use of biocontrol agents and materials that increase the resistance of apple leaves to mildew. If successful these methods will eventually replace sulphur for mildew control in the summer.

CONCLUSIONS TO DATE

- The results achieved in the first four years of the project (2001-2004) for the zero pesticide residue strategy look promising.
- The zero residue strategy gave acceptable mildew control, but it was not as good as the conventional.
- Alternative treatments for mildew control are needed and research is in progress to identify these.
- The zero residue programme resulted in as good as or better control of scab than in the conventional, even in high risk scab years.
- Pest control in the zero residue system appears to be satisfactory but new problems may arise.
- Storage rot control has been satisfactory under the zero residue programme, but other approaches are needed for *Nectria* rot and other cheek rots.

REFERENCES

Berrie A M (2000). Pre-harvest assessment of the risk of storage rots in Cox apples. *IOBC/WPRS Bulletin*, **23**, pp. 159-169.

Berrie A M; Xu X M (2003). Managing apple scab and powdery mildew using Adem. *International Journal of Pest Management*. **49**, pp. 243-250

Cross J V; Berrie A M (2001). Integrated pest and disease management in apple production. In: *The Best Practice Guide for UK Apple Production, Department for Environment, Food & Rural Affairs* (Defra), Horticulture Research International, Farm Advisory Services Team Ltd, ADAS, Worldwide Fruit/Qualytech, pp. 2.1-2.94.

Reducing pesticide use in protected strawberry crops. Commercial experience and grower trials to improve control of the glasshouse whitefly, *Trialeurodes vaporariorum*

C Sampson
Biological Crop Protection Ltd, Occupation Road, Wye, Kent, TN25 5EN, UK

ABSTRACT

Biological Crop Protection Ltd. has developed an Integrated Pest Management (IPM) programme for the main pest species attacking protected strawberry crops. Uptake of this programme by commercial growers has resulted in reduced insecticide use and improved pest control. The glasshouse whitefly, *Trialeurodes vaporariorum*, is an increasing problem in protected strawberry crops. In laboratory experiments, the starch polymer reduced all whitefly stages by over 95%. In a commercial crop, two treatments of the starch polymer resulted in 99% control when the plants were small and good leaf cover could be achieved, but only 55% control when the canopy was dense. Weekly releases of the parasitic wasp *Encarsia formosa*, once temperatures exceeded 15°C, reduced whitefly numbers by 90% and prevented crop damage. Sulphur burning for the control of powdery mildew was restricted to two hours per night, and this was considered a key factor in the success of IPM.

INTRODUCTION

Biological Crop Protection Ltd, produce and supply natural enemies for the control of pests. Biological control has been used in UK strawberries since the 1960s (Garthwaite, 2000). Until the 1980s, *Phytoseiulus persimilis* was the main predator used, for the control of spider mites (*Tetranychus urticae)*. Since then the biological programme has expanded to control thrips, aphids, tarsonemid mites, caterpillars and vine weevils. The area of glasshouse strawberry crops in the UK has doubled in the last decade to over 115 ha in 2004 (MAFF statistics). Demand for biological control has also increased, partly driven by resistance to available pesticides, especially in thrips and spider mite populations (Price *et al.*, 2002). Increasingly, consumers demand pesticide free produce and workers are reluctant to spray chemicals. Following a decade of experience and grower trials in protected strawberry crops around the country BCP Ltd has developed a biological programme to control the main pest species (Table 1).

In recent years the glasshouse whitefly (*Trialeurodes vaporariorum),* has increased as a pest in protected strawberries and control methods are required that do not disrupt the biological control of other pests. A combination of factors have led to the increase in whiteflies including the lack of IPM compatible pesticides registered for whitefly control. The parasitic wasp *Encarsia formosa*, is an effective control for the glasshouse whitefly in protected salad crops (Garthwaite, 2000), but the use of sulphur burners for powdery mildew control and low winter temperatures, compromise its establishment in protected strawberries. *E. formosa* has very low activity below 15°C (Madueke & Coaker, 1984). This paper reports on laboratory and grower trials to determine whether early season use of the physical product Eradicoat (starch polymer) followed by weekly releases of the parasitic wasp *E. formosa* would control *T. vaporariorum* in a spring crop of protected strawberries.

Table 1. BCP Biological programme for protected strawberry crop

Pest Species	Natural enemy species and release rates			Comments
	Preventative	Low	High	
Spider mites *Tetranychus uricae*	Ambsure (cal) *Amblysieulus californicus* 3 x 2 per m^2 fortnightly	Phytosure (p) *Phytoseiulus persimilis* @ 2.5 to 10 per m^2	Felsure *Feltiella acarisuga* @ 1 tub per hot-spot for up to 4 weeks	Use *P.persimilis* or *F. acarisuga* for outbreaks Use of *A. californicus* permitted in permanent structures only.
Thrips *Frankliniella occidentalis*	Ambsure ABS *Amblyseius cucumeris* @ 1 sachet per 2 m, before flowering Hyposure *Hypoaspis miles* @ 150-250 per m^2	Ambsure (c) *Amblyseius cucumeris* @ 50-100 per m^2 at flowering. Repeat if thrips build up.	Orisure *Orius laevigatus* @ Up to 2 per m^2 Eradicoat or Majestik Use over the tops of flowers if thrips numbers approach 3 per flower	Establish *A. cucumeris* before flowering and before thrips occur. From flowering, extra *A. cucumeris* may be required in hot-spots *Orius* can be used between March and September on everbearer crops
Aphids *Aphis gossypii* *Myzus ascalonicus* *Macrosiphum* sp. *Aulacorthum* sp.	Aphidosure *Aphidoletes aphidimyza* or Aphisure *Aphidius colemani* or *ervi* @ 0.25 per m^2 weekly	*Aphidoletes* sp. or *Aphidius* spp. @ 0.5 to 1 per m^2 weekly	*Aphidoletes* sp. or *Aphidius* spp. @ 1 to 2 per m^2 weekly, 5 to 10 per m^2 in hot spots	*Aphidoletes* go into diapause in short daylengths. Use from March- October or in hot-spots Use *A. colemani* for *Myzus & Aphis* spp. and *A. ervi* for *Macrosiphum* and *Aulacorthum spp.*
Vine weevil *Otiorhynchus salcatus*	Nemasys L *Steinernema krausseri* 25,000 nematodes per plant if present			Drench larvae in late autumn >5°C. Re-treat in spring for high populations
Caterpillar *Tortrix spp.*	Monitor with pheromone traps for specific species	Spray Dipel DF *Bacillus thuringiensis* when moths are seen at 100g/100 litres of water Repeat sprays at 3 week intervals		Good spray cover is essential.

MATERIALS AND METHODS

Laboratory trial

Leaf discs (3cm diameter) were cut from a tobacco leaf (*Necotiana tabacum*). To prevent leaf dehydration the leaf discs were placed onto a 2 % agar solution inside a 3 cm diameter x 3 cm high-ventilated pot. The leaf discs were infested with 1-2 day old whitefly eggs (*T. vaporariorum*), 2-3 day old whitefly pupae or 2-3 day old whitefly adults. The leaf discs were then sprayed using a Potters tower with either tap water (control) or the starch polymer (25ml per litre of water). After 4 days (25 ^{0}C ± 1 ^{0}C, 60 – 70% RH) the numbers of dead or live insects were counted. Each treatment had 4 replicates. Statistical analysis of the data was carried out using Genstat program version 4, using general linear modelling of binomial proportions by logit.

Grower use

Assessments were done at Polehouse Nurseries in Lawford, Essex (7 glasshouse blocks, 30,000 sq m). The crops (cv Elsanta) were grown in raised peat troughs and had an existing whitefly population. In mid-February 2005, the grower applied two treatments of the starch polymer (25ml per litre of water) at a seven-day interval after the outer leaves had been trimmed and the blocks heated to initiate new growth. The plants were sprayed to run-off with a boom sprayer, using flat fan nozzles. On fortnightly visits, between five and ten plants were examined at random per block and the numbers of adult whiteflies per plant estimated. The numbers of whiteflies were compared to those of the previous year when the starch polymer was not used.

Encarsia formosa grower trial

The trial was conducted in commercial strawberry crops (cv Elsanta) grown in raised peat troughs at Hempnall, Norfolk. *E. formosa* pupae were released at 10 per m^2 per week into three glasshouse blocks (4092, 3720 & 2880 sq m) from 22nd March to 31st May 2005. The loose pupae were placed in release cups using one cup per 100 sq m. Average block temperatures were c.16°C and maximum daytime temperatures c. 25°C. Three blocks (1160, 5292 & 11,328 sq m) were left untreated as a control, until the whiteflies caused honeydew, when two treatments of the starch polymer were applied on 5th and 10th May. Blocks were separated by sliding doors. Sulphur burning for the control of powdery mildew was restricted to two hours per night. Yellow sticky traps (10cm x 25cm) were placed 10 cm above the crop foliage, with one per 250 sq. m. The numbers of adult whiteflies per trap were counted weekly and the traps replaced.

To assess numbers of whiteflies on plants, one row was selected at random from around the middle of each block. Every fortnight, ten plants were selected at random down the length of the row and the numbers of adult whiteflies counted on the tallest, vertical leaf. On the final assessment, the sample leaves were collected and examined under the microscope. On each sample leaf the numbers of live, dead and parasitised whitefly scales were counted. Statistical analysis of the data was carried out using analysis of variance.

RESULTS

Laboratory trial

The starch polymer treatment significantly reduced numbers of whiteflies in all stages compared to the control ($p<0.001$), giving 99%, 96% and 100% control of eggs, pupae and adults (Figure 1).

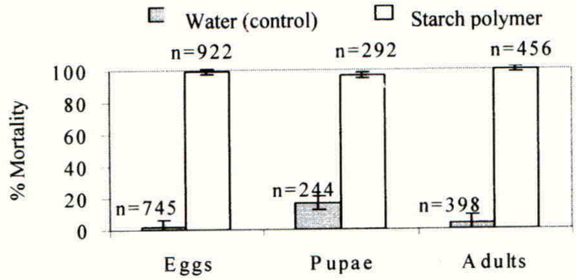

Figure 1. Effect of the starch polymer on different stages of the glasshouse whitefly

Grower use

In 2005, two starch polymer treatments together with leaf trimming reduced whitefly numbers from 30 per leaf to 0.1 per plant (Table 2). This reduction was not observed in 2004 when other physical control products were used.

Table 2. Effect of the starch polymer on whitefly numbers in a commercial crop

Year (Treatment)	Approximate numbers of whitefly adults per plant		
	Mid-February	Mid-March	Mid-April
2004	50	50-100	550
2005 (Starch polymer)	30	0.1	10

Encarsia formosa grower trial

Releases of *E. formosa* significantly reduced the numbers of adult whiteflies on traps ($p<0.01$, Figure 2) and on leaves ($p<0.01$, Figure 3) in treated blocks.

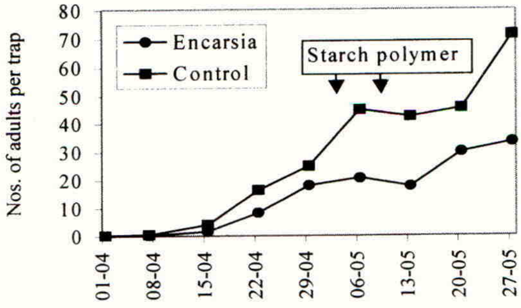

Figure 2. Effect of *Encarsia formosa* releases on adult whitefly numbers on sticky traps

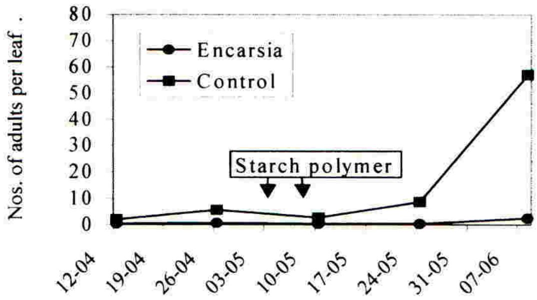

Figure 3. Effect of *Encarsia formosa* releases on adult whitefly numbers on plants

On the final assessment, the numbers of live whitefly scales on leaves were reduced by a factor of ten in the treated blocks and 64% of the unhatched scales were either dead or parasitised compared to 24% dead in the untreated blocks (Table 3).

Table 3. Mean numbers of live, hatched dead and parasitised whitefly scales per leaf in blocks with and without *E. formosa* (n=10)

Block	Live whitefly scales	Hatched whitefly scales	Dead scales	Parasitised scales
1 – Treated	1.9	0	2.2	0.2
2 – Treated	8.1	0	6.8	1.4
3 – Treated	9.3	18.1	17.8	2.3
4 - Untreated	92.1	18.3	29.9	0
5 - Untreated	44.4	12.4	6.8	0
6 – Untreated	91.6	111.3	36.8	0

DISCUSSION

Adoption of the BCP biological programme in protected strawberries at Polehouse Nurseries has led to continued reduction in insecticide use and improved pest control. In the spring 2005 crop at Martham, Norfolk, ten insecticide treatments were applied in a block without biological control compared to two in a block where IPM was used (Polehouse Nurseries spray records). The use of *A. cucumeris* for the control of thrips (*Frankliniella occidentalis)*, had the greatest impact. In the spring 2005 crop, no chemical insecticide treatments were required for thrips control in 21 separate glasshouses where *A. cucumeris* was used. Where chemical control was used in a glasshouse at the same nursery, six insecticide applications failed to prevent crop damage.

For whitefly control, the starch polymer showed excellent efficacy in laboratory experiments (Figure 1). Good leaf cover is essential in order to achieve control as the starch polymer acts physically, causing suffocation by blocking the spiracles in invertebrates (Cordon, unpublished data). This explains why two the starch polymer treatments were very effective in February (99% control, Table 1), when the numbers and size of the leaves were relatively small (c. 4-5 leaves), but less effective in May (55% control, Fig. 3), when the canopy was dense (>10 leaves) and difficult to penetrate.

The *E. formosa* trial began once block temperatures exceeded the lower threshold for development of 13°C (Madueke & Coaker, 1984). As mean block temperatures were below optimum, a high release rate of 10 per m^2 per week was used. *E. formosa* maintained low whitefly numbers throughout the trial period and prevented crop damage. Further trials using rates down to 1 per m^2 per week will follow. On the final assessment, no live whiteflies had hatched out of sample leaves in two of the treated blocks and more scales had been killed by host feeding than by parasitism (Table 3). Whitefly numbers were greater in block 3 which was adjacent to two untreated blocks. The doors between the blocks were often left open and there was an exchange of whiteflies between blocks. Monitoring adults did not give the best measure of whitefly populations because adults are highly mobile. However, adults were used as they are easy to see and count without the need for a microscope, considering the time constraints of a commercial trial.

The greatest constraint to establishing biological control in protected strawberry crops is the burning of sulphur, which is a cheap and effective control of powdery mildew, *Spaerotheca macularis f. sp. fragariae*. Sulphur burning is harmful to many natural enemies including predatory mites and *E. formosa* (Sterk & Put, 2004). At Polehouse Nurseries, improved establishment of natural enemies has been achieved by reducing sulphur burning from 24 hours per day to 2 hours at night. Powdery Mildew was successfully controlled by wet sprays of mycobutanol, azoxystrobin, bupirimate and mepanipyrim. With a small number of effective pesticides registered for use in protected strawberries, integrating their use with biological control reduces the numbers of applications needed, delays the development of resistance and minimises the amount of pesticide residues in food.

ACKNOWLEDGEMENTS

Thanks go to Peter Wensak, Jon Marcar, Judy Randon and Igor Chpak at Polehouse Nurseries, for enabling trials to take place and for trying biological control and new techniques. Also thanks to Richard Cordon (BCP Ltd) who carried out the laboratory experiments using the starch polymer and to Adam Root (BCP Ltd) who assessed parasitism on leaves from the field trial.

REFERENCES

Garthwaite D (2000). Changes in biological control usage in Great Britain between 1968 and 1995 with particular reference to biological control on tomato crops. *Biocontrol Science and Technology* **10**, pp. 451-457.

Madueke E D N; Coaker T H (1984). Temperature requirements of the white fly *Trialeurodes vaporariorum* (Homoptera: Aleyrodidae) and its parasitoid *Encarsia formosa* (Hymenoptera: Aphelinidae). *Entomologia Generalis* **9,** pp. 149-154.

Price J F; Legard D E; Chandler C K (2002). Twospotted spider mite resistance to abamectin miticide on strawberry and strategies for resistance management. *Acta Horticulturae* **567** pp. 683-685.

Sterk G; Put K (2004). Side effects manual. *Biobest Biological Systems*, pp.26-27.