Project title:	On-farm evaluation of zero residue system for apples
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The results and conclusions in this report are based on an investigation conducted over a one-year period. The conditions under which the experiments were carried out and the results have been reported in detail and with accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.

AUTHENTICATION

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

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CONTENTS

GROWER SUMMARY

Headline

- A zero residue management system provided commercially acceptable control of apple scab, storage rots and pests

Background and expected deliverables

Consumers want perfect apples of known varieties which are free of pesticide residues. Consequently the same demand is being made by the major supermarkets. Unfortunately the main UK apple varieties – Cox, Gala and Bramley are susceptible to most pest and diseases and the UK climate ensures that one or other of these problems occur in most seasons. The zero residue requirement is therefore a major challenge for growers.

The zero residue management system (ZRMS) was developed to achieve residue-free apples whilst offering a sustainable production system for the grower. The system is based on the use of conventional pesticides up to petal fall and after harvest, but biocontrol agents or sulphur are relied upon during fruit development in the summer. The key to success is achieving disease control during the dormant season to minimise inoculum carryover into the new season. The system has been evaluated in experimental plots at East Malling Research (EMR) on scab susceptible and scab resistant varieties for 6 years as part of a Defra-funded project HH3122STF and HDC project TF164. In these trials scab, mildew and storage rot control were equal to or better than that achieved in conventional plots and pest control was also satisfactory.

The system has been evaluated in four commercial orchards (two Cox and two Gala) in Kent over three years, also with promising results, particularly on Gala. This work finished in March 2007.

This project (TF 173) is further evaluating the ZRMS in commercial orchards, specifically targeting other fruit growing areas, where the disease risk is higher (Gloucestershire), and on other varieties (Bramley and Braeburn). This will provide the industry with more information on the robustness of the system and identify any new problems that could affect its long-term uptake and success.

If the extended evaluation is successful then it will provide growers with a pest and disease management system to satisfy their customers.

Summary of the project and main conclusions

2009

In 2009 the evaluation of the ZRMS was continued in four commercial orchard sites. Comparisons were again made at the established trial site on Gala (established in 2004 as part of the Defra-funded project) located at Broadwater Farm, West Malling, Kent A second year's data was collected from the Gala site at Castle Fruit Farm, Newent, Gloucestershire and two sites in Kent on Bramley (Foxbury Farm, Stone Street) and Braeburn (Rodmersham Court, Rodmersham). At each site the pest and disease control achieved by the ZRMS (Table 1B at end of Grower Summary), applied to half the orchard was compared to that achieved by the grower's conventional programme applied to the other half of the orchard. Pest and disease incidence was assessed at monthly intervals from green-cluster to harvest. At harvest 1,000 fruit were picked from each half of all the orchards and assessed for pest and disease. Where possible, 10 bins of fruit from each plot were stored and the rot incidence assessed at the end of the storage period.

The weather conditions in 2009 were much drier than in 2008. Hence the scab risk was much lower and this, combined with the additional spray rounds in the ZRMS Gala plots, meant that scab control was generally good in both the trial sites. Scab control in the ZRMS plots at the Bramley and Braeburn sites was as good as that in the conventional plots (Table 1A). It is clear that if a ZRMS system is to succeed then a more flexible approach to fungicide use post-bloom needs to be available for susceptible varieties such as Gala.

The incidence of primary mildew was generally low at the Gala and Braeburn sites but secondary mildew on extension growth rapidly built up in the summer to between15-97% infected shoots. The high incidence of secondary mildew did not appear to affect yield or fruit quality. The incidence of primary mildew in the Bramley orchard was exceptionally high in both plots. Consequently the incidence of secondary mildew rapidly increased to almost 90% infected shoots. Again the high incidence of secondary mildew did not appear to affect yield or fruit quality. In the experimental plots at East Malling Research (2001-2006) control of powdery mildew in the ZRMS was always acceptable. However, mildew control in the ZRMS plots in the commercial orchard trials has not been acceptable. Reasons for this are not understood but the problem clearly needs to be addressed.

Generally control of storage rots has been as good or better in ZRMS plots compared to conventional plots. In 2009 only fruit from the Braeburn trial was stored. The incidence of rots in fruit from the ZRMS plots at the Braeburn site was very low (<1%) compared to no rots in fruit from the conventional plot.

The control of insect pests was commercially acceptable in ZRMS plots at all sites although the incidence of damage was generally higher in the ZRMS fruit at harvest compared to the conventional plots.

No pesticide residues were detected in fruit sampled from ZRMS plots at harvest. Penconazole, myclobutanil, captan, pyraclostrobin, boscalid, pirimicarb, indoxacarb, chlorpyrifos and methoxyfenozide, were detected in fruit sampled from conventional plots but not above the Maximum Residue Level (MRL).

The growers participating in the trials all perceived that the ZRMS was more expensive. Actual costs of the pesticide programme applied were greater in only one of the three sites (Table 1A). More careful monitoring of pests and diseases may be required compared to the conventional system. The main concern is that under a ZRMS system the fruit is more at risk from pest and disease damage. At present there is no incentive to follow such a system, for example requirement by retailers or a financial reward for ZRMS fruit.

Table 1A. Summary of pest and disease on fruit at harvest, powdery mildew on shoots in June and relative costs of spray programmes applied to ZRMS and conventional plots in June 2009

Variety / site	Treatment	% fruit with scab at harvest	% fruit with pest damage at harvest	% mildewed shoots in June	Cost of insecticide /fungicide spray programme £/ha
Gala Broadwater	ZRMS	2.2	6.2	97.0	590
	Conventional	0.5	3.2	22.0	1034
Bramley Foxbury	ZRMS	0.7	3.0	76.0	739
	Conventional	0.3	1.6	87.0	592
Braeburn Rodmersham	ZRMS	0	0.3	33.8	962
	Conventional	0	0.3	8.8	1,295
Gala Newent	ZRMS	0.8	6.6	15.0	
	Conventional	0.2	3.0	2.0	

General conclusions on ZRMS (2004-2010)

- ZRMS is achievable.

- Stopping the conventional control programme at petal fall is acceptable in most seasons. Commercially acceptable control of scab, storage rots and pests was achieved in five of the six seasons.

- Scab control in ZRMS plots was as good as that in conventional plots in five of the six seasons.

- For varieties very susceptible to scab, a more flexible approach is required, as in high risk seasons sprays for scab may need to be continued for two or more rounds after petal fall.

- Control of powdery mildew was generally poor and above 30% threshold in most of the orchard ZRMS plots and in the conventional plots. This indicates a general underlying mildew control problem which needs to be addressed.

- ZRMS does not appear to result in higher incidence of rots.

- Pest control appears to be satisfactory, but there are potential pest problems such as woolly aphid and mussel scale.

- In high pest or disease risk seasons, it may be necessary to extend the conventional system beyond petal fall and rely on extending the harvest interval to avoid residues.

- Careful pest and disease monitoring is essential to detect problems early and take appropriate action.

- No residues were detected in the fruit from ZRMS plots. However, with analytical methods continuously being improved and able to detect extremely low residues, zero residues may not be an appropriate name for the system.

Financial benefits

Experience from the Defra-funded project has shown that use of sulphur in the post-blossom period in ZRMS plots resulted in a saving of approximately £100/ha. However, use of more selective insecticides results in an increased cost so that overall, spray costs for the ZRMS and conventional plots were similar. In 2009 the cost of the pesticides applied to ZRMS plots was significantly lower in two of the three sites costed. There are additional costs in management as more careful monitoring is required in ZRMS plots. Currently, there are no premiums paid for fruit from ZRMS plots other than that of satisfying customer requirements.

Action points for growers

- The results in 2008 indicate that for varieties such as Gala that are very susceptible to scab, a more flexible approach to fungicide use post-bloom in the ZRMS may need to be adopted when scab risk is high.

- Scab inoculum level in the orchard is critical to the success of the ZRMS and particularly the inoculum reduction programme applied post-harvest.

- Growers can evaluate the system for themselves but It is important initially not to be too ambitious. Select one or two orchards on the farm to manage according to the system to gain experience before embarking on a wider adoption of the system.

When setting up a ZRMS in an orchard, the following points should be considered:

The key feature of the zero residue management system is to reduce the populations of pest and disease during the dormant season to ensure negligible inoculum carryover from one season to the next. Choice of orchard, starting at the right time and meticulous and sustained orchard monitoring and implementation of the management programme are vital to success.

Choice of orchard

It is important that orchards selected for a ZRMS programme have a low incidence of pests and diseases at the outset, especially powdery mildew.. Those with a history of disease or pest problems should be avoided. The orchard must be well managed and trees trained and pruned to ensure an open canopy for good air circulation and spray penetration. Our trials experience so far has been on Cox, Gala, Fiesta, Bramley and Braeburn and on scab resistant varieties where we have had good success. Use orchards of these varieties first.

When to start

It is important to start the ZRMS programme in the autumn, shortly after harvest to implement the important late season and dormant period tasks that are vital to success.

Zero residue management system

The features of the zero residue management system are summarised in the Table 1B (below).

Management of the herbicide strip

Management of the tree strip is the same as in conventional production. Excessive weed growth is undesirable, but if weeds are managed, they could provide soil cover to prevent soil splash to fruit pre-harvest. A dead-grass mulch is ideal. Applying a straw mulch would also prevent soil splash.

Orchard monitoring

A rigorous, regular programme of orchard monitoring for pests and diseases is vital. This enables timely corrective action to be taken. Orchard inspection for scab during blossom and petal fall is critical. If significant levels of scab are present then proceeding with the zero residue programme is not advisable. Similarly, if a problem gets out of control between petal fall and harvest then it may be necessary to intervene with pesticide applications. This should rarely be necessary and may not result in residues if a sufficiently long harvest interval can be observed.

Table 1B. Summary of treatments in the zero residue management system

Timing	Pest/Disease target	Treatment
Post-harvest (conventional pesticides)		
September/October	scab/mildew	Systhane+ Captan
October	nectria canker	Folicur*
October (approx. 7-14 Oct)	aphids	Aphox or other aphicide but different chemical group to Calypso
Pre-leaf fall	scab	Urea
Leaf fall	nectria canker	Cuprokylt Folicur*
Winter	overwintering codling	Nematodes
Winter	canker	Removal in pruning
Winter/spring	scab	Macerate leaf litter
Pre bud burst (conventional pesticides)	scab/nectria canker	Cuprokylt
Bud burst – petal fall (conventional pesticides)		
Bud burst - petal fall	scab	Dithianon Captan Systhane
Petal fall – June	scab - On very susceptible cultivars such as Gala conventional sprays can be continued for 2 to 3 rounds after petal fall in high risk years	Systhane + Captan
Bud burst - petal fall	mildew	Systhane or Nimrod or Topas
Mouse ear/green cluster	tortrix/winter moth	Runner
Pink bud	tortrix	Insegar
	aphids/weevils/sawfly/capsids	Calypso
Blossom and petal fall	nectria/storage rots	Bellis or Captan
Petal fall	tortrix/codling moth	Insegar
	aphids/weevils/sawfly/capsids	Calypso
Petal fall – harvest (sulphur, biocontrol or cultural control only)		
Petal fall – harvest	mildew	Sulphur
Petal fall – harvest	codling moth	Granulosis virus
Petal fall – harvest	tortrix	Dipel* (*Bacillus thuringiensis*)
Petal fall – harvest	storage rots	Rot risk assessment Inoculum removal Selective picking

* Off label Approval

SCIENCE SECTION

Introduction

Consumers want perfect apples of known varieties that are free of pesticide residues. Consequently, this is also becoming a demand on growers by the major supermarkets. Unfortunately the main UK apple varieties – Cox, Gala and Bramley – are susceptible to most pest and diseases and the UK climate ensures that one or other of these problems occur in most seasons. The zero residue requirement is therefore a major challenge for growers.

The zero residue management system (ZRMS) was developed to achieve residue free apples whilst still remaining profitable and sustainable for the grower. The system is based on the use of conventional pesticides up to petal-fall and after harvest, but only using biocontrol agents or sulphur during fruit development in summer. The key to success is disease control during the dormant season to minimise inoculum carryover into the new season. The system has been evaluated in experimental plots at East Malling Research (EMR) on scab susceptible and scab resistant varieties for 6 years as part of Defra-funded project HH3122STF and HDC project TF 164.

At EMR in a large replicated orchard experiment the ZRMS was applied to established plots containing scab susceptible (Cox, Gala, Fiesta, Discovery) or scab resistant cultivars (Saturn, Ahra, Discovery) and compared with conventionally sprayed or unsprayed plots of the same cultivars. Both 2004 and 2006 were high risk years for scab with 56-89% (2004) and 24-92% (2006) scabbed fruit recorded at harvest in untreated plots. Despite this, the scab control achieved in ZRMS plots in 2004 (<1% scabbed fruit) and in 2006 (0.2-5.8%), was as good as or better than that in conventional plots (<1% scabbed fruit in 2004 and 0.7-6.2% scabbed fruit in 2006) which had received season-long fungicides. The risk of powdery mildew was high in all three years (up to 100% mildewed shoots in untreated plots). However, the control achieved by the ZRMS programme, based on elimination of primary mildew and fungicides pre-bloom combined with low dose sulphur sprays post-bloom, was as good as that achieved by the conventional programme of sprays. Losses due to rots in store were generally less in fruit from ZRMS plots, than in conventional plots that had received pre-harvest captan or tolylfluanid sprays only, or untreated plots. To limit storage rots the emphasis in the ZRMS was on cultural control, rot risk assessment and selective picking, Rhynchites weevil (*Coenorhinus aequatus*), totrix moth (*Adoxophes orana, Archips podana*) and rosy apple aphid (*Dysaphis plantaginea*) were the main pests recorded at damaging levels in untreated plots. Pest control in ZRMS plots was based on IPM monitoring and treatment pre-bloom and at petal fall with selective insecticides and with granulosis virus for codling moth (*Cydia pomonella*) control in summer. ZRMS pest control was as good as that achieved in conventional plots, where control was based on conventional pesticides (including organophosphate insecticides) pre- and post-blossom. Fruit russet was similar in both ZRMS plots and conventional plots, indicating that there was no effect of sulphur on the fruit quality. In all three seasons there were savings in the cost of fungicides in ZRMS plots of around £100/ha, but these were offset by the higher costs of the selective insecticides used, resulting in most cases in similar pesticides costs in both programmes. Additional costs were incurred in ZRMS plots for pest and disease monitoring, inoculum removal and selective harvesting. No residues were detected (analysed to limit of detection) in fruit sampled at harvest from ZRMS plots. In these trial plots the ZRMS has given comparable pest and disease control to that in the conventional system. The key to the success has been the emphasis on control in the dormant season and pre-bloom, meaning that minimal problems have been carried to the post-bloom period.

In 2004 to 2006, as part of projects HH3122STF and TF 164, trials were conducted in four commercial orchards in Kent (two on cv. Cox and two on cv. Gala) in which the pest and disease control achieved by the ZRMS established in half the orchard was compared to that in the other half receiving the grower's standard pesticide programme. In general, scab control in the ZRMS was acceptable and as good as in the grower plots. Where scab occurred at higher incidence it was not attributable to the ZRMS approach. Powdery mildew was the main disease problem encountered in three of the sites due to a high incidence of primary mildew at the start of the trial. In such circumstances reduced dose sulphur gave poor control. The ZRMS is not suitable for orchards with a moderate to high incidence of primary mildew and powdery mildew control must be restored by conventional means before adopting the system in these orchards. In the trial sites control of storage rots was similar in both plots, but none of the orchards were stored long-term for the system to be thoroughly tested. In the ZRMS in the four orchard sites pest control was variable, but in general similar to that in the conventional half. These trials have demonstrated the practical feasibility of the system.

Defra strategic funding for the ZRMS finished in March 2007. This project further evaluates the ZRMS in commercial orchards specifically targeting other fruit growing areas, where the disease risk is higher, and other varieties such as Bramley, Braeburn or Cameo. This will provide the industry with more information on the robustness of the system and identify any new problems that could affect its long term success.

If the extended evaluation is successful then it will provide the industry with a pest and disease management system to satisfy their customers.

Overall aim of project

To test and demonstrate the zero residue management system (ZRMS) under a range of conditions on commercial farms, to identify any problems and to encourage uptake of the system by fruit growers.

Specific Objectives

1. To continue evaluation of ZRMS in existing trial sites in Kent in order to monitor the long-term effects of the system in commercial orchards
2. To evaluate the ZRMS in commercial orchards located in UK fruit growing areas outside Kent where the pest and disease risk may be higher
3. To evaluate the ZRMS system in commercial orchards on other varieties such as Bramley and Braeburn

Summary of the project and main conclusions from 2007 and 2008

2007

In two established trial sites on cv. Gala (established in 2004 as part of the Defra-funded project) and located at Broadwater Farm, West Malling, and Mount Ephraim, Hernhill, the pest and disease control achieved by the ZRMS applied to half the orchard was compared to that achieved by the grower's conventional programme applied to the other half of the orchard. Pest and disease incidence was assessed at monthly intervals from green cluster to harvest. At harvest 1,000 fruit were picked from each half of the orchards and assessed for pest and disease.

Weather conditions pre-blossom were dry and did not favour apple scab, whereas May, June and July were exceptionally wet and favourable for scab infection. At Mount Ephraim, scab control in the ZRMS plot (0.1% on fruit at harvest compared to 0.8% in the conventional plot) was as good as that in the conventionally-sprayed plot. At Broadwater Farm no scab was recorded until August, when it was noted on the youngest leaves on the extension growth in both plots. Around 2% scabby fruit were present in the ZRMS plots and none recorded in the conventional plot at Broadwater.

The incidence of primary mildew was generally low at both sites but secondary mildew on extension growth rapidly built up in the summer to around 40-100% infected shoots in both plots at both sites. The high incidence of secondary mildew did not appear to affect yield or fruit quality

Only fruit from the trial at Broadwater was stored, and only short-term until December. Losses due to rots were very low in fruit from both conventional and ZRMS plots.

The incidence of pests at both sites was in general low and treatments applied in ZRMS plots gave satisfactory control of pests compared to conventional plots. At Mount Ephraim the main pest problem was codling moth. This was adequately controlled by the use of codling moth granulosis virus in ZRMS plots. The incidence of fruit tree red spider mite built up to damaging levels in both ZRMS plots and conventional plots at Mount Ephraim in August and required intervention with an acaricide. Reasons for the increase are not clear as there were adequate numbers of predatory mites present in the orchard, but the problem was not due to the ZRMS.

No pesticides were detected in fruit sampled from ZRMS plots at harvest apart from myclobutanil at 0.01 mg/kg. Penconazole, myclobutanil, fenpyroximate, boscalid and pyraclostrobin were detected in fruit sampled from conventional plots but not above the MRL.

2008

The evaluation of ZRMS was continued in four commercial orchard sites. The comparison was continued at the established trial site on cv. Gala (established in 2004 as part of the Defra-funded project) located at Broadwater Farm, West Malling. Three new sites, two in Kent and one in Gloucestershire were identified for trials in 2008/9. A second Gala site was established at Castle Fruit Farm, Newent, Gloucestershire. Two additional trial sites were set up in Kent on Bramley (Foxbury Farm, Stone Street) and Braeburn (Rodmersham Court, Rodmersham). At each site the pest and disease control achieved by the ZRMS applied to half the orchard, was compared to that achieved by the grower's conventional programme applied to the other half of the orchard. Pest and disease incidence was assessed at monthly intervals from green-cluster to harvest. At harvest 1,000 fruit were picked from each half of the orchards and assessed for pest and disease.

Rainfall in 2008 was above average in March, April, May, July and August. Consequently weather conditions were exceptionally favourable for scab infection. The scab control achieved in the ZRMS plots at the two Gala sites was not as good as that in the conventional plots, with around 10% of fruit with scab at harvest compared to up to 2% in fruit from the conventional plots. For practical reasons the post-harvest scab inoculum reduction programme was not applied to either of these sites in 2007 which may have resulted in greater inoculum carryover and accounted for the poor result. Scab control in the ZRMS plots at the Bramley and Braeburn sites was as good as that in conventional plots despite the high scab risk in 2008. It is clear that Gala is an extremely scab susceptible variety and if a ZRMS system is to succeed then a more flexible approach to fungicide use post-bloom may need to be available for such varieties in high scab risk seasons.

The incidence of primary mildew was generally low at the Gala and Braeburn sites but secondary mildew on extension growth rapidly built up in the summer to around 12-50% infected shoots. The high incidence of secondary mildew did not appear to affect yield or fruit quality. The incidence of primary mildew in the Bramley orchard was exceptionally high in both plots. Consequently the incidence of secondary mildew rapidly increased to almost 100% infected shoots. Again, the high incidence of secondary mildew did not appear to affect yield or fruit quality. In the experimental plots at East Malling Research control of powdery mildew in the ZRMS was always acceptable. However, mildew control in the ZRMS plots in the commercial orchard trials has not been acceptable. Reasons for this are not understood but the problem clearly needs to be addressed.

The incidence of pests at three of the sites was in general low and treatments applied in ZRMS plots gave satisfactory control of pests compared to conventional plots.

No pesticides were detected in fruit sampled from ZRMS plots at harvest. Penconazole, myclobutanil, captan, carbendazim (thiophanate-methyl), fenoxycarb and boscalid were detected in fruit sampled from conventional plots but not above the MRL.

2009

Objective 1 - Evaluation of ZRMS in existing trial sites in Kent

In 2009 the established trial comparing ZRMS system with the grower's conventional system was continued at the remaining site in Kent on cv. Gala. The continuation of this trial for a further season aimed to obtain further data under different weather conditions and identify any new problems that might arise in low pesticide input systems. The results from 2007 and 2008 for this site are summarized above.

Materials and methods

Site

One existing orchard trial site was used in 2009. The site was located at Broadwater Farm, West Malling, (No. 1 Gala). At this site the orchard was a single row Gala orchard on M26 rootstock with *Malus* pollinators. The zero residue trial was established in this orchard in 2004.

Experimental details

The orchard was split, the grower's current programme being applied to one half as a comparison to the ZRMS applied to the other half. A zero residue protocol was established as part of Defra project HH3122STF. The main principles of the system are as follows:

- Dormant season treatments (DMI fungicide (e.g. myclobutanil) and urea applied pre-leaf fall) to minimize overwintering scab inoculum
- Aphicide applied in early October to control rosy apple aphids returning to apple trees from summer hosts to prevent egg laying
- A pre-bud burst copper spray to control scab overwintering on the tree
- Conventional fungicides and insecticides (no organo-phosphate insecticides) up to petal-fall for scab, mildew and pest control. Use of ADEM or other scab warning system where possible to assist in decisions on fungicide use
- The wet weather in 2008 resulted in unacceptable incidence of scab on fruit in the zero residue plot. Therefore, because of the likely carry-over of inoculum, provision was made for the conventional fungicide treatments to be continued for 2-3 sprays beyond petal fall before switching to the sulphur programme. The need for this action was obviously dependent on weather conditions in spring 2009 with no need for the extended programme if conditions were exceptionally dry
- Reduced dose sulphur during the post-bloom period for mildew control
- Biocontrol agents (*Bacillus thuringiensis* and codling moth granulosis virus) for control of tortrix, codling moth and other caterpillars post-bloom
- Storage rot management was based on inoculum removal, rot risk assessment and selective picking at harvest

A typical ZRMS spray programme (including the modification for Gala) from bud burst to harvest and post-harvest is shown in Tables 2 and 3.

Table 2. Summary of treatments in zero residue management system

Timing	Pest/Disease target	Treatment
Post-harvest (conventional pesticides)		
September/October	scab/mildew	Systhane+ Captan
October	nectria canker	Folicur*
October (approx. 7-14 Oct)	aphids	Aphox or other aphicide but different chemical group to Calypso
Pre-leaf fall	scab	Urea
Leaf fall	nectria canker	Cuprokylt Folicur*
Winter	overwintering codling	Nematodes
Winter	canker	Removal in pruning
Winter/spring	scab	Macerate leaf litter
Pre bud burst (conventional pesticides)	scab/nectria canker	Cuprokylt
Bud burst – petal fall (conventional pesticides)		
Bud burst - petal fall	scab	Dithianon Captan Systhane
Petal fall + 2-3 sprays (Gala trials only)	scab	Captan Systhane
Bud burst - petal fall	mildew	Systhane or Nimrod or Topas
Mouse ear/green cluster	tortrix/winter moth	Runner
Pink bud	tortrix	Insegar
	aphids/weevils/sawfly/capsids	Calypso
Blossom and petal fall	nectria/storage rots	Bellis or Captan
Petal fall	tortrix/codling moth	Insegar
	aphids/weevils/sawfly/capsids	Calypso
Petal fall – harvest (sulphur, biocontrol or cultural control only)		
Petal fall – harvest	mildew	Sulphur
Petal fall – harvest	codling moth	Granulosis virus
Petal fall – harvest	tortrix	Dipel* (Bacillus thuringiensis)
Petal fall – harvest	storage rots	Rot risk assessment Inoculum removal Selective picking

* Off label Approval

Assessments

Pest and disease incidence was assessed at standard key times (Cross & Berrie, 2001) and pheromone traps used to assist in decision making on pesticde use. Full assessments of key pests (rosy apple aphid, apple grass aphid, caterpillars, sawfly, capsid) and scab and mildew incidence were made pre-bloom, at petal-fall and on two occasions before harvest (Cross & Berrie, 1995). The assessments were done on 25-50 trees in each half of the orchard. ZRMS plots were monitored more frequently for decision making on pest and disease treatments.

At harvest, pest and disease incidence was assessed on a random sample of 1,000 fruit from each half of the orchard, consisting of 20 fruit taken at random from 50 trees per plot. A random sample of ten bulk bins of fruit, each containing approximately 2,000 fruit, from each plot were labeled and stored. Rot incidence and grade out was assessed at the end of the storage period.

Standard nutrient programmes were applied to both plots. Random samples of 25 fruit per plot were taken at harvest and sent for analysis for pesticide residues. Records of treatment costs were kept for comparison.

Table 3. Treatments applied to ZRMS plots post-harvest in 2008

Timing	Target pest/disease	Treatment	Rate/hectare
Early October	scab/mildew	Systhane 20EW + Captan	0.45 L + 1.2 kg
October (approx 7-14 October)	aphids	Aphox or Mainman	420 g or 0.14 kg
October (pre-leaf fall)	scab/canker	Folicur (Off Label Approval)	0.6 L
Pre-leaf fall	scab	Urea	5%
October	overwintering codling and tortrix	Nematodes	Nemasys C (*Steinernema carpocapse*) 1.5 billion/hectare
Post-harvest 10% leaf fall	canker	Cuprokylt FL	5.0 L/1000L
Post-harvest 50% leaf fall	canker	Cuprokylt FL	5.0 L/1000L
Winter pruning	canker	Removal during pruning	-

Results and discussion

Diseases

Rainfall in 2009 was average (Table 4) or below average for most months apart from July. Consequently weather conditions were much less favourable for scab infection compared to 2008. Apple scab was recorded on shoots at trace incidence only (Table 5). At harvest in September, the scab incidence on fruit from ZRMS plots was 2.2% compared to 0.5% on fruit from the conventional plot.

Primary vegetative mildew recorded in May (Table 6) was at similar incidence in both plots. Despite this low incidence of primary mildew, secondary mildew on extension growth rapidly built up in the summer to more than 95% infected shoots in the ZRMS plot. The incidence of mildewed shoots was much lower in the conventional plot compared to the ZRMS plot (Table 6).

No assessment of storage rots was made as fruit was scheduled for early marketing

Table 4. Apple growth stages, monthly rainfall (mm) and number of days on which rain fell recorded at EMR in March to October in 2009, compared to 50 year average for rainfall

Month	Apple growth stage (date)	Rainfall mm	Number of rain days	50 year average rainfall
March	Bud burst (10 March)	41.2	16	44.3
April	Mouse ear (8 April) Green cluster/pink bud (18 April) Full bloom (28 April) Petal fall (15 May)	34.4	13	44.5
May		24.2	13	45.8
June		27.2	8	49.7
July		60.0	22	46.4
August		20.8	11	52.0
September	Harvest (22 September)	26.4	9	63.7
October		47.4	19	65.5

Table 5. Apple scab incidence as % infected shoots or fruit in 2009 at Broadwater Farm, West Malling

Date assessed	ZRMS	Conventional
20 May % infected shoots	1.0	0
29 June % infected shoots	1.0	0
% infected shoots		
Harvest 14 September % infected fruit	2.2	0.5

Pests

The ZRMS pest control programme was continued as in the protocol with no conventional pesticides applied after petal fall and before harvest.

The incidence of pests recorded at Broadwater Farm in both plots pre- and post-blossom was very low. Moth trap catches are shown in Table 7. Codling moth did not reach the threshold until mid July. Fruit tree tortrix catches in the pheromone traps did not reach threshold in either plot and therefore did not require treatment. Summer fruit tortrix and light brown apple moth were above threshold in late May but numbers were low in June and July. Runner (methoxyfenozide) was applied for tortrix control in the conventional plot post-blossom. Pest damage recorded on the fruit at harvest is shown in Table 8. Total pest damage recorded on the fruit from ZRMS plots was higher than in the previous year (6.2%) and higher than that recorded in the conventional plot (3.2%). Most of the difference was accounted for by increased incidence of fruit damage due to rhynchites weevils, earwigs and tortrix in the ZRMS plots. Only Runner pre-bloom was applied for tortrix control in the ZRMS plot, compared to pre and post-bloom applications in the grower plot. In addition chlorpyrifos was applied in early June in the grower plot which gave control of rhynchites weevil. These differences in insecticide application account for the differences in pest damage recorded at harvest. Actual losses were relatively low and commercially acceptable.

Table 6. Powdery mildew incidence as % infected blossoms or shoots in 2009 at Broadwater Farm, West Malling

Mildew assessment	Broadwater 'Gala'	
	ZRMS	Conventional
Primary vegetative – Number of shoots on 25 trees 20 May	9	8
29 June % infected shoots	97.0	22.0

Table 7. Moth trap catches for ZRMS and conventional plots in No. 1 Gala at Broadwater Farm, West Malling in 2009

Date	ZRMS plot				Conventional plot			
	codling	SFT	FTT	LBAM	codling	SFT	FTT	LBAM
29 May	4	20	0	49	10	8	2	55
5 June	1	33	3	29	1	10	1	26
15 June	0	14	1	3	4	17	2	3
22 June	2	12	2	4	2	8	4	4
29 June	7	5	6	4	13	3	14	6
6 July	9	0	9	5	18	0	11	6
13 July	15	0	2	4	17	0	2	4

Traps were put out on 22 May. SFT = summer fruit tortrix, FTT = fruit tree tortrix
LBAM = light brown apple moth

Table 8. Pest damage to fruit recorded as % damaged fruit at harvest 2009 at Broadwater Farm, West Malling

Pest	Broadwater 'Gala'	
	ZRMS	Conventional
Rosy apple aphid	0	0
Sawfly	1.3	1.1
Tortrix	1.5	0.2
Early caterpillar	0.1	0.1
Codling moth	0	0
Earwig	1.7	0.6
Rhynchites	1.6	0.6
Capsid	0	0
Blastobasis	0	0
Mussel scale	0	0.6
Total Pest damage	6.2	3.2

<u>Pesticide residues</u>

The results of the pesticide residue analysis conducted on fruit collected at harvest is shown in Table 9. Most of the pesticide applications to both ZRMS and conventional plots did not result in detectable residues. Residues were detected for products applied near harvest (myclobutanil, methoxyfenazide, chlorpyrifos and captan) in the conventional plot. None were above the Maximum Residue Level (MRL) permitted.

Table 9. Chemical residues (mg/kg) detected in apple samples taken at harvest

Site	Chemical	Residue detected mg/kg		Reporting level	MRL mg/kg
		ZRMS	Conventional		
Broadwater Gala	myclobutanil	0	0.04	0.01	0.5
	captan	0	0.21	0.01	3.0
	chlorpyrifos	0	0.02	0.01	0.5
	methoxyfenozide	0	0.07	0.01	2.0
Newent Gala	methoxyfenozide	0	0.04	0.01	0.5
	indoxacarb	0	0.03	0.01	2.0
12 Acre Bramley	methoxyfenozide	0	0.02	0.01	2.0
	indoxacarb	0	0.02	0.01	0.5
Rodmersham Braeburn	boscalid	0	0.35	0.01	2.0
	pyraclostrobin	0	0.18	0.01	0.3
	penconazole	0	0.02	0.01	0.2
	myclobutanil	0	0.03	0.01	0.5
	captan	0	0.41	0.01	3.0
	methoxyfenozide	0	0.01	0.01	2.0
	indoxacarb	0	0.01	0.01	0.5
	pirimicarb	0	0.01	0.01	2.0

Objective 2 - Evaluation of ZRMS in trial sites outside Kent

The trial established in March 2008 in a Gala orchard at Castle Fruit Farm, Newent, Gloucestershire was evaluated for a further season.

Materials and methods

<u>Site</u>

The site was located at Castle Fruit Farm, Newent (Big Acketts Gala). At this site the orchard was a single row intensive Gala orchard on M9 rootstock with *Malus* pollinators, planted on a post and wire system. The orchard was planted in 2006.

Experimental details

The orchard was split; the grower's current programme being applied to one half as a comparison to the ZRMS applied to the other half. A zero residue protocol was established as part of Defra project HH3122STF. The main principles of the system are as given under objective one (page 17) and in Tables 2 and 3, including the additional 2 or 3 sprays after petal fall.

Assessments

The incidence of leaf litter remaining in spring was assessed in March using a modified point transect method. A diagonal was walked across each plot and the presence or absence of fallen leaves recorded every 0.5 m. Leaf litter incidence was expressed as percentage of assessed points at which leaves were found.

Pest and disease incidence was assessed at standard key times as under objective one. Standard nutrient programmes were applied to both plots. Random samples of 25 fruit per plot were taken at harvest and sent for analysis for pesticide residues. Records of treatment costs were kept for comparison.

Results and discussion

Diseases

There was a high incidence of overwintering leaf litter remaining in both plots (Table 10) which was a potential source of scab inoculum as a low / moderate incidence of apple scab had been recorded in the orchard in 2008.

The weather was relatively dry in Newent in 2009. Consequently weather conditions were not as favourable for scab infection as in 2008. Apple scab was recorded at very low incidence in both plots with <1 % fruit scab at harvest (Table 10).

The incidence of primary vegetative shoot mildew was low and similar in both plots (Table 11). Despite this low incidence of primary mildew, secondary mildew on extension growth built up in the summer to more than 15% infected shoots in the ZRMS plot in June compared to 2% in the conventional plot (Table 11). However, by the final assessment in July the incidence of secondary mildew had increased to above threshold (Cross & Berrie, 2001) in both plots, especially the conventional plot.

No assessment of storage rots was made as fruit was scheduled for early marketing.

Table 10. Apple scab incidence as % infected shoots or fruit in 2009 at Castle Fruit Farm, Newent, Gloucestershire

Date assessed	Assessment type	ZRMS	Conventional
11 March	% leaf litter	51.7	65
28 May	% infected trees	0	0
17 June	% infected shoots	0	0
22 July	% infected shoots	1.0*	0
15 September	Harvest % infected fruit	0.8	0.2

*Scab observed on 1 leaf only

Table 11. Powdery mildew incidence as % infected blossoms or shoots in 2009 at Castle Fruit Farm, Newent, Gloucestershire

Date assessed	Mildew assessment	Big Acketts 'Gala'	
		ZRMS	Conventional
28 May	Primary vegetative – Number of shoots / tree	0.04	0.04
17 June	% infected shoots	15.0	2.0
22 July	% infected shoots	34.0	49.0

<u>Pests</u>

The incidence of pests recorded at Castle Fruit Farm in both plots pre- and post-blossom was in general low. The Exosect mating disruption system was deployed for control of codling moth. Codling moth catches in the pheromone traps never reached threshold in the ZRMS plots and therefore did not require additional treatment. No codling moth damaged fruit were recorded at harvest in either plot (Table 12). Pest damage recorded on the fruit at harvest is shown in Table 12. Total pest damage recorded on the fruit in the ZRMS plot was relatively low 6.6% but double that in the grower's plot. Most of the damage was accounted for by early caterpillar and tortrix damage but actual losses were low and acceptable commercially. Significant levels of rust mite (*Aculus schlechtendali*) were present on trees in the grower's plot in July but not in the ZRMS plot.

Table 12. Pest damage to fruit recorded as % damaged fruit at harvest 2009 at Castle Fruit Farm, Newent, Gloucestershire

Pest	Big Acketts 'Gala'	
	ZRMS	**Conventional**
Rosy apple aphid	0	0
Sawfly	0.7	1.4
Tortrix	1.4	0.8
Early caterpillar	3.0	0.2
Codling moth	0.2	0.1
Earwig	0.7	0.3
Rhynchites	0.6	0.2
Capsid	0	0
Blastobasis	0	0
Mussel scale	0	0
Total Pest damage	**6.6**	**3.0**

<u>Pesticide residues</u>

The results of the pesticide residue analysis conducted on fruit collected at harvest are shown in Table 9. Most of the pesticide applications to both ZRMS and conventional plots did not result in detectable residues. Residues were detected for products applied near harvest in the conventional plot (methoxyfenozide and indoxycarb). No residues were detected in the ZRMS plot. None of the residues were above the MRL.

Objectives 3 – Evaluation of ZRMS in commercial orchards of other varieties

The trial sites for Bramley and Braeburn established at Foxbury Farm, Stone Street, Ightham and at Rodmersham Court, in Kent in 2007 were evaluated for a further season.

Materials and methods

<u>Site</u>

The Bramley orchard (12 acres) was located at Goldings Hop Store, Bewley Lane, and consisted of a single row of mature trees on MM106 rootstock with cv. Egremont Russet pollinators in alternate rows. The Braeburn orchard (Jazeels) was located at Rodmersham Court, Rodmersham, and consisted of intensive single row trees on M.9 rootstock with Gala pollinators, planted in 2006 and trained on a post and wire system.

Experimental details

Each orchard was split, the grower's current programme being applied to one half as a comparison to the zero residue system applied to the other half. A zero residue protocol was established as part of Defra project HH3122STF. The main principles of the system are as given under objective one (page 17) and in Tables 2 and 3. The spray programme applied to the Bramley orchard was modified with applications of Dithianon up to petal fall in place of Captan as applications of the recommended dose of Captan to Bramley can result in leaf spotting or defoliation. Standard nutrient programmes were applied to both plots.

Assessments

Pest and disease incidence was assessed at standard key times as under objective one. Random samples of 25 fruit per plot were taken at harvest and sent for analysis for pesticide residues. Records of treatment costs were kept for comparison. Ten bins of apples from each of the Braeburn plots were labeled and stored until February 2010. At the end of the storage period the incidence of rots was assessed. No bins were labeled in the Bramley trial as they were to be stored until June 2010 and therefore could not be assessed until after the end of the project.

Results and discussion

Diseases

Overwintering leaf litter had almost disappeared by bud burst in the Braeburn orchard but no formal assessment of leaf litter was conducted. Similarly, no formal assessment of leaf litter was made in the Bramley orchard, but overwintered leaf litter was obvious under most trees in the orchard. In both orchards scab incidence in 2008 had been negligible, so any leaf litter remaining was not expected to be a significant source of scab inoculum.

Rainfall in 2009 was average (Table 4) or below average for most months apart from July. Consequently, weather conditions were much less favourable for scab infection compared to 2008. Apple scab was not recorded on shoots in either orchard (Table 13) and was present at trace incidence on the fruit in the Bramley orchard at harvest.

The incidence of primary vegetative mildew was high and similar in both Bramley plots. Consequently the incidence of secondary mildew increased rapidly on shoots such that mildew was recorded on almost all shoots in both plots in early June. Secondary mildew continued to be recorded at high incidence in both plots throughout the summer but was generally lower in ZRMS plots compared to the conventional plots. Bramley appears to be more tolerant of powdery mildew compared to Cox. So a high incidence of mildew would not be expected to reduce yield and fruit quality. In addition the fruit from this orchard is generally sold for processing where quality requirements are less stringent. The incidence of primary blossom and vegetative mildew in Braeburn at Rodmersham Court was negligible in both plots (Table 14). The incidence of secondary mildew in the ZRMS was generally higher than in the conventional plot (Table 14) but was at an acceptable commercial incidence.

Table 13. Apple scab incidence as % infected shoots or fruit in 2009 at Foxbury Farm (Bramley) or Rodmersham Court (Braeburn), Kent

Date assessed	Assessment type	Bramley (Foxbury Farm)		Braeburn (Rodmersham Court)	
		ZRMS	Conventional	ZRMS	Conventional
19 May	% infected trees	0	0	0	0
15 June / 22 June	% infected shoots	0*	0	0	0
28 August	% infected shoots	-	-	0	0
30 September	% infected shoots	0	0	-	-
22 September	Harvest % infected fruit	0.7	0.3	-	-
10 October	Harvest % infected fruit	-	-	0	0

* Scab seen on a leaf on each of 2 trees, but not on the assessed shoots

Table 14. Powdery mildew incidence as % infected shoots in 2009 at Foxbury Farm (Bramley) or Rodmersham Court (Braeburn), Kent

Date assessed	Assessment type	Bramley (Foxbury Farm)		Braeburn (Rodmersham Court)	
		ZRMS	Conventional	ZRMS	Conventional
19 May	primary vegetative mildew total number shoots on 25 trees	18	19	1	2
15 June / 22 June	% infected shoots	76.0	87.0	33.8	8.8
28 August	% infected shoots	-	-	20	5
30 September	% infected shoots	80	85	-	-

Table 15. Incidence of rots as % rotted fruit recorded on Bramley on 30 June 2009 at the end of the storage period. A total of 250 rotted fruit assessed

Fungal rot	ZRMS	Conventional
Brown rot	0.8	1.2
Botrytis rot	1.2	2.8
Penicillium rot	4.8	5.3
Nectria rot	9.2	19.1
Cheek rot	0	1.2
Eye rot	0.4	1.2
Stalk rot	4.4	9.6
Colletotrichum	9.6	17.3
Fusarium	57.2	33.6
Core rots	12.0	7.6
Botryosphaeria	0	0.2
Total loss	**10.0**	**7.5**

Table 16. Incidence of rots as % rotted fruit recorded on Braeburn on 25 February 2010 at the end of the storage period. 1000 fruit assessed per bin

Fungal rot	ZRMS	Conventional
Brown rot	0.4	0
Botrytis rot	0.1	0
Penicillium rot	0.2	0
Mucor rot	0	0
Total rots	**0.7**	**0**

The incidence of rots in stored fruit from the 2009 Bramley trial was not assessed. The incidence of rots in fruit from 2008 trial is shown in Table 15. Ten bins of fruit from each plot were stored until June 2009. At the end of the storage period all ten bins from each plot were graded and the rots removed. Total rotting amounted to one bin from the ZRMS plot (approximately 10%) and three quarters of a bin from the grower's plot (approximately 7.5%). Most of the rotting was due to a mixture of *n*ectria rot, *c*olletotrichum rot, *f*usarium rot and core rots. The incidence of storage rots in fruit from the Braeburn orchard was assessed on 1000 fruit (200 fruit from each of five bins) from each plot at the end of the storage period on 25 February 2010. The incidence of rots in the ZRMS plots was <1% compared to zero rots in the conventional plot (Table 16).

<u>Pests</u>

The incidence of pests recorded in Bramley ZRMS plot was generally low (3%) and reasonably well controlled by the early season insecticide programme. Codling moth catches in pheromone traps exceeded threshold frequently and required intervention with granulovirus, which appeared to give effective control as <0.5% codling moth-damaged fruit was recorded at harvest. Most damage was due to tortrix caterpillars (1%). The incidence of pests in the conventional plot was just over half that in the ZRMS plot (1.6%). Most of the difference in damage was accounted for by a higher incidence of tortrix, early caterpillar and sawfly damage in the ZRMS plot (Table 17). It is surprising that these pests, although at relatively low incidence, were not better controlled by the pre-blossom and petal fall insecticide programme (see appendix) compared to the minimal programme (chlorpyrifos – Parapet) for caterpillars applied in the conventional programme. The insecticides were applied at different timings in the two plots so it is possible that this could have accounted for the differences in control.

Pest damage recorded at harvest was negligible (0.3% - Table 17) in Braeburn fruit from both conventional and ZRMS plots at Rodmersham. Most of the damage in both plots was due to tortrix and earwig.

Table 17. Pest damage to fruit recorded as % damaged fruit at harvest 2009 at Foxbury Farm (Bramley) or Rodmersham Court (Braeburn), Kent

Pest	**Bramley (Foxbury Farm)**		**Braeburn (Rodmersham Court)**	
	ZRMS	**Conventional**	**ZRMS**	**Conventional**
Rosy apple aphid	0	0	0	0
Sawfly	0.7	0.2	0	0
Tortrix	1.0	0.4	0.1	0.1
Early caterpillar	0.5	0.1	0	0
Codling moth	0.2	0.6	0	0
Earwig	0.5	0	0.2	0.2
Rhynchites	0	0	0	0
Capsid	0	0	0	0
Blastobasis	0	0	0	0
Mussel scale	0.1	0.3	0	0
Total Pest damage	3.0	1.6	0.3	0.3

Pesticide residues

The results of the pesticide residue analysis conducted on fruit collected at harvest is shown in Table 9. Most of the pesticide applications to both ZRMS and conventional plots did not result in detectable residues. In Bramley residues were detected for products applied near harvest (Nimrod, Steward and Runner) in fruit from the conventional plot. None of the residues were above the MRL. No residues were detected in fruit from ZRMS plot. Similarly in Braeburn residues were detected from all pesticides applied near harvest to the conventional plot (See appendix). No residues were detected in fruit from ZRMS plot. None of the residues detected in the fruit from conventional plots were above the MRL. The spray programmes applied to the plots at Rodmersham Court and Foxbury Farm are given in the appendix.

General - ZRMS Costs

The relative costs per hectare of the pesticide programmes applied to ZRMS and conventional plots are shown in Table 18.

Table 18. Relative costs per hectare of fungicides and insecticides applied to ZRMS and Grower plots in 2009 in relation to percentage of damaged fruit at harvest

Cultivar/Site	Treatment	Number of spray rounds	Cost of spray programme £/ha	% of fruit with pest and scab damage at harvest
Gala Broadwater	ZRMS	15	590	8.4
	Grower	15	1034	3.7
Bramley Foxbury	ZRMS	16	739	3.7
	Grower	17	592	1.9
Braeburn Rodmersham	ZRMS	22	962	0.3
	Grower	23	1295	0.3
Gala Newent	ZRMS			7.4
	Grower			3.2

Numbers of spray rounds applied were in general similar. At two of the sites the spray costs were less on the ZRMS plot (Broadwater and Rodmersham) than on the conventional plots. At Rodmersham this was a clear saving as fruit damage at harvest (Table 18) was negligible and similar on both plots. At Broadwater the incidence of damaged fruit at harvest was more than twice that in the conventional plot, which is probably not balanced by the saving in pesticide costs. Most of this damage was due to pests as only Runner was applied pre-blossom to the ZRMS plot (see appendix). If additional treatments for tortrix, sawfly and *r*hynchites had been applied pre-bloom and at petal fall (at a cost of £160/ha), pest damage to fruit would have been reduced and with reduced spray costs compared to the conventional plot. Most of the extra cost in the ZRMS Bramley plot was accounted for by the use of selective insecticides (Insegar £56/ha at 0.6kg/ha) pre- and post-bloom compared to the broad spectrum organophosphate insecticide chlorpyrifos (£8/ha at 1 litre rate) used in the conventional plot.

General discussion

The weather conditions in 2009 were much drier than in 2008. Hence the scab risk was much lower and this, combined with the additional spray rounds in the ZRMS Gala plots, meant that scab control was generally good in all the trial sites. It is clear that if a ZRMS system is to succeed then a more flexible approach to fungicide use post-bloom needs to be available for susceptible cultivars such as Gala.

It is important to apply the post-harvest programme to minimise scab inoculum carryover. However, with late harvested varieties or where picking sub-standard fruit for juice is delayed until after the main harvest there may be practical difficulties in actually applying these treatments. The Braeburn were not harvested until 15 October, however it was still possible to use the post-harvest treatments for scab and aphids which were applied on 15 October. The purpose of these commercial trials was to identify any practical difficulties which would not have arisen in experimental plots.

As in previous years the control of powdery mildew in ZRMS plots was poor at all sites compared to the conventional plots, despite the low incidence of primary mildew recorded in spring at three of the four sites. In the original trials in experimental plots at East Malling Research the control of powdery mildew in ZRMS plots with sulphur was adequate. The reasons why the same approach in the trials in commercial orchards did not result in adequate control of mildew is not clear.

Generally control of storage rots has been as good as or better in ZRMS plots compared to conventional plots. In 2009 only fruit from the Braeburn trial was stored. The incidence of rots in fruit from the ZRMS plots at the Braeburn site was very low (<1%) compared to no rots in fruit from the conventional plot.

There appeared to be no real problems in controlling pests provided the pesticide was applied early in the season.

No residues were detected in any of the fruit from ZRMS plots. Residues of pesticides used near harvest were detected in all the fruit from conventional plots, although below the MRL. However, with analytical methods continuously being improved and able to detect extremely low residues, zero residues may not be an appropriate name for the system.

The growers participating in the trials all perceived that the ZRMS was more expensive. Actual costs of the pesticide programme applied were greater in only one of the three sites.

More careful monitoring of pests and diseases may be required compared to the conventional system.

The main concern is that under a ZRMS system the fruit is more at risk from pest and disease damage and while there is no incentive to follow such a system, for example a customer requirement or a financial reward for ZRMS fruit, then why take the risk?

Conclusions

- Control of apple scab in ZRMS plots was as good as that in conventional plots in the Braeburn and Bramley trial sites
- The incidence of scab on fruit at harvest was higher in ZRMS fruit in the two Gala trials than in the conventional plots, but was commercially acceptable
- The incidence of secondary mildew in the ZRMS plots was higher than that in conventional plots in the Braeburn and two Gala trial sites.
- In the Bramley trial the incidence of secondary mildew in the ZRMS plot was lower than in the conventional plot but still at high incidence
- The control of insect pests was commercially acceptable in ZRMS plots at all sites, although the incidence of damage was generally higher in the ZRMS fruit at harvest compared to the conventional plots
- Only fruit from the Braeburn trial were stored. The incidence of rotting assessed in February 2010 was <1% in ZRMS plot compared to 0% in conventional fruit
- No residues were detected in fruit from ZRMS plots. Residues of pesticides applied near harvest were detected in fruit from all the conventional plots. None of the residues were above the MRL
- The cost of the pesticide programme applied was cheaper in 2 of the 3 sites

Technology transfer

- The results from the project were presented at the EMRA day at EMR in November 2009
- The project was presented at a meeting of Danish fruit growers in February 2010
- Results from the project were also presented at the BIFGA Technical day on 12 January 2011

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APPENDIX

Table A1 Typical spray programme applied to ZRMS plots from bud burst to harvest in 2008
Crop: GALA Spray Interval: 10 days Spray Volume: 150-200 L/ha

Growth Stage/ Timing	Pest/Disease	Chemical Product	Rate/hectare	Comments
Pre bud-burst	Scab/canker	Cuprokylt Fl	5 L/1000 L water	Apply before bud burst. Phytotoxic to young foliage Note maximum spray concentration on label
Bud burst	Scab/canker Fruit tree red spider	Dithianon WG + Scala	750 g + 1.0 L	Apply promptly at bud burst. Inspect orchards for winter eggs. Where numbers high, earmark for checking and possible treatment later
Mouse ear	Scab/canker	Dithianon WG + Scala	750 g + 1.0 L	**Don't use Dithianon on Gala after green cluster**
Green cluster	Caterpillars Sawfly Scab/mildew Scab	Runner sticky traps Systhane 20 EW + Captan 80	0.6 L 0.33 L + 2.0 kg	See notes re caterpillar control Put out in orchards Add reduced rate Captan to enhance scab protection.and for canker control If weather cold or wet, increase rate of Captan
Late green cluster	Tortrix caterpillars	Insegar	600 g	See notes re caterpillar control Insegar is high risk to bees Do not apply to crops in open flower or where bees are actively foraging or when flowering weeds are present
Pink bud	Aphids/ capsid,/sawfly	Calypso	375 ml	

Growth Stage/ Timing	Pest/Disease	Chemical Product	Rate/hectare	Comments
	Scab/mildew Scab Primary mildew	Systhane 20 EW + Captan 80	0.33 L + 2.0 kg	Add Captan to enhance scab protection on fruitlets. Increase rate to 2kg/ha if weather wet or cold, especially on Gala. Pick off primaries and remove from orchard. See notes re mildew control
Blossom	Scab/mildew	Systhane 20 EW + Captan 80	0.33 L + 1.5 kg	Time sprays to fall at the start and end of blossom if possible, but if blossom period is extended, spray as necessary.
Late blossom	Storage rots	Bellis	0.8 kg	In orchards where canker is a problem
Petal fall	Aphids/capsid/ sawfly Tortrix/codling Scab/mildew Codling/Tortrix Primary mildew	Calypso Insegar Systhane 20 EW + Captan 80 Pheromone traps	375 ml 600g 0.33 L + 2.0 kg	See notes re caterpillar control Put out traps in orchards, and monitor weekly. Pick off primaries and remove from orchard. See notes re mildew control
+ 10 days	Mildew	Sulphur	5 L	Rate of sulphur use will be adjusted according to the mildew risk. **See notes re maximum number of sprays**

Table A1. Continued
Crop: COX, GALA Spray Interval: 7-10 days Spray Volume: 150-200 l/ha

Growth Stage/Timing	Pest/Disease	Chemical Product	Rate/hectare	Comments
+7- 10 days	Mildew Fruit nutrition Codling moth	Sulphur Calcium chloride Granulovirus	3.0 L 100 ml	Rate of sulphur adjusted according to mildew risk Start calcium programme on Cox. Check traps: Spray 7-10 days after threshold catch. Repeat at 7-10 days intervals for 3 sprays against first generation **Granulovirus has experimental approval**
+ 10 days	Codling moth Summer fruit tortrix caterpillars Mildew	Granulovirus Dipel Sulphur	100 ml 0.75 kg 3.0 L	Check traps. Repeat sprays as necessary. **Granulovirus has experimental approval.** See notes re caterpillar control. **Dipel has Off label approval** Rate of sulphur adjusted according to mildew risk
Early July	Fruit tree tortrix/ Blastobasis (codling moth) Mildew	Dipel Sulphur	0.75 kg 3.0 L	Inspect moth traps. Spray 7-10 days after threshold count if necessary. See notes re caterpillar control Rate of sulphur adjusted according to mildew risk
Late July/earl;y August	Codling moth	Granulovirus	100 ml	Check traps: Spray 7-10 days after threshold catch. Repeat at 7-10 days intervals for 3 sprays against second generation. **Granulovirus has experimental approval.**
Continue a ten day programme of sulphur sprays at 3.0 L/ha until end of extension growth . **See notes re maximum number of sulphur sprays per crop**				

Notes:

1. Read product label carefully before applying any sprays

2. Scab control

   - The programme is based on Dithianon WG and Captan and Systhane. Topas 100 at 0.5 L/ha could be used in place of Systhane if preferred. Dithianon WG can cause poor fruit finish on Gala. **Do not use after green cluster**

3. Mildew control

   - Mildew control is based on minimising the inoculum post-bloom. This means as far as possible removing any primary mildew promptly at pink bud and petal-fall
   - In 2005 there were high levels of primary mildew, especially primary vegetative mildew, in the trial plots. In 2006 it is essential that the inoculum from the primary mildew is minimised. Primaries will be removed by hand as far as possible. In addition, at pink bud and at petal fall additional fungicide treatments may be applied depending on mildew incidence. Possible treatments include Systhane at 450 ml/ha plus Nimrod at 1.4 L/ha or Systhane at 450 ml/ha plus Stroby at 0.2 kg/ha. These will be advised according to assessed primary mildew incidence
   - The rate of sulphur used post-bloom will depend on the mildew risk, but is usually 30-50% of the full rate. Mildew will be regularly assessed in the zero residue plots post-bloom and any changes in the sulphur rate requested by email, fax or phone. **Please note that Headland Sulphur Flowable and United Phosphorus Sulphur Flowable both have a maximum number of sprays for disease control of four per crop**
   - Potassium bicarbonate has been used for mildew control on some farms with success. And could be used to reduce mildew. Up to 60 kg of potassium bicarbonate can be **used per hectare per annum.** A starting rate of 5 kg per hectare in 500 to 1000 litres of water is suggested. A suitable wetter should also be used. **This must be applied as a separate spray.**

4. 4. Caterpillar control

   - Runner (methoxyfenozide) should be applied at green cluster to control winter moth. At this timing it will also give some control of overwintering tortrix caterpillars. This product appears to be more effective against the younger tortrix caterpillars and therefore should work better if applied earlier pre-bloom
   - Insegar (fenoxycarb) will be used for control of summer fruit tortrix caterpillars. To ensure that this product is applied pre-bloom it will be applied at late green cluster. If the weather is very warm and there is a risk of rapid progression to

flowering then the Insegar may need to be applied earlier possibly in combination with Runner at green cluster. A further treatment must be applied at petal-fall when it will also give some control of codling moth

- **N.B. Insegar is high risk to bees. Do not apply Insegar to crops in open flower or to those in which bees are actively foraging. Do not apply when flowering weeds are present**
- After petal fall Dipel (BT) can be used for control of tortrix moth and clouded drab moth caterpillars. This product will give very little control of codling moth. This is an Off Label Approval. A copy of the SOLA is included

5. Codling moth control

- Codling moth granulosis virus (CpGV) is widely used for codling moth control in other parts of Europe. This product is currently not approved for use in the UK. However there is experimental approval for a CpGV product for use in these trials. This will be used in response to pheromone trap catches to control codling moth. Sprays are applied at the start of egg hatch. A maximum of 3 sprays should be applied against each generation, at 7-10 day intervals, starting 7-10 days after the threshold catch

6. Woolly aphid

- Woolly aphid was starting to appear in some plots in 2005
- The aphid appeared to be suppressed by the use of magnesium sulphate at 2.5-3.0 kg/ha

7. **Nutrients**

- **NB Nutrients can be applied as normal to both plots**

Table A2. Spray programme applied to ZRMS plot of cv. Gala, No. 1 orchard, Broadwater Farm, West Malling, Kent in 2009

Application date	Product	Rate/ha
11 March	Headland Copper	5 kg
27 March Bud burst	Dithianon Flowable	1.0 L
6 April	Dithianon Flowable	1.0 L
15 April Green cluster	Dithianon Flowable Scala Systhane	1.0 L 1.0 L 0.33 L
22 April Pink bud	Systhane Dithianon Flowable Runner	0.33 L 1.1 L 0.6 L
3 May Blossom	Systhane Captan 80 Scala Potassium bicarbonate	0.33 L 2.0 kg 1.0 L 1.0 kg
13 May Petal fall	Systhane Captan 80 Scala Mainman	0.33 L 2.0 kg 1.0 L 0.14 L
22 May	Headland Sulphur	2 L
2 June	Headland Sulphur Potassium bicarbonate	2 L 1.0 kg
15 June	Headland Sulphur Potassium bicarbonate	2 L 1.0 kg
23 June	Headland Sulphur Potassium bicarbonate Runner	2 L 1.0 kg 0.6 L
5 July	Headland Sulphur	2 L
16 July	Headland Sulphur	2 L
30 July	Headland Sulphur	2 L
28 October	Captan 80 Systhane Riza	2.0 kg 0.33 L 0.6 L

Table A3. Spray programme applied to Grower plot of cv. Gala, No. 1 orchard, Broadwater Farm, West Malling, Kent in 2009

Application date	Product	Rate/ha
11 March	Headland Copper	5 kg
27 March Bud burst	Dithianon Flowable	1.0 L
6 April	Dithianon Flowable	1.0 L
15 April Green cluster	Dithianon Flowable Scala Systhane	1.0 L 1.0 L 0.33 L
22 April Pink bud	Systhane Dithianon Flowable Runner	0.33 L 1.1 L 0.6 L
3 May Blossom	Systhane Captan 80 Scala Potassium bicarbonate	0.33 L 2.0 kg 1.0 L 1.0 kg
13 May Petal fall	Systhane Captan 80 Scala Mainman	0.33 L 2.0 kg 1.0 L 0.14 L
22 May	Systhane Captan 80 Nimrod	0.5 L 2.0 kg 0.6 L
2 June	Topas Captan 80 Nimrod Potassium bicarbonate Parapet	0.33 L 2.0 kg 0.6 L 1.0 kg 1.2 L
11 June	Captan 80 Stroby Systhane Potassium bicarbonate	2.0 kg 0.2 kg 0.33 L 1.0 kg
23 June	Captan 80 Systhane Runner	2.0 kg 0.33 L 0.6 L
3 July	Captan 80 Topas	2.0 kg 0.5 L
16 July	Captan 80 Systhane Runner	1.5 kg 0.33 L 0.6 L
28 July	Captan 80 Systhane Parapet	1.5 kg 0.33 L 1.2 L
28 October	Captan 80 Systhane Riza	2.0 kg 0.33 L 0.6 L

Table A4 Spray programme applied to ZRMS plot of cv. Bramley, 12 Acres orchard, Foxbury Farm, Stone Street, Kent in 2009

Application date	Product	Rate/ha
18 March Bud burst	Dithianon WG Scala	0.75 kg 0.5 L
27 March	Dithianon WG Scala	0.5 kg 0.5 L
2 April	Dithianon Flowable Indar Runner	0.75 L 1.0 L 0.6 L
15 April Mouse ear	Systhane Dithianon Flowable Insegar	0.3 L 0.5 L 0.6 kg
22 April Pink bud	Systhane Dithianon Flowable Calypso	0.3 L 0.5 L 0.375 L
28 April Early flower	Systhane Dithianon WG	0.25 L 0.5 kg
6 May 1st Petal fall	Bellis	0.6 kg
12 May 100% petal fall	Dithianon WG Systhane Insegar Calypso	0.5 kg 0.25 L 0.6 kg 0.3 L
20 May Post blossom	Sulphur	2.5 L
28 May	Sulphur	2.5 L
4 June Early fruit	Sulphur	2.5 L
11 June	Sulphur	2.5 L
19 June	Sulphur Granulosis virus Dipel	2.5 L 0.1 L 0.75 kg
25 June	Sulphur	5 L
4 July	Sulphur Granulosis virus	5 L 0.5 L
30 July	Kumulus Granulosis virus	3 kg 0.1 kg

Table A5. Spray programme applied to Grower plot of cv. Bramley, 12 Acres orchard, Foxbury Farm, Stone Street, Kent in 2009

Application date	Product	Rate/ha
18 March Bud burst	Syllit	2.013 L
27 March	Dodifon	1.883 L
2 April	Dithianon Flowable	0.727 L
15 April Mouse ear	Scala Dithianon Flowable	0.727 L 0.485 L
22 April Pink bud	Dithianon Flowable Systhane Parapet	0.5 L 0.3 L 0.602 kg
28 April Early Flower	Switch Calypso	0.593 kg 0.247 L
6 May 1st Petal fall	Bellis Systhane	0.597 kg 0.247 L
12 May 80% petal fall	Maccani	1.952 kg
20 May Post blossom	Systhane Dithianon WG Mainman	0.25 L 0.602 kg 0.139 kg
28 May	Dithianon WG	0.58 kg
4 June Early fruit	Systhane Dithianon WG	0.25 L 0.498 kg
11 June	Dithianon WG Runner	0.498 kg 0.597 L
19 June	Nimrod Dithianon WG	0.25 L 0.498 kg
25 June	Dithianon WG	0.498 kg
4 July	Dithianon WG Nimrod	0.541 kg 0.268 L
8 July	Dithianon WG	0.61 kg
30 July	Steward	0.212 kg

Table A6. Spray programme applied to ZRMS plot of cv. Braeburn at Rodmersham Court, Rodmersham in Kent in 2009

Application date	Product	Rate/ha
24 February	Cuprokylt	2.0 kg
18 March	Dithianon Flowable Scala	1.1 L 0.75 L
27 March	Dithianon Flowable Scala Zintrac Urea	1.1 L 0.75 L 1.0 L 4.0 kg
3 April	Robut 20 Alpha Captan Runner Bortrac urea	0.33 L 1.5 kg 0.6 L 1.0 L 5.0 kg
16 April	Robut 20 Alpha Captan Insegar Mainman Bortrac urea	0.33 L 1.5 kg 0.4 kg 0.14 kg 1.0 L 2.0 kg
28 April	Robut 20 Alpha Captan Scala	0.33 L 1.5 kg 1.0 L
2 May	Systhane Alpha Captan Scala	0.33 L 2.0 kg 1.0 L
6 May	Robut 20 Alpha Captan Bellis Insegar WG Calypso Seniphos urea	0.33 L 1.5 kg 0.8 kg 0.6 kg 0.3 L 10 L 2 kg
18 May	Systhane 20 EW Alpha Captan 80 Stoppit Urea	0.33 L 1.0 kg 10 L 3.0 kg
26 May	United Sulphur Stoppit Urea	4 L 10 L 3.0 kg
8 June	United Sulphur Stoppit Urea Cyd-x	4 L 10 L 3.0 kg 0.1 L

Application date	Product	Rate/ha
18 June	United Sulphur Stoppit Urea Cyd-x	4 L 10 L 3.0 kg 0.1 L
29 June	United Sulphur Dipel DF Urea	3 L 0.75 kg 3.0 kg
30 June	Cyd-x	0.1 L
6 July	Headland Sulphur Stoppit Urea	4 L 10 L 2.0 kg
9 July	Seniphos Mantrac 500 Urea	10 L 1.0 L 3.0 kg
14 July	Dipel DF Cyd-x	0.75 kg 0.1 L
23 July	United Sulphur Stoppit Maxicrop TS	4 L 10 L 2.0 L
31 July	Headland Sulphur Stoppit	3 L 10 L
4 August	Magflo 300 Ferleaf	4.0 L 1.0 L
10 August	Headland Sulphur Stoppit	3.0 L 10 L
18 August	United Sulphur Stoppit	3.0 L 10 L
28 August	Headland Sulphur Stoppit	3.0 L 10 L
10 September	Bortrac Zintrac urea	2 L 1 L 15 kg
16 October	Robut 20 PP Captan 80 WG Aphox Folicur Magnesium sulphate	0.45 L 1.2 kg 0.42 kg 0.6 L 8.0 kg

Table A7. Spray programme applied to grower's plot of cv. Braeburn at Rodmersham Court, Rodmersham in Kent in 2009

Application date	Product	Rate/ha
24 February	Cuprokylt	2.0 kg
18 March	Dithianon Flowable	1.1 L
27 March	Dithianon Flowable Zintrac Urea	1.1 L 1.0 L 4.0 kg
3 April	Robut 20 Alpha Captan Alpha Chlorpyrifos Bortrac Urea	0.33 L 1.5 kg 1.0 L 1.0 L 5.0 kg
16 April	Robut 20 Alpha Captan Insegar Mainman Bortrac Urea	0.33 L 1.5 kg 0.4 kg 0.14 kg 1.0 L 2.0 kg
28 April	Robut 20 Alpha Captan Scala	0.33 L 1.5 kg 1.0 L
6 May	Robut 20 Alpha Captan Bellis Insegar WG Calypso Seniphos Urea	0.33 L 1.5 kg 0.8 kg 0.6 kg 0.3 L 10 L 2 kg
18 May	Systhane 20 EW Alpha Captan 80 Scala Stoppit Urea	0.33 L 1.0 kg 0.75 L 10 L 3.0 kg
26 May	Stroby WG Indar 5EW Robut 20 Stoppit Urea	0.2 kg 0.75 L 0.33 L 10 L 3.0 kg
8 June	Stroby WG Systhane 20EW Indar 5EW Stoppit Maxicrop Steward	0.2 kg 0.33 L 1.0 L 10 L 1.0 L 0.2 kg
18 June	Systhane 20EW Alpha Captan 80 Stoppit Maxicrop TS	0.33 L 2.0 kg 10 L 1.0 L

Application date	Product	Rate/ha
29 June	Systhane 20EW PP Captan 80WG Urea Steward Phantom	0.33 L 2.0 kg 3.0 kg 0.250 kg 0.560 kg
3 July	Seniphos Mantrac 500 Urea	10 L 1.0 L 3.0 kg
6 July	Systhane 20EW PP Captan 80 WG Stoppit Urea	0.33 L 2.0 kg 10 L 2.0 kg
14 July	Systhane 20EW PP Captan 80 WG Runner Stoppit Maxicrop TS	0.33 L 2.0 kg 0.4 L 10 L 2.0 L
19 July	Headland Sulphur Stoppit Maxicrop TS	4 L 10 L 2.0 L
23 July	Systhane 20EW PP Captan 20EW Stoppit Maxicrop TS	0.33 L 1.0 kg 10 L 2.0 L
31 July	Systhane 20EW PP Captan 80WG Stoppit	0.33 L 1.0 kg 10 L
2 August	Magflo 300 Ferleaf	4.0 L 1.0 L
10 August	Topenco PP Captan 80WG Stoppit	0.5 L 1.0 kg 10 L
18 August	Topenco PP Captan 80WG Stoppit	0.5 L 1.0 kg 10 L
26 August	Topenco 100EC Stoppit	0.5 L 10 L
10 September	Seniphos Bellis	10 L 0.8 kg
24 September	Seniphos Bellis	10 L 0.8 kg
15 October	Bortrac Zintrac Urea	2.0 L 1.0 L 15 KG
4 November	Headland Copper Magnesium sulphate Folicur	4.0 L 8.0 kg 0.6 kg