Project title	Aphid control in lettuce and brassicas
Project number:	FV 250
Project leader:	Dr Rosemary Collier, University of Warwick
Report:	Final report, June 2007
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Key staff:	Dr Rosemary Collier
Location of project:	University of Warwick
Project coordinator:	Mr Fred Tyler, Alphagrow Ltd Mr John Sedgwick, Kettle Produce Ltd
Date project commenced:	1 October 2003
Date project completed:	31 December 2006

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

Executive Summary

Aphids infesting the foliage of lettuce and brassica crops are becoming increasingly difficult to control. This is because 1) the range of useful/potent insecticides has decreased through the withdrawal of effective products, 2) of the incidence of insecticide resistance in field populations of *Myzus persicae* (peach-potato aphid) and, to a lesser extent, *Nasonovia ribisnigri* (currant-lettuce aphid) and 3) aphids become inaccessible to insecticides as crops mature. The purpose of this 3-year project was to develop an IPM strategy for aphid control on lettuce and brassica crops. It focused on *N. ribisnigri, M. persicae* and *Brevicoryne brassicae* (cabbage aphid). The objectives of the project were to:

1. Transfer knowledge gained during the project to the horticultural industry.
2. Measure the susceptibility of adults and nymphs of three aphid species (*Myzus persicae, Brevicoryne brassicae, Nasonovia ribisnigri*) to proprietary biopesticides based on insect pathogenic fungi.
3. Devise insecticidal control strategies for the pest aphids of lettuce and brassica foliage that will minimise the development of insecticide resistance.
4. Develop an empirical forecast for *Brevicoryne brassicae*.
5. Develop and validate an IPM strategy for the control of pest aphids of salad and brassica crops.

The project was part-funded in its first year by the Horticultural Development Council (HDC) and close contact was maintained with the HDC throughout (Objective 1). A project Advisory Group was formed and included the HDC project coordinators (FV 250). The group met with the project team on two occasions each year.

In 2004, four proprietary fungal biopesticides were evaluated against populations of M. persicae, B. brassicae and N. ribisnigri in a laboratory bioassay (Objective 2). Adults of each species were treated using a Potter tower. All of the biopesticides tested infected the three aphid species examined. The most virulent biopesticide examined was BotaniGard. This product consistently resulted in fungal-induced mortality, regardless of aphid species. BotaniGard was then evaluated in a field experiment against the three aphid species. Treatment with two sprays of BotaniGard reduced the numbers of all three aphid species, but did not provide effective control. However, there was evidence of a small amount of fungal mycosis, suggesting that the infection could be recycled throughout the population.

During the project, a number of novel insecticides were compared with products already approved for aphid control on lettuce and brassica crops (Objective 3). They included seed treatments and foliar sprays. Since the project started, Biscaya (thiacloprid) has been approved (SOLA) for use as a foliar spray on some brassica crops and this was included in

the experiments each year, initially as a coded product. Similarly, Gazelle (acetamiprid) has been approved (SOLA) for use on lettuce and this was evaluated in 2004. Both of these are neonicotinoids, but other relatively effective coded products that have been tested as foliar sprays have novel modes of action and at least one of these may become available to brassica and lettuce growers in the near future. The performance of all insecticide spray treatments varied between occasions and in the case of N. ribisnigri, this could sometimes be related to crop age, as aphids became relatively inaccessible to insecticides as the lettuce plants formed hearts.

Recent information on the insecticide resistance status of M. persicae indicates that all three mechanisms of resistance (carboxylesterase esterase, kdr, MACE) have persisted in field populations and that MACE resistance is relatively persistent in areas such as south Lincolnshire where brassicas and other host crops are grown intensively. Where insecticides were applied to control either insecticide-resistant or insecticide-susceptible clones in this project, pirimicarb (Aphox) was ineffective against aphids with the MACE resistance mechanism and pyrethroid insecticides were ineffective against aphids with kdr resistance. The experiments within this project confirmed that neonicotinoid insecticides are effective against the pest aphids of lettuce and brassica crops and the effects of the imidacloprid seed treatment (Gaucho) can persist throughout the life of the crop. However, the increasing use of neonicotinoids on a wider range of crops will increase the selection pressures that may lead to the evolution of significant resistance in the future. However, to date no resistance of practical importance has been found in this species but vigilance is essential to detect problems as early as possible and alter control recommendations if necessary.

When this project began in 2004, insecticide resistance to pirimicarb in N. ribisnigri was considered to be widespread, but levels varied. In addition, between 1999 and 2001 the levels of resistance to pyrethroids appeared to have increased in some strains of N. ribisnigri in the UK and resistant aphids commonly showed cross-resistance to a range of pyrethroid compounds. One of the aims of this project was to monitor levels of insecticide resistance in field populations to determine whether insecticide resistant individuals were becoming increasingly common. Most of the N. ribisnigri samples were sent to Rothamsted Research because of control failure and so it was anticipated that some of these aphids might be resistant. However, there was no strong evidence that populations of N. ribisnigri had high levels of resistance to any of the insecticides tested.

Data on suction trap captures of B. brassicae were extracted from the historical data sets held by the Rothamsted Insect Survey (Objective 4). For the suction trap data, statistical analyses were done to look at relationships between the date of the first capture of B. brassicae each year and 1) site longitude, latitude and altitude, 2) monthly average temperatures November-May and 3) monthly rainfall October-May. Latitude and longitude affected the date of first flight and first flight was earlier at sites with a lower latitude or higher longitude. The average temperatures for December, January, February and May had a statistically significant effect and in all cases higher temperatures led to an earlier first flight. The timing of the early summer peak (prior to the mid-summer crash) appeared to be explained reasonably well by winter (Jan-Feb) and late spring (May) temperatures and latitude. Little of the variability in the numbers of aphids captured at the time of the peak was accounted for by either weather or latitude, although similar temperature variables appeared to be the most important. Records of captures of B. brassicae by the suction trap located at Kirton in Lincolnshire were compared with crop monitoring data collected at Kirton and at other sites in south Lincolnshire. Comparisons between suction trap captures and the numbers of winged aphids on Brussels sprout plants were particularly similar and there was an indication that the suction trap captures provided an 'early warning' of the arrival of winged B. brassicae in crops.

Discussion with the Advisory Group indicated that levels of B. brassicae control, particularly later in the season, were of greatest concern to brassica growers and so a final set of field experiments was designed to focus on treatments applied to Savoy cabbage and lettuce at different times in the growing season, as part of the overall control strategy (Objective 5). All experiments were infested with aphids. These experiments confirmed that several active ingredients provided comparable levels of control of B. brassicae at different times of the year. M. persicae was relatively abundant in July, but numbers declined subsequently. After a spray application in July, all of the insecticide treatments, with the exception of Hallmark with Zeon Technology (lambda-cyhalothrin), controlled insecticide-susceptible M. persicae, whereas Hallmark with Zeon Technology, Aphox and Dovetail (pirimicarb + lambda-cyhalothrin) were ineffective against insecticide-resistant M. persicae. On lettuce, all of the insecticides provided some control of N. ribisnigri compared with the insecticide-free control treatment in late August. However, following three further applications of insecticides made in September – early November, aphid numbers on the insecticide-free control plots were similar to, or lower than, those on the treated plots, suggesting that natural enemies were particularly effective during this period. Indeed, for all three species of aphid there was evidence that treatment with pyrethroid insecticides increased aphid numbers, rather than providing control, suggesting that natural enemies had been killed by the application of a broad-spectrum insecticide. Although application of a pyrethroid insecticide treatment is unlikely to be recommended for aphid control on lettuce or brassica crops, pyrethroids are applied to control caterpillars and this highlights the importance of considering all pests as part of the control strategy, as insecticides applied to control one pest may actually exacerbate problems with another either on that crop or, primarily in the case of M. persicae, other crops that the aphids subsequently move to.

The project has been presented and discussed at 22 industry events and has stimulated considerable interest amongst growers, consultants and agrochemical companies. A set of guidelines for aphid control in brassica crops, including resistance management strategies for M. persicae are currently being refined and will be made available on the Insecticide Resistance Action Group website hosted by the Pesticides Safety Directorate.

In terms of further research, there is a continuing need to evaluate new insecticides and other novel treatments for their efficacy against the pest aphids of brassica and lettuce crops. It is also important to continue to monitor the resistance status of the pest aphids of these crops, including Macrosiphum euphorbiae (the potato aphid). At the moment it is particularly vital to monitor populations of M. persicae for resistance to neonicotinoid insecticides, since their use is increasing. This is being done through an SA-Link project (LK 0953). There is still a need for a greater understanding of the population dynamics of the pest aphids of brassica and salad crops, in order to target treatments and to avoid treatments when they are unnecessary. This includes an understanding of the causes of the mid-summer crash in aphid numbers and of the effectiveness of key natural enemies. Although the application of biopesticides containing entomopathogenic fungi did not appear promising in this project, it was not possible to optimise application strategies, due to limited resources. A further study might indicate application techniques and timings that increased their efficacy. Identification of further sources of pest resistance in host plants (resistance to N. ribisnigri is available in commercial varieties), which could be bred into new varieties, would reduce the need for insecticidal control.

Introduction

Aphids infesting the foliage of lettuce and brassica crops are becoming increasingly difficult to control. This is because the range of potent/useful insecticides has decreased through the withdrawal of effective products and because of the incidence of insecticide resistance in field populations of *Myzus persicae* (peach-potato aphid) and, to a lesser extent, *Nasonovia ribisnigri* (currant-lettuce aphid). The increased constraints on aphid control have come at a time when growers are under considerable pressure from supermarkets to reduce pesticide use and to adopt integrated pest management (IPM) practices. However, they must still maintain effective control, since there is a 'nil' tolerance for contamination by all insects, including aphids, in marketed produce.

Several aphid species infest the foliage of lettuce, of which N. ribisnigri, Macrosiphum euphorbiae (potato aphid) and M. persicae are the most important. N. ribisnigri is particularly difficult to control, as it infests the heart of the plant and is therefore inaccessible to foliar sprays of insecticide. Brevicoryne brassicae (cabbage aphid) is the main pest aphid of the foliage of brassica crops, although M. persicae has become increasingly important in recent years, and in the latter species, the occurrence of significant levels of insecticide resistance has made some infestations difficult to control. Both B. brassicae and M. persicae cause distortion and contamination of produce and M. persicae is implicated particularly in the transmission of plant viruses.

The intensive use of a small range of insecticides for aphid control is not sustainable, because it leads to the rapid selection of insecticide-resistant aphids. Much research on insecticide resistance in the pest aphids of horticultural crops has been done at Rothamsted Research. Three forms of resistance have been identified in M. persicae, conferring resistance to a range of carbamate, organophosphorus and pyrethroid insecticides. This includes extreme resistance to pirimicarb in aphids that have the MACE (modified acetylcholinesterase) resistance mechanism. MACE resistance has shown a northward expansion in its European distribution in recent years and was particularly evident in field populations (on potatoes and brassica crops) in 1996 and since 2001. Imidacloprid has a similar mode of action to nicotine. As yet there is no evidence of field resistance to imidacloprid within the UK. However, this compound and other neonicotinoids are not immune to the evolution of resistance, which has already been seen in several pests including whiteflies, potato-Colorado beetles and planthoppers. Furthermore, M. persicae in the UK and elsewhere shows variation in response to neonicotinoids which may represent a 'stepping stone' to greater resistance capable of causing control failures, a possibility made more likely by its plasticity in evolving resistance to a wide range of other products. It is therefore important to adopt strategies that will prevent or, at least stall, this from happening.

Insecticide resistance to pirimicarb in N. ribisnigri is now widespread, but levels vary. However, between 1999 and 2001 the levels of resistance to pyrethroids appeared to have increased in some strains of N. ribisnigri in the UK and resistant aphids commonly show cross-resistance to a range of pyrethroid compounds. There is no evidence of resistance to imidacloprid in N. ribisnigri. For M. euphorbiae, no practical resistance to any insecticide has been demonstrated in the field, although some individuals collected between 1998 and 2002 have shown low-level resistance to pirimicarb and lambda-cyhalothrin. Similarly, there is no evidence that populations of B. brassicae have developed resistance to any insecticide in the UK. Finally, there is also no evidence of resistance to the relatively new compound pymetrozine (Plenum) in any of the pest aphids of lettuce and brassica crops.

The purpose of this 3-year project was to develop an IPM strategy for aphid control on lettuce and brassica crops. The project was a collaboration between Warwick HRI and Rothamsted Research and was part-funded by the Horticultural Development Council (FV 250). The project focused on N. ribisnigri, M. persicae and B. brassicae, because the need for effective control of these three pest aphid species was the most urgent. The objectives of the project were to:

1. Transfer knowledge gained during the project to the horticultural industry.
2. Measure the susceptibility of adults and nymphs of three aphid species (*Myzus persicae, Brevicoryne brassicae, Nasonovia ribisnigri*) to proprietary biopesticides based on insect pathogenic fungi.
3. Devise insecticidal control strategies for the pest aphids of lettuce and brassica foliage that will minimise the development of insecticide resistance.
4. Develop an empirical forecast for *Brevicoryne brassicae*.
5. Develop and validate an IPM strategy for the control of pest aphids of salad and brassica crops.

EXPERIMENTAL

Transfer knowledge gained during the project to the horticultural industry.

A project Advisory Group was formed. Industry members of the group and HDC project coordinators (FV 250) were Fred Tyler, John Sedgwick and Robert Montgomery. The group met with the project team on two occasions each year. Other knowledge transfer activities are detailed at the end of the report.

Measure the susceptibility of adults and nymphs of three aphid species (Myzus persicae, Brevicoryne brassicae, Nasonovia ribisnigri) to proprietary biopesticides based on insect pathogenic fungi.

Four proprietary fungal biopesticides (Vertalec, PFR, BotaniGard and Naturalis) and two adjuvants (Addit and Codacide) were obtained from UK based suppliers and evaluated against populations of M. persicae, B. brassicae and N. ribisnigri in a laboratory bioassay. Fixed age adults of each species were treated at the manufacturers' recommended rate using a Potter tower. The 45 most active individuals were then transferred to three four-week-old plants of either Brussels sprout cv Montgomery (M. persicae and B. brassicae) or lettuce cv Saladin (N. ribisnigri) enclosed within a bread bag. Plants were maintained within a controlled environment room at 20OC ± 2OC, 60% humidity, photoperiod 16h, for nine days. Aphid mortality was recorded every third day and nymphs were removed and counted. Any dead aphids were removed daily and incubated on damp filter paper within Petri dishes (20 ± 1OC, darkness) for seven days and inspected for the presence of mycelium on the cadavers. The presence of sporulating mycelium was taken as evidence of fungus-induced mortality. Each aphid species was examined in separate bioassays and each bioassay was replicated on five separate occasions.

All of the biopesticides tested showed evidence of infection in the three aphid species examined. Differences in the susceptibility of aphids were observed between species and between treatments (Table 1). M. persicae was the most susceptible aphid species to the fungal biopesticides examined. The most virulent biopesticide examined was BotaniGard. This product consistently resulted in fungal-induced mortality, regardless of aphid species. All biopesticides produced conidia on aphid cadavers, although the proportion of sporulating cadavers was lower for B. brassicae. It is possible that the waxy cuticle of this aphid species inhibits the production of conidia, which could affect further cycling of the infection.

Table 1. Predicted cumulative percentage mortality 6 days after treatment with biopesticides. The data were analysed using a generalised linear model with a logit link function and a binomial distribution (assuming an over dispersed distribution).

Treatment	***Myzus***	***Nasonovia ribisnigri***	***Brevicoryne brassicae***	**Mean**
Untreated control	6	25	39	23.3
Codacide	6	27	47	26.7
Addit	6	33	51	30.0
Naturalis	31	36	58	41.7
Vertalec + Codacide	37	54	45	45.3
Vertalec	56	50	47	51.0
Vertalec + Addit	47	45	62	51.3
PFR	42	50	70	54.0
BotaniGard	83	73	92	82.7

Bioassay using nymphs

A laboratory bioassay was done with nymphal populations of varying ages (1-3 days old) of the three aphid species using two commercial treatments (BotaniGard and PFR) (3 treatments in total, including an untreated control). The bioassay was done on one occasion with 9 plants per treatment/aphid species combination. The numbers of adults and nymphs (and total aphids) were counted at days 0, 7 and 10. Overall, BotaniGard was the best product tested regardless of the aphid species examined. However there was a species effect of PFR, it having a smaller effect on *M. persicae* than on *N. ribisnigri* and *B. brassicae*. There was very little mycosis with any of the treatments, probably as a result of moulting.

Efficacy in the field

Based on the results of the laboratory bioassays, BotaniGard was evaluated in a field experiment against the three aphid species. The treatments were replicated in four plots and the plots were arranged as a split-plot design, with treatment (mycopesticide, control) applied to main plots and aphid species applied to sub-plots. Each plot consisted of 20 plants (2 rows x 10 plants) and was infested artificially and enclosed within an insect cage (Figure 1). The experiment was done on two occasions (August and September 2004). On the first occasion, B. brassicae was the only species examined and on the second occasion all three aphid species were examined.

Figure 1. Field plots enclosed with fine mesh netting.

There was evidence that, when the numbers present before the first spray were taken into account, treatment with two sprays of BotaniGard reduced the numbers of all three aphid species (Table 2). However, the first spray alone had a greater effect in reducing the population size. This is probably a direct result of the application method and the increasing size of the plants, resulting in a lower direct hit of the target species. There was also evidence of a small amount of fungal mycosis suggesting that the infection could be recycled throughout the population.

Table 2. Total number of aphids per plant (back-transformed) after two weekly treatments with BotaniGard. The data were analysed using an ANOVA.

	Prespray		**Post spray 1**		**Post spray 2**	
	Untreated	**Treated**	**Untreated**	**Treated**	**Untreated**	**Treated**
Brevicoryne	28	25	23	10	47	15

brassicae						
Myzus persicae	14	18	10	8	11	9
Nasonovia ribisnigri	4	3	4	0	7	0

Devise insecticidal control strategies for the pest aphids of lettuce and brassica foliage that will minimise the development of insecticide resistance.

In 2004, insecticides were evaluated against populations of aphids in a field experiment at Warwick HRI, Wellesbourne. The plots were planted on two occasions, 25 June and 18 August, and two replicates of each treatment were planted on each occasion. To ensure that all three target aphid species were tested, the plots were infested artificially. Details of the aphids used in the experiment are shown in Table 2. Both an insecticide-susceptible and an insecticide-resistant clone of M. persicae (supplied by Rothamsted Research) were included. Lettuce (cv Saladin) was used as a host plant for N. ribisnigri and cabbage (cv Celtic) for the two other species. All plots were covered with fine mesh netting (Figure 1) to prevent colonisation by other species/clones of aphids.

Table 2. Aphid species and clones used in field experiments throughout project.

Species	**Clone**	**Crop**
Nasonovia ribisnigri	Field-collected	Lettuce
Brevicoryne brassicae	K3 - most common clone in UK	Cabbage
Myzus persicae	MP1S (susceptible to all insecticides)	Cabbage
Myzus persicae	2050A (esterase-R2, MACE, kdr-SR resistances)	Cabbage

The treatments included novel insecticides, industry standards and insecticide-free controls (Table 3). Some of the insecticides were applied as seed or granule treatments, whilst the majority were applied as foliar sprays. The spray treatments were applied five (first planting) or three (second planting) weeks after planting. The seed and granule treatments were assessed 2 and 6 weeks after planting by infesting the plants with fixed numbers of aphids, which were then enclosed in clip cages. Aphid survival and reproduction were assessed subsequently (Table 4). The data were analysed using a GLM.

There were some pronounced differences between treatments and between the effects of certain treatments on different species or clones of aphid (Figures 3 & 4). Spray treatments to control N. ribisnigri were generally more effective on the second planting, probably because the plants were younger and the aphids more accessible. Of the insecticides applied as sprays to cabbage to control B. brassicae and M. persicae, Plenum (pymetrozine) was the most effective and in this case it was applied with a wetter (Phase II). There were some pronounced differences in the efficacy of certain treatments against B. brassicae compared with M. persicae, and also a difference between insecticide-resistant and -

susceptible clones of M. persicae in their susceptibility to Aphox (pirimicarb), due to the presence of MACE resistance in the resistant clone.

On lettuce, a single novel seed treatment (Exp T) was compared with Gaucho (imidacloprid) seed treatment. Both seed treatments gave effective control of N. ribisnigri 2 weeks after planting, but were less effective (but still > 70% effective) after 6 weeks. On cabbage, a novel granule treatment (Exp T) was compared with Gaucho (imidacloprid) seed treatment. The granule treatment proved to be effective and persistent. The imidacloprid treatment was less persistent, but still gave > 70% control after 6 weeks.

Table 3. Treatments applied in 2004.

Product	Active ingredient	Application	Wetter	Rate lettuce	Rate cabbage
Exp T		Seed treatment or granule		Seed treatment – SLPA03-12-02	Granule – 100g a.i./ha
Gaucho	Imidacloprid	Seed treatment		120 g a.i./unit	140 g a.i./unit
Plenum	Pymetrozine	Spray	Phase II – cabbage only	0.4 kg/ha	0.4 kg + Phase II @ 0.5%
Exp U	Thiacloprid	Spray		0.4l/ha	0.4l/ha
Aphox	Pirimicarb	Spray	Agral for cabbage only	500 g/1000l water (=150 g/ha @ 300l/ha)	420g/ha + Agral @ 250ml/1000l
Hallmark with Zeon Technology	Lambda-cyhalothrin	Spray	Agral for cabbage only	75 ml/ha	50 ml/ha + Agral @ 300ml/1000l
Exp A		Spray		3 ml/litre water (=1.8 l/ha @ 600 l/ha)	3 ml/litre water (=1.8 l/ha @ 600 l/ha)
Exp H		Spray		200g/ha	200g/ha
Control – no insecticide					

Table 4. Schedule for evaluating seed and granule treatments in 2004.

	Replicates 1 & 2	Replicates 3 & 4
Planted	25-Jun	18-Aug
Infested	08-Jul	31-Aug
Assessed	15-Jul	08-Sep
Infested	04-Aug	28-Sep
Assessed	10-Aug	11-Oct

Figure 3. The effect of insecticide seed and granule treatments on *M. persicae, B. brassicae* and *N. ribisnigri* in 2004. Myzus S = insecticide-susceptible clone and Myzus R = insecticide-resistant clone (see Table 2). Data expressed as aphids remaining on treated plots as a percentage of the aphids remaining on the insecticide-free control plots.

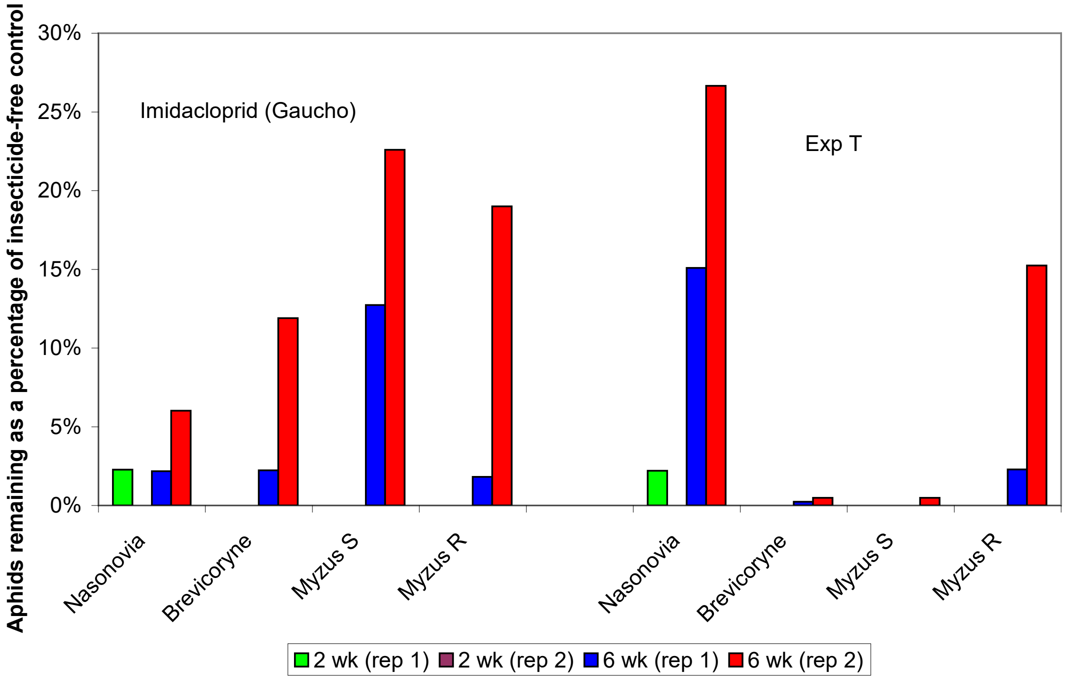


Figure 4. The effect of insecticide spray treatments on *M. persicae* and *B. brassicae* 14 days (Reps 1 & 2) and 12 days (Reps 3 & 4) after treatment in 2004. Data expressed as aphids remaining on treated plots as a percentage of the aphids remaining on the insecticide-free control plots.

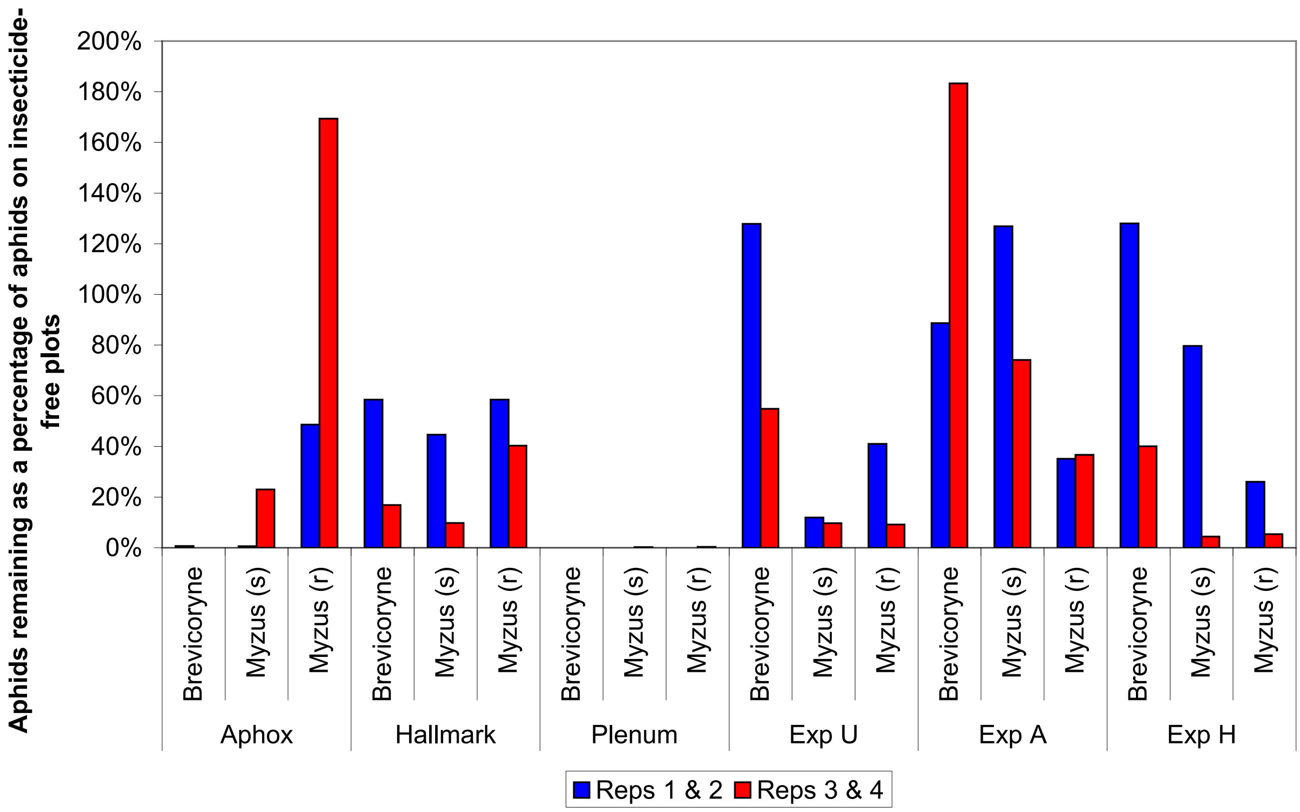
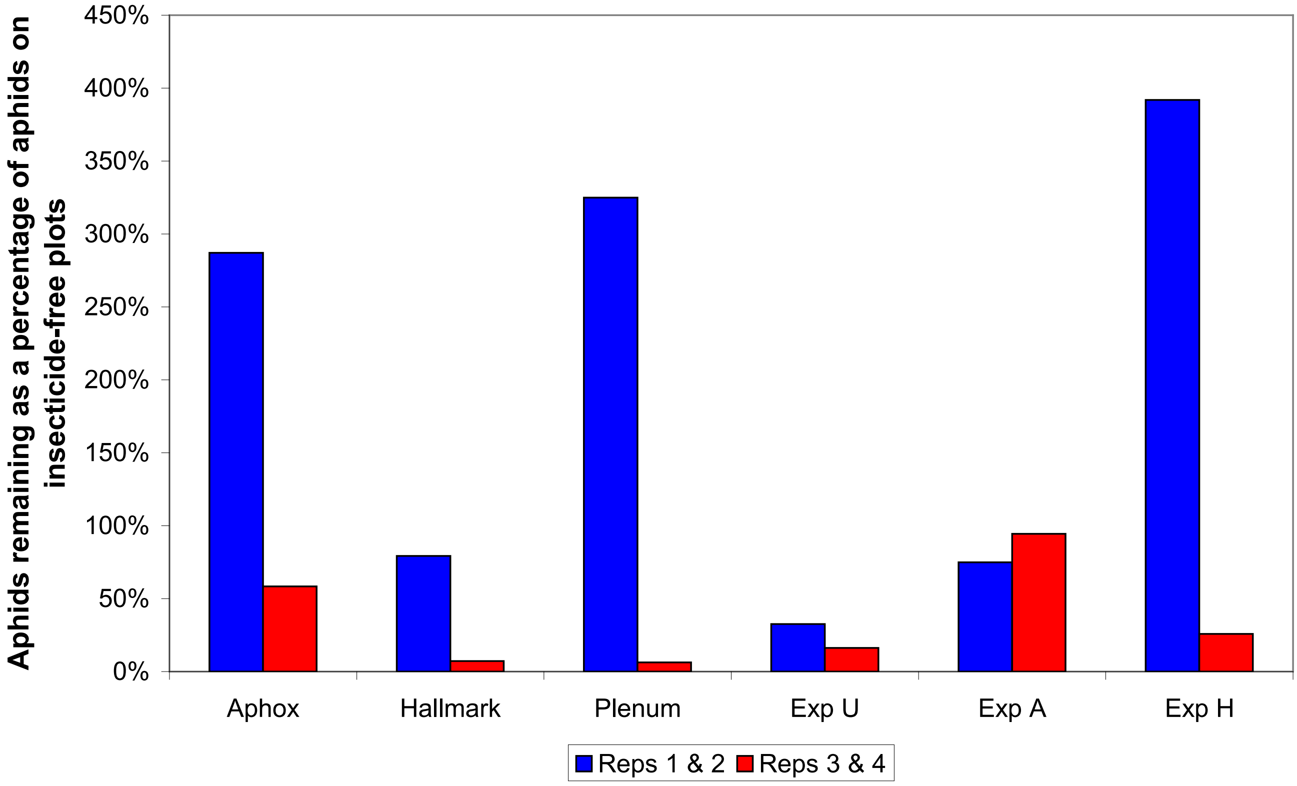


Figure 5. The effect of insecticide spray treatments on *N. ribisnigri* 14 days (Reps 1 & 2) and 12 days (Reps 3 & 4) after treatment in 2004. Data expressed as

aphids remaining on treated plots as a percentage of the aphids remaining on the insecticide-free control plots.



In 2005, the most effective insecticide treatments from 2004, the most effective biopesticide treatment (BotaniGard) and some industry standard treatments (Table 5) were applied to plots of brassicas (2 replicates Savoy cabbage (cv Firensa), 2 replicates Brussels sprout (cv Diablo)) and lettuce (4 replicates cv Saladin) that were exposed to natural aphid infestations. In addition, the plots were inoculated at intervals with the key aphid species (insecticide-resistant and -susceptible *M. persicae, B. brassicae* and *N. ribisnigri* as in Table 2).

The 'growth cycle' of each crop was divided into two periods (approximately 'before' and 'after' the mid-summer crash in aphid numbers). A particular treatment was applied to replicate plots at fortnightly intervals for the first half of the growth period and another treatment was applied at fortnightly intervals during the second half. This was to establish whether any particular treatment was more, or less, effective either early or late in the growth cycle. Treatments were changed on 23 August. The plants were sampled at regular intervals to record aphid numbers. The Savoy cabbage and Brussels sprout plots were planted on 2-3 June and a total of 8 sprays were applied, at 2 week intervals. Because it was such a large experiment, the insecticide-free control treatment (untreated control) was replicated more times than the other treatments.

Table 5. Treatments applied in 2005.

Product	Active ingredient	Application	Wetter	Rate lettuce	Rate cabbage
Gaucho	imidacloprid	Seed		120 g a.i./unit	140 g a.i./unit

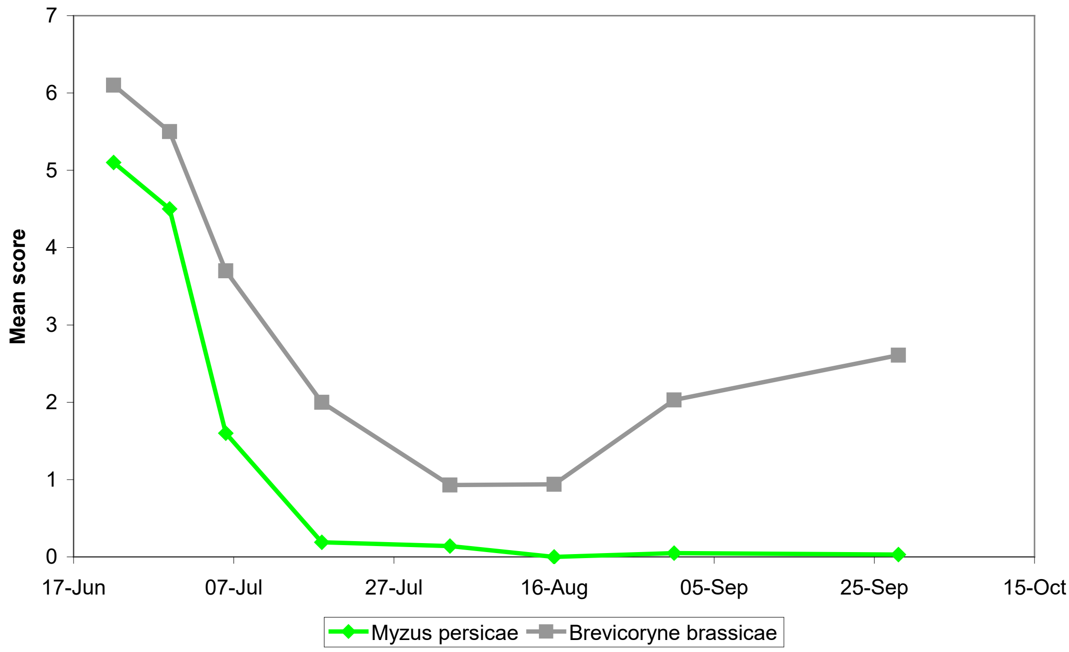
		treatment			
Gaucho	imidacloprid	Drench		1.2 mg a.i./plant	1.4 mg a.i./plant
Dovetail	Lambda cyhalothrin + pirimicarb	Foliar spray	Agral – brassica only	1.5 l/ha	1.5 l/ha + Agral @ 300 ml/1000 l (400 l/ha)*
Aphox	pirimicarb	Foliar spray	Agral – brassica only	500 g/1000 l water (=150 g/ha @ 300l/ha)	420g/ha + Agral @ 250 ml/1000 l
Plenum	pymetrozine	Foliar spray	Phase II – brassica only	0.4 kg/ha	0.4 kg/ha + Phase II @ 0.5%
Exp U	thiacloprid	Foliar spray	Phase II – brassica only	0.4 l/ha	0.4 l/ha + Phase II @ 0.5%
BotaniGard	Beauveria bassiana	Foliar spray		2.44 ml/l water (=976 ml/ha @ 400 l/ha)*	2.44 ml/l water (=976 ml/ha @ 400 l/ha)*
Control – no insecticide					

*All other treatments applied @ 300 l/ha

Table 6. Treatment programmes in 2005. All plots were infested artificially with the exception of the treatment: Untreated (natural infestation only).

Pre-crash treatment	**Post-crash treatment**
Gaucho (ST)	Dovetail
Gaucho (drench)	Dovetail
Dovetail	Dovetail
Aphox	Aphox
Plenum	Plenum
Exp U	Exp U
BotaniGard	BotaniGard
Plenum	BotaniGard
BotaniGard	Plenum
Exp U	BotaniGard
BotaniGard	Exp U
Exp U	Plenum
Plenum	Exp U
Aphox	Plenum
Plenum	Aphox
Aphox	Exp U
Exp U	Aphox
Aphox	BotaniGard
BotaniGard	Aphox
Untreated	Untreated
Untreated	Untreated
Untreated	Untreated
Untreated	Untreated
Untreated (natural infestation only)	Untreated (natural infestation only)

Figure 6. Aphid infestations on insecticide-free brassica plants in 2005.



On the brassica plots, aphid numbers were high soon after planting but then declined, and the mid-summer crash occurred in mid-August, just before the treatments were changed (23 August). Numbers of *B. brassicae* increased again after the crash, but numbers of *M. persciae* did not recover (Figure 6). Because aphid numbers were so high initially, a scoring system was used to assess numbers on each plant (Table 7).

Table 7. Scoring system used to assess aphid numbers on each plant.

Score	**Aphid numbers**
0	0
1	1-3
2	4-10
3	11-30
4	31-100
5	101-300
6	301-1,000
7	1,001-3,000
8	3,001-10,000

Figure 7 shows the mean scores for M. persicae and B. brassicae following the first spray application. Several of the insecticide treatments were relatively effective. Figure 8 shows the mean scores for B. brassicae after the mid-summer crash. The Gaucho seed treatment and the Gaucho drench followed by Dovetail (from 23 August) were the most effective treatments, confirming the value of 'soil' treatments with a systemic insecticide.

Figure 7. First post-spray assessment on brassica plants on 6 July 2005. Aphid numbers were scored (Table 7).

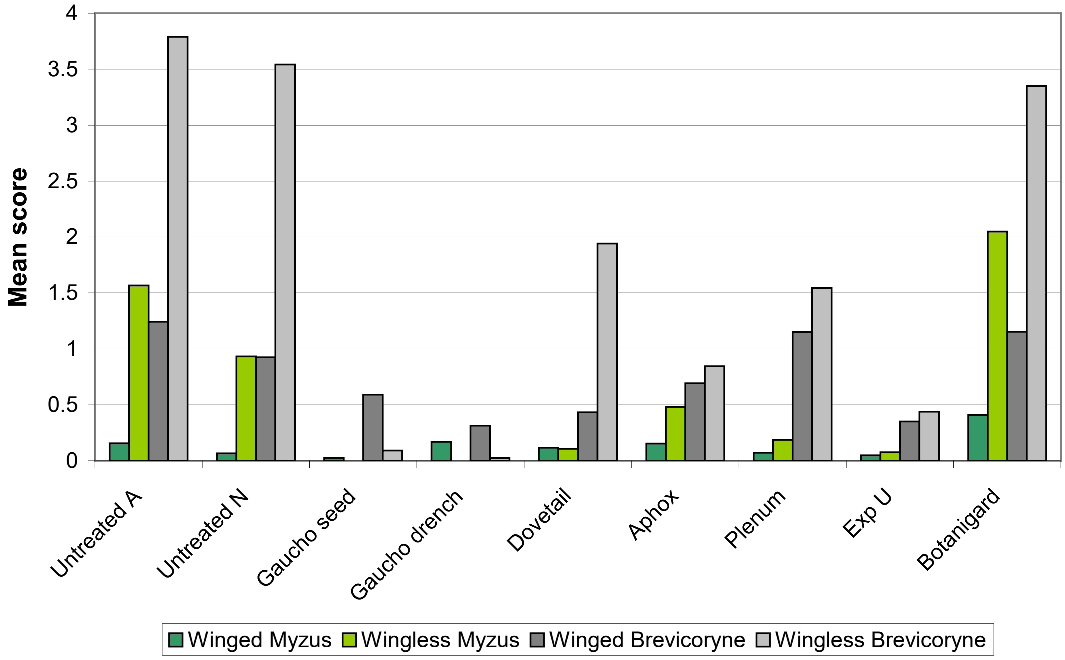
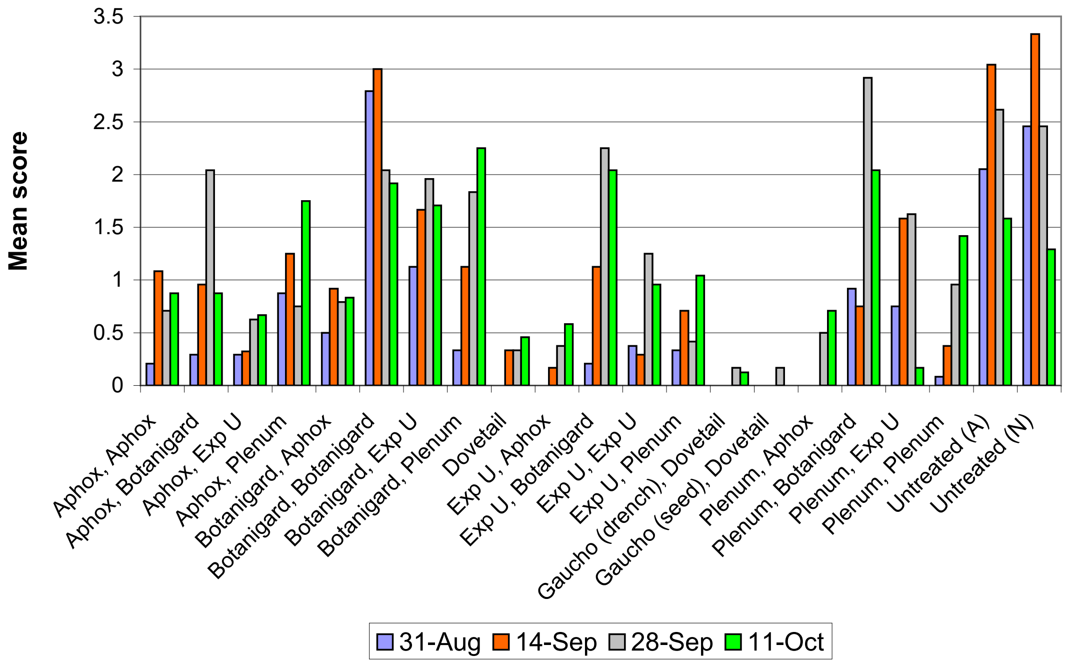
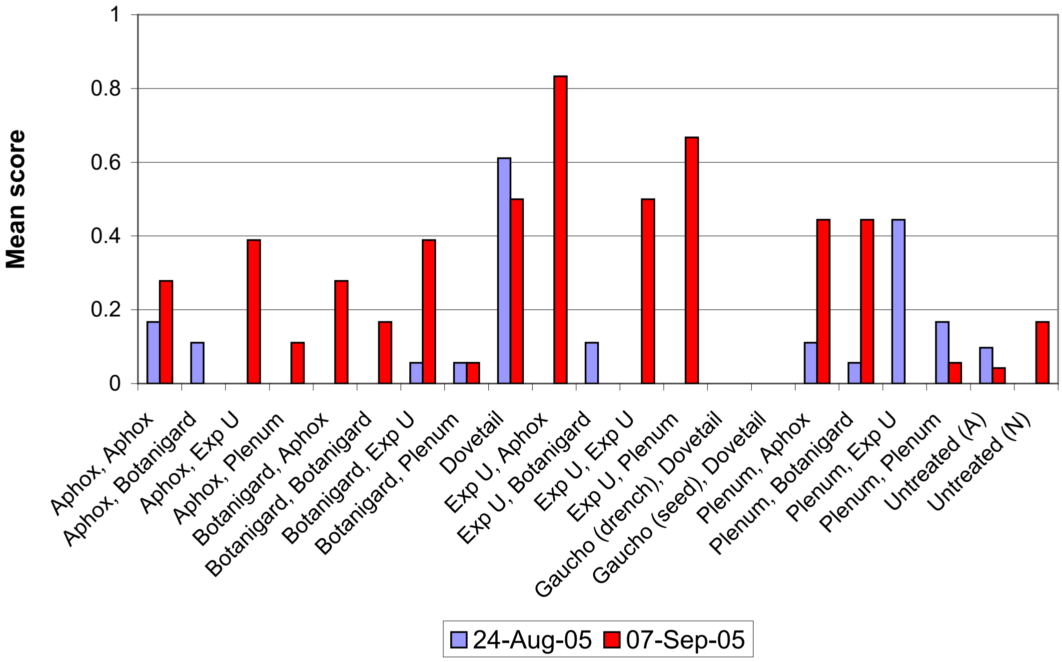


Figure 8. Numbers of wingless adult *B. brassicae* and nymphs after the mid-summer crash. The treatments applied before and after the crash are shown. Aphid numbers were scored (Table 7).



The lettuce were planted on 4-5 July and infested with *N. ribisnigri*. They were treated with a similar programme of insecticides to the brassica plots but two treatments were applied before the treatment changeover date (on 16 August) and two treatments were applied afterwards. Despite the attempt to infest the plots artificially, aphid numbers were relatively low. Figure 9 shows the effects of the treatment programmes on the two post-crash assessment dates, but numbers were very low.

Figure 9. Numbers of wingless adult *N. ribisnigri* and nymphs after the mid-summer crash. The treatments applied before and after the crash are shown. Aphid numbers were scored (Table 7).



Throughout the project, Rothamsted Research monitored the resistance status of field populations of M. persicae and N. ribisnigri. Monitoring of M. persicae resistance was funded through SA-LINK project LK0953: 'Stewardship of neonicotinoid insecticides' whilst monitoring of N. ribisnigri was funded within this project.

The HDC Pest Bulletin web pages, the HDC Weekly e-mail and the British Leafy Salads Association newsletter were used to request samples of M. persicae and N. ribisnigri for insecticide resistance testing. Most of the N. ribisnigri samples were sent to Rothamsted Research because of control failure, so it was anticipated that some of these aphids might be resistant to one or more insecticides. Table 8 summarises data for the samples received. There was no strong evidence that populations of N. ribisnigri had high levels of resistance to any of the insecticides tested.

Table 8. *Nasonovia ribisnigri* – percentage affected + dead of samples from field crops with diagnostic topical doses (shown in parenthesis) of insecticides.

Received	Origin	Imidacloprid	Pirimicarb (100 ppm)	Pymetrozine (50 ppm)	Lambda-cyhalothrin (2.5 ppm)
29/09/2003	Lincolnshire	100/97	100	30.3	100/54
09/07/2004	Sussex	100	96.3	88	100
19/08/2004	Sussex	100	100	84.6	92
24/09/2004	Cambridgeshire	100	100	78.3	96
30/09/2004	Lancashire	85.4	100	94.3	88
11/11/2004	Lincolnshire	92.9	100	52.9	77
15/09/2005	Cambridgeshire	100	97	90	83
20/09/2005	Lincolnshire	100	100	100	100
20/09/2005	Lincolnshire	100	97	97	94
20/10/2005	Worcestershire	100	100	90	100
20/10/2005	Worcestershire	100	93	80	93
24/04/2006	Sussex	96	81.8		100
01/08/2006	Fife	100			92
16/08/2006	Norfolk	100/100		100	93/61
27/09/2006	Cambridgeshire	100/100		95/94	100/98
19/10/2006	Sussex	100			92
26/10/2006	Worcestershire	100			95
30/11/2006	Sussex	100			74

Develop an empirical forecast for *Brevicoryne brassicae*.

Data on suction trap captures of *B. brassicae* were extracted from the historical data sets held by the Rothamsted Insect Survey. For the suction trap data, statistical analyses were done to look at relationships between the date of the first capture of *B. brassicae* each year and 1) site longitude, latitude and altitude, 2) monthly average temperatures November-May and 3) monthly rainfall October-May. There were 409 site years altogether and 51 missing values – no first flight (40) or no data (11). Latitude and longitude affected the date of first flight and first flight was earlier at sites with a lower latitude or higher longitude. The average temperatures for December, January, February and May had a statistically significant effect and in all cases higher temperatures led to an earlier first flight (59% of variance accounted for). The coefficients of the fitted equation are:

	coefficient	standard error
Average temperature May	-8.14	2.759
Average temperature Feb	-10.51	2.684
Average temperature Jan	-9.56	2.571
Average temperature Dec	-5.34	2.421
Latitude	18.33	4.400
Longitude	-0.16	4.240
Constant	183.69	4.111

This equation accounted for a large proportion of site-to-site and year-to-year variability, but not much site x year interaction variability. The effect of temperature was still significant after its relationship with latitude and longitude had been taken into account, indicating that not all the effect of temperature is because of geographical location.

The data were then inspected to determine the site x year combinations where there was a clear peak in aphid numbers prior to a mid-summer crash. Although there were data for 411 site/years; 240 of these had no recorded peak for one reason or another (no discernible peak, no recorded flight, missing data). Generally, the percentage of discernible peaks showed little trend with time, but a reasonably strong trend with latitude and longitude. The data for the years with discernible peaks were then analysed further to look at relationships between the timing of the peak and the size of the peak and weather variables/latitude/longitude as above.

The timing of the peak (prior to the mid-summer crash) appeared to be explained reasonably well by winter (Jan-Feb) and late spring (May) temperatures and latitude (63% variance accounted for). The fitted equation is:

The coefficients of the fitted equation are:

	coefficient	standard error
Average temperature May	-0.627	0.3215
Average temperature Feb	-1.567	0.3236
Average temperature Jan	-0.590	0.2943
Latitude2	4.297	1.0480
Latitude	-2.457	1.0221
Longitude	0.278	0.1955
Constant	29.434	0.3245

Little of the variability in the numbers of aphids captured at the time of the peak was accounted for by either weather or latitude, although similar temperature variables appeared to be the most important.

Records of captures of B. brassicae by the suction trap located at Kirton in Lincolnshire were compared with crop monitoring data collected at Kirton and at other sites in south Lincolnshire. The crop monitoring data were collected prior to the start of this project as part of the Warwick HRI pest monitoring service. The numbers of all pest insects were recorded on insecticide-free Brussels sprout plants from May until early autumn. Comparisons between suction trap captures and the numbers of winged aphids on Brussels sprout plants were particularly similar and there was an indication that the suction trap captures provided an 'early warning' of the arrival of winged B. brassicae in crops (Figures 10-11).

Figure 10. Comparison of the numbers of winged aphids captured in a suction trap at Kirton, Lincolnshire and the numbers of winged aphids on insecticide-free Brussels sprout plants at Kirton in 1998 (log scale).

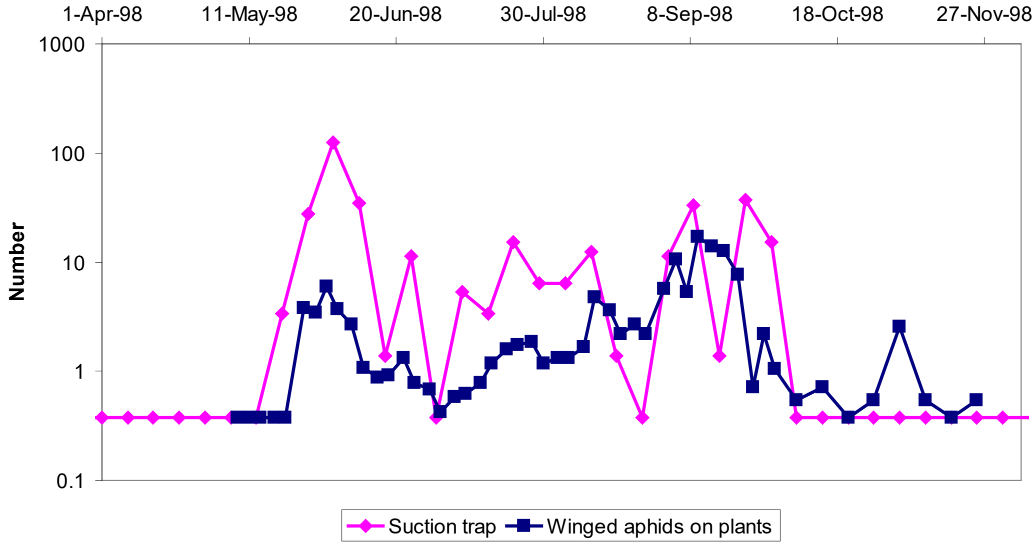
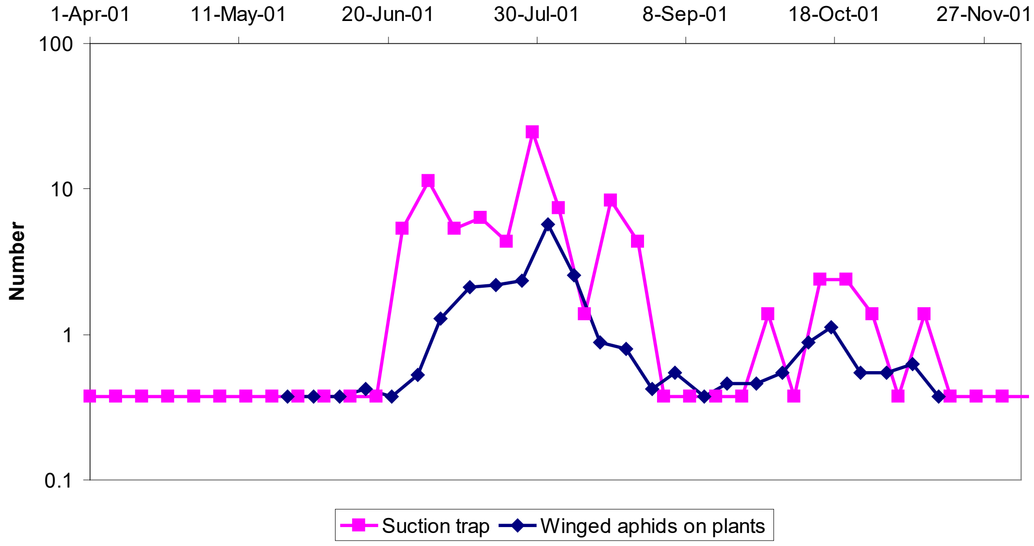


Figure 11. Comparison of the numbers of winged aphids captured in a suction trap at Kirton, Lincolnshire and the numbers of winged aphids on insecticide-free Brussels sprout plants at Kirton in 2001 (log scale).



Develop and validate an IPM strategy for the control of pest aphids of salad and brassica crops.

Discussion with the Advisory Group indicated that levels of control, particularly later in the season, were of greatest concern to growers and so a final set of field experiments was designed to evaluate the performance of approved and novel insecticides at different times in the growing season. The crops used in these experiments were Savoy cabbage (cv Firensa) (planted on 8 June 2006) and lettuce (cv Saladin) (planted on 7 August and 5 September 2006). All experiments were infested with aphids (as in Table 2) and following infestation, the plots were covered temporarily with fine mesh netting to allow the infestations to establish. Foliar sprays were applied to the cabbage experiment on 3 occasions (early, mid and late season – 10 July, 21 August, 17 October) and to each of the two lettuce experiments on 2 occasions (Experiment 1 - 22 August, 8 September; Experiment 2 - 6 October, 24 October). The treatments are shown in Table 9.

Table 9. Treatments applied in insecticide experiments in 2006.

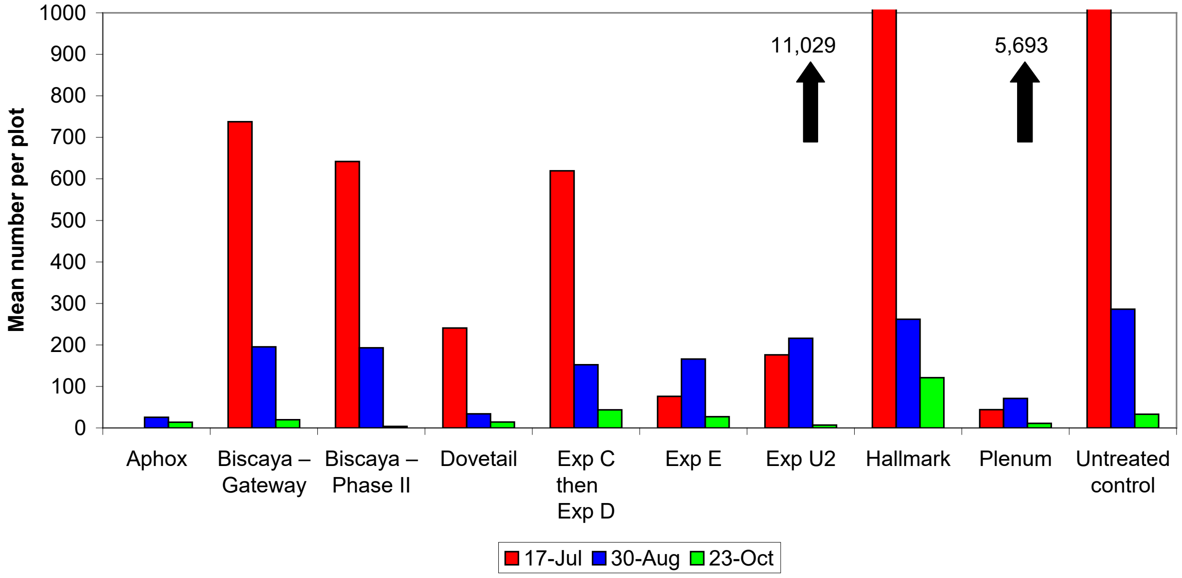
Savoy cabbage			
Product	Active ingredient	Wetter	Rate
Aphox	Pirimicarb	Agral	420 g/ha + Agral @ 300 ml/1000 l
Biscaya	Thiacloprid	Phase II	400 ml/ha + Phase II @ 0.5%
Biscaya	Thiacloprid	Gateway	400 ml/ha + Gateway @ 0.125%
Dovetail	Lambda-cyhalothrin + pirimicarb	Agral	1500 ml/ha + Agral @ 300 ml/1000 l
Exp C		Agral	250 g/ha + Agral @ 300 ml/1000 l (400 l/ha)*
Exp E		Phase II	160 g/ha + Phase II @ 0.5%
Exp U2		Phase II	480 g/ha + Phase II @ 0.5%
Exp D		Agral	1500 ml/ha + Agral @ 300 ml/1000 l
Hallmark with Zeon Technology	Lambda-cyhalothrin	Agral	100 ml/ha + Agral @ 300 ml/1000 l
Plenum	Pymetrozine	Phase II	400 g/ha + Phase II @ 0.5%
Untreated control			
Lettuce			
Product	Active ingredient	Wetter	Rate
Aphox	Pirimicarb		500 g/1000l water (=150 g/ha @ 300l/ha)
Biscaya	Thiacloprid		400 ml/ha
Dovetail	Lambda-cyhalothrin +pirmicarb		1500 ml/ha
Exp C			250g/ha
Exp E			160 g/ha
Exp U2			480 g/ha
Exp X			1500 ml/ha
Hallmark with Zeon Technology	Lambda-cyhalothrin		75 ml/ha
Plenum	Pymetrozine		400 g/ha
Plenum	Pymetrozine	Breakthru	400 g/ha + Breakthru @ 200 ml/ha
Untreated control			

*All other treatments 300 l/ha

The cabbage spray experiment was designed as a Trojan square and each of the 10 treatments were replicated four times. ANOVA was used to analyse the data.

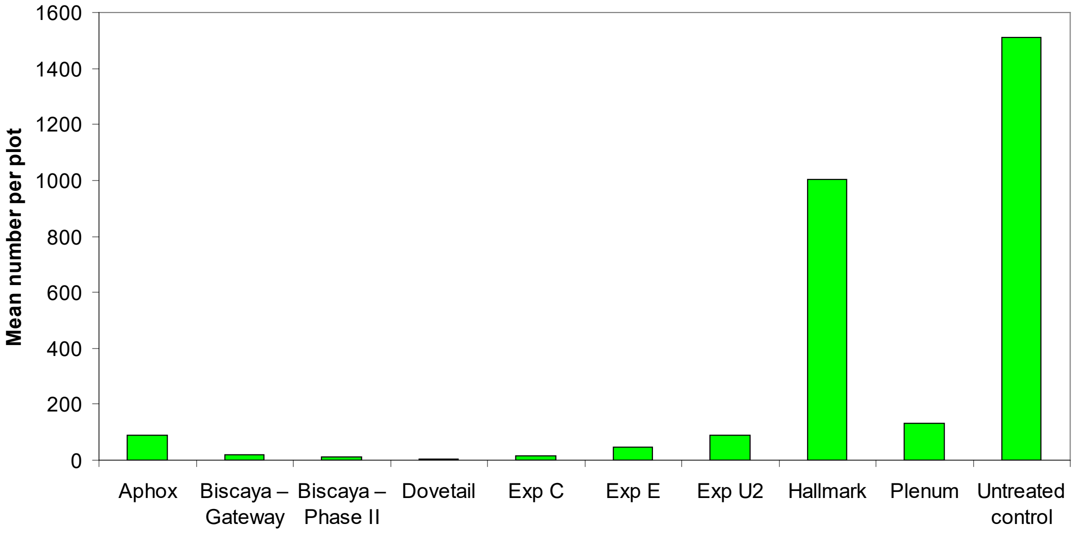
Figure 12. The numbers of wingless *B. brassicae* (nymphs and adults) on Savoy cabbage plants – assessments made approximately one week after each of

three treatment applications. N.B. On 23 October, Exp D had been applied instead of Exp C.



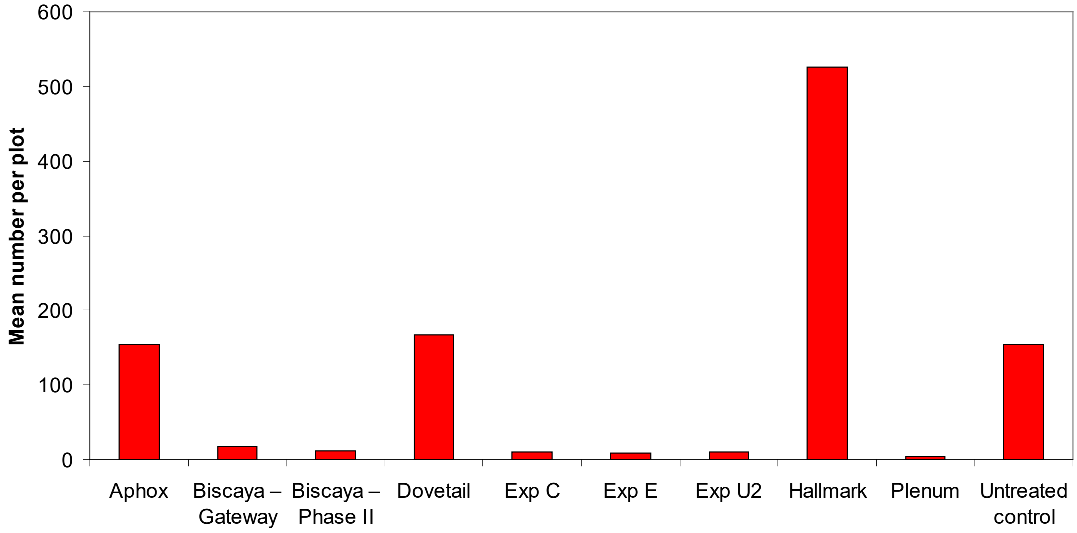
On 17 July, all insecticides, with the exception of Hallmark with Zeon Technology, controlled *B. brassicae* effectively compared with the insecticide-free control ($p < 0.05$) (Figure 12). On 30 August, Aphox, Dovetail and Plenum controlled *B. brassicae* compared with the control treatment. Finally, on 23 October there were few differences between treatments ($p < 0.05$). However, there were fewer aphids on the Biscaya+ Phase II treatment than on the Hallmark with Zeon Technology treatment.

Figure 13. The numbers of insecticide-susceptible wingless *Myzus persicae* (nymphs and adults) on Savoy cabbage plants on 17 July 2006 – one week after the first spray application.



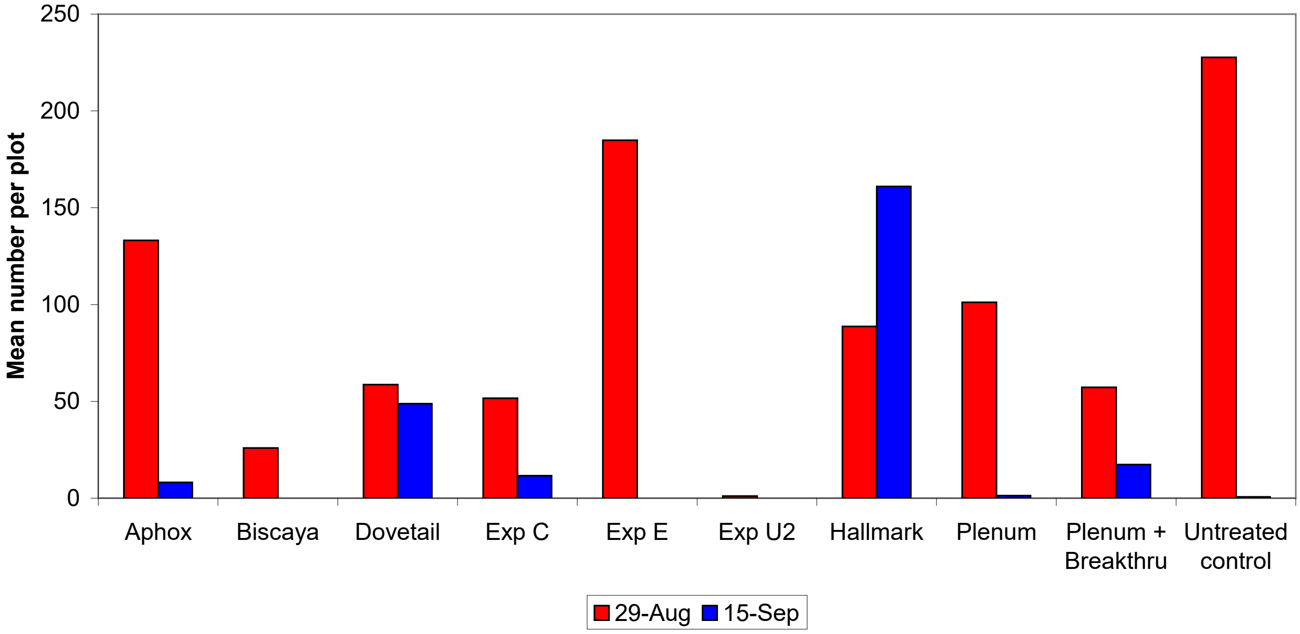
Myzus persicae was relatively abundant in July, but numbers declined subsequently. On 17 July, after the first spray application, all of the insecticide treatments controlled insecticide-susceptible M. persicae, with the exception of Hallmark with Zeon Technology ($p < 0.05$) (Figure 13). Hallmark with Zeon Technology, Aphox and Dovetail were ineffective against insecticide-resistant M. persicae and aphid numbers on the plots treated with Hallmark with Zeon Technology were particularly high (Figure 14)

Figure 14. The numbers of insecticide-resistant wingless *Myzus persicae* (nymphs and adults) on Savoy cabbage plants on 17 July 2006 – approximately one week after the first spray application.



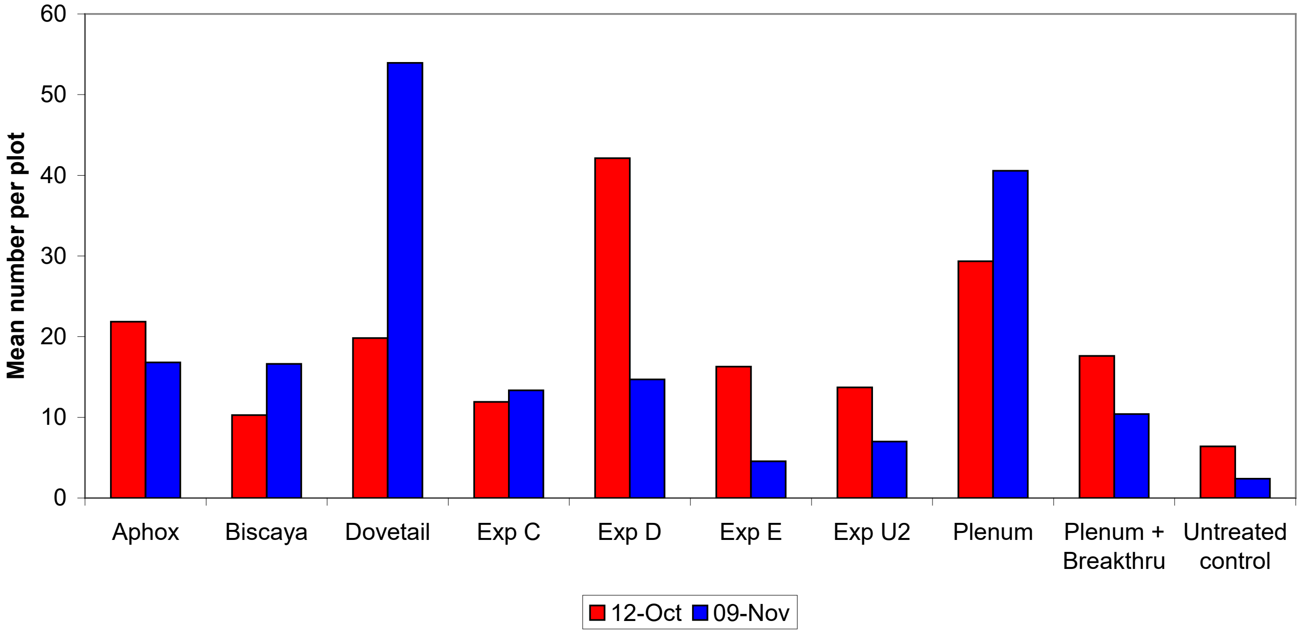
In the first insecticide spray experiment on lettuce (Figure 15), all of the insecticides provided some control on 29 August compared with the insecticide-free control treatment (p<0.05). On 15 September, after the second spray, there were no statistically significant differences between any of the treatments, with the exception of the Hallmark with Zeon Technology treatment, where aphid numbers were higher than all other treatments, including the insecticide-free control (p<0.05).

Figure 15. The effect of insecticide spray treatments on the numbers of *Nasonovia ribisnigri* on lettuce – Experiment 1.



In the second spray experiment on lettuce (Figure 16), surprisingly low numbers of aphids were found on the insecticide-free control plots. Some of the treatments were noticeably more infested than the insecticide-free control plots.

Figure 16. The effect of insecticide spray treatments on the numbers of *Nasonovia ribisnigri* on lettuce – Experiment 2.



There was a separate seed treatment experiment for both brassicas and lettuce using treated seed provided by insecticide companies. Consequently several crops/varieties were evaluated in the experiments. The plants were infested with fixed numbers of aphids (B. brassicae and M. persicae (resistant clone) on brassica plants and N. ribisnigri on lettuce) which were retained on the plants using clip cages. The results of the brassica seed treatment experiment are shown in Table 12. Exp S and Gaucho controlled B. brassicae 68 days after sowing, but their effectiveness had declined after 109 days. Only Gaucho controlled M. persicae effectively.

Table 10. The total numbers of *B. brassicae* and *M. persicae* on brassica plants grown from seed treated with insecticide. The plants were sown on 26 May and the plots planted on 4 July. Plants were infested with aphids approximately 7 days before assessment. DAS = days after sowing. Values in parenthesis are the numbers on treated plants as a percentage of those on untreated plants of same type.

	Brevicoryne brassicae		**Myzus persicae**	
Treatment	**02-Aug (68 DAS)**	**12-Sep (109 DAS)**	**09-Aug (75 DAS)**	**28-Sep (125 DAS)**
Exp B cabbage cv Lennox	10.80	3.80 (13%)	36.00	0.80 (400%)
Untreated cabbage cv Lennox	48.00	28.20	26.50	0.20
Exp S Savoy cabbage cv Alaska	0.00 (0%)	5.80 (23%)	42.50 (70%)	36.20 (86%)
Untreated Savoy cabbage cv Alaska	30.20	24.80	61.00	42.20
Exp S cauliflower cv. Tetris	1.50 (2%)	38.20 (46%)	69.80 (63%)	100.80 (87%)
Untreated cauliflower cv. Tetris	67.20	83.80	111.00	116.50
Gaucho cabbage cv Petrosa	2.00 (2%)	9.00 (68%)	2.50 (5%)	0.80 (11%)
Untreated cabbage cv Petrosa	118.80	13.20	46.80	7.20
F-prob; 18 df	<0.001	0.002	<0.001	<0.001
SED	17.81	16.06	16.8	23.16
LSD (95%)	37.43	33.75	35.3	48.67

In the lettuce seed treatment experiment, Gaucho and Exp B provided effective control 62 days after sowing but their effectiveness had declined after 89 days (Table 13).

Table11. The mean numbers of *N. ribisnigri* on lettuce plants grown from seed treated with insecticide. The plants were sown on 26 May and the plots planted on 26 June. Plants were infested with aphids approximately 7 days before assessment. DAS = days after sowing. Values in parenthesis are the

numbers on treated plants as a percentage of those on untreated plants of same type.

Treatment	27 Jul 62 DAS	23 Aug 89 DAS
Exp B cv Invierno de Mallorca and Brest	1.8 (3%)	24.3 (65%)
Gaucho cv Invierno de Mallorca and Brest	0.8 (2%)	18.4 (50%)
Untreated cv Invierno de Mallorca and Brest	35.8	37.1
Exp S cv Challenge	2.9 (26%)	12.5 (60%)
Untreated cv Challenge	11.0	20.8
F-prob	<0.001	0.638
SED	3.53	15.98
LSD (95%)	8.15	36.84
df	8	8

DISCUSSION

Insecticide resistance

Recent information on the insecticide resistance status of *M. persicae* (S. Foster, personal communication) indicates that all three mechanisms of resistance (carboxylesterase, kdr, MACE) have persisted in field populations and that MACE resistance is relatively prevalent in areas such as south Lincolnshire, where brassicas and other host crops are grown intensively. Where insecticides were applied to control either insecticide-resistant or insecticide-susceptible clones in this project, pirimicarb (Aphox) was ineffective against aphids with the MACE resistance mechanism and pyrethroid insecticides were ineffective against aphids with kdr resistance.

To date there is no evidence of pronounced resistance in M. persicae to neonicotinoid insecticides such as imidacloprid, thiacloprid, acetamiprid and clothianidin (S. Foster, personal communication). However, the increasing use of neonicotinoids on a wider range of crops would indicate that the selection pressures are increasing. The experiments within this project and in other studies (HDC Project FV 208) show that neonicotinoid insecticides are particularly effective against the pest aphids of brassicas and that the effects of the Gaucho seed treatment often persist throughout the life of the crop. Thus, it is important to 'protect' these valuable treatments as much as possible by managing the selection pressure for resistance. However, M. persicae is frequently a less damaging pest of brassica crops than B. brassicae and neonicotinoids have an important role to play in the control of the latter, particularly on long season crops such as Brussels sprout where it is difficult to sustain good levels of control.

When this project began in 2004, insecticide resistance to pirimicarb in N. ribisnigri was considered to be widespread, but levels varied. In addition, between 1999 and 2001 the levels of resistance to pyrethroids appeared to have increased in some strains of N. ribisnigri in the UK and resistant aphids commonly showed cross-resistance to a range of pyrethroid compounds. One of the aims of this project was to monitor levels of insecticide resistance in field populations to determine whether insecticide resistant individuals were becoming increasingly common. Most of the N. ribisnigri samples were sent to Rothamsted Research because of control failure and so it was anticipated that some of these aphids might be resistant. However, there was no strong evidence that there has been a shift towards greater resistance or that the samples of N. ribisnigri had high frequencies of resistance to any of the insecticides tested.

An SA-LINK project (LK0953) is currently addressing concerns over the risks posed by increased use and diversification of neonicotinoids available for aphid control in the UK. Although no resistance of practical significance has been detected in any aphid species so far, the intensity of selection now being exerted requires constant vigilance and concerted action by representatives of all the crops being treated with neonicotinoids against M. persicae. Growers of brassica crops and their representatives have an important role to play in this respect.

Insecticide efficacy and novel insecticides

The products containing the active ingredients primicarb, pirimicarb + lambda-cyahlothrin, pymetrozine and imidacloprid were all approved for the control of aphids on brassica and lettuce crops when this project started and since then, the neonicotinoid thiacloprid (Biscaya) has also been approved for use as a foliar spray on some brassica crops. Biscaya was evaluated as a coded product (Exp U) in years 2004 and 2005 of this project. The decision was made to apply it with a wetter (Phase II) in experiments in 2005 and 2006, because this approach had been shown previously to improve the performance of Plenum. Similarly, Gazelle (acetamiprid), another neonicotinoid, has been approved (SOLA) for use on lettuce and this was evaluated (Exp H in 2004). Of the other coded products tested, Exp C is a neonicotinoid, whilst Exp A, Exp E, Exp U2 and Exp D have novel modes of action.

The performance of all insecticide spray treatments varied between occasions and in the case of N. ribisnigri, this could sometimes be related to crop age, as aphids became relatively inaccessible to insecticides as the lettuce plants formed hearts. This project confirms the difficulties associated with the control of N. ribisnigri on maturing lettuce crops and the approval of insecticides with systemic activity would be likely to improve control.

On occasions, aphid numbers were lower on insecticide-free control plots than on plots treated with insecticide and this was sometimes associated with relatively high aphid numbers on plants that had been treated with pyrethroids. This implies that natural enemies may have been particularly effective, but had been killed by the application of a broad-spectrum insecticide. Although application of a pyrethroid insecticide treatment is unlikely to be recommended for aphid control on lettuce or brassica crops, pyrethroids are applied to control caterpillars and this highlights the importance of considering all pests as part of the control strategy, as insecticides applied to control one pest may actually exacerbate problems with another.

All of the novel seed treatments evaluated in the project contained neonicotinoids and some of these treatments appeared to have persistence and efficacy comparable with Gaucho. At least one of these seed treatments may become available commercially in the future.

In the final year of the project, some comparisons were made between wetters. A comparison was made of the use of either Gateway or Phase II with Biscaya applications to Savoy cabbage and there was no apparent difference between wetter treatments. Most wetters are phytotoxic to lettuce. However, a comparison was made of the application of Plenum with or without wetter (Breakthru). Although the addition of Breakthru appeared to improve control of N. ribisnigri, this was not a statistically significant difference.

Aphid phenology and treatment timing

This project focused on the phenology of B. brassicae because it provided an opportunity to use data sets held by the Rothamsted Insect Survey and Warwick HRI to undertake the type of analysis that has been done already for M. persicae, and which forms the basis of the forecasts provided to sugar beet growers. The first step was to determine whether the timing of the first flight of winged B. brassicae into new season brassica crops was related to environmental conditions during the previous winter and spring, as well as to latitude and longitude. Such a relationship has now been confirmed and can be used to provide a 'long-range' forecast each year. In essence, B. brassicae flies later at sites with a higher latitude or lower longitude. Higher temperatures in December, January, February and May also lead to an earlier first flight.

It is now well known that, in most years, populations of the pest aphids of brassica and lettuce crops 'crash' mid-season. The reasons for this dramatic fall in numbers are still unclear, but are likely to include the effects of natural enemies (predators, parasitoids, fungal disease). Since the crash occurs at the same time of year on crops of all ages (most brassica and lettuce crops are planted sequentially to provide continuity of supply) it is unlikely to be related to plant age. Examination of the Insect Survey data showed that the 'crash' is often evident from suction trap records and comparison of suction trap data with crop monitoring data for Kirton in Lincolnshire showed that suction trap catches and counts of winged aphids on plants show a similar pattern. There was also an indication that suction trap captures may provide an 'early warning' of the arrival of winged B. brassicae in crops.

Of greatest interest was the finding that the timing of the peak in B. brassicae numbers (prior to the mid-summer crash) appeared to be explained reasonably well by winter (Jan-Feb) and late spring (May) temperatures and latitude and as for first flight, the crash occurred earlier at lower latitudes and when temperatures in January, February and May were higher. This relationship is of interest because it implies that the timing of the mid-season crash is predictable from physical conditions, although it provides no further information on the mechanisms involved. There appeared to be no consistent relationships between these variables and the abundance of B. brassicae.

Conclusions

- All three mechanisms of insecticide resistance in Myzus persicae (carboxylesterase, kdr, MACE) have persisted in field populations and MACE resistance was relatively prevalent in areas such as south Lincolnshire, where brassicas and other host crops are grown intensively.
- Where insecticides were applied to control either insecticide-resistant or insecticide-susceptible clones of M. persicae in this project, pirimicarb (Aphox) was ineffective against aphids with the MACE resistance mechanism and pyrethroid insecticides were ineffective against aphids with kdr resistance
- There was no strong evidence that populations of N. ribisnigri had high levels of resistance to any of the insecticides tested.
- The performance of all insecticide spray treatments varied between occasions and in the case of N. ribisnigri, this could sometimes be related to crop age, as aphids became relatively inaccessible to insecticides when the lettuce plants formed hearts.
- The project confirms the difficulties associated with the control of N. ribisnigri on maturing lettuce crops and the approval of insecticides with systemic activity would be likely to improve control.
- On occasions, aphid numbers were lower on insecticide-free control plots than on plots treated with insecticide and this was sometimes associated with relatively high aphid numbers on plants that had been treated with pyrethroids. This implies that natural enemies may have been particularly effective, but had been killed by the application of a broad-spectrum insecticide. Although application of a pyrethroid insecticide treatment is unlikely to be recommended for aphid control on lettuce or brassica crops, pyrethroids are applied to control caterpillars and this highlights the importance of considering all pests as part of the control strategy, as insecticides applied to control one pest may actually exacerbate problems with another.
- All of the novel seed treatments evaluated in the project contained neonicotinoids and some of these treatments appeared to have persistence and efficacy comparable with Gaucho.

- A comparison was made of the use of either Gateway or Phase II with Biscaya applications to Savoy cabbage and there was no apparent difference between wetter treatments.
- A comparison was made of the application of Plenum with or without the wetter, Breakthru. Although the addition of Breakthru appeared to improve control of N. ribisnigri, this was not a statistically significant difference.
- The first flight of Brevicoryne brassicae occurs later at sites with a higher latitude or lower longitude. Higher temperatures in December, January, February and May also lead to an earlier first flight.
- Examination of the Rothamsted Insect Survey data showed that the mid season ‘crash’ in B. brassicae populations is often evident from suction trap records and comparison of suction trap data with crop monitoring data for Kirton in Lincolnshire showed that suction trap catches and counts of winged aphids on plants follow a similar pattern.
- There was an indication that suction trap captures may provide an ‘early warning’ of the arrival of winged B. brassicae in crops.
- The timing of the peak in B. brassicae numbers (prior to the mid-summer crash) appeared to be explained reasonably well by winter (Jan-Feb) and late spring (May) temperatures and latitude and as for first flight, the crash occurred earlier at lower latitudes and when temperatures in January, February and May were higher. There appeared to be no consistent relationships between these variables and the abundance of B. brassicae.

Future research

- There is a continuing need to evaluate new insecticides and other novel treatments for their efficacy against the pest aphids of brassica and lettuce crops.
- It is also important to continue to monitor the resistance status of the pest aphids of these crops, including Macrosiphum euphorbiae. At the moment it is particularly vital to monitor populations of M. persicae for resistance to neonicotinoid insecticides, since their use is increasing and diversifying into foliar applications.
- There is still a need for a greater understanding of the population dynamics of the pest aphids of brassica and salad crops, in order to target treatments and to avoid treatments when they are unnecessary. This includes an understanding of the causes of the mid-summer crash in aphid numbers and of the effectiveness of key natural enemies.
- Although the application of biopesticides containing entomopathogenic fungi did not appear promising in this project, it was not possible to optimise application strategies due to limited resources. A further study might indicate application techniques and timings that increased their efficacy.

- Identification of further sources of pest resistance in host plants (resistance to N. ribisnigri is available in commercial varieties), which could be bred into new varieties, would reduce the need for insecticidal control.

Acknowledgements

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Knowledge Transfer

Presentations	
14 Jan 2004	Brassica Growers Association Conference
28 Jan 2004	HDC/Defra aphid meeting
03 Feb 2004	HDC Roadshow Scotland
17 Feb 2004	HDC Roadshow Kent
10 Mar 2004	HDC Roadshow Lancashire
17 Mar 2004	HDC Roadshow Cornwall
08 Jun 2004	Brassica Pest Workshop at Warwick HRI Kirton
13 Jul 2004	Leafy salads meeting STC
22 Jul 2004	HRIA Growers Walk, Wellesbourne
07 Dec 2004	Lancashire growers meeting
09 Feb 2005	HDC Roadshow Yorkshire
16 Mar 2005	Syngenta Brassica meeting, Boston
21 Mar 2005	VTS training brassica and salad pests, Kirton
17 Aug 2005	Gardeners & Growers Walk, Wellesbourne
11 Jan 2006	Brassica Growers Association Conference
23 Jan 2006	Syngenta training
30 Jan 2006	Syngenta growers meeting, Boston
1 Feb 2006	Syngenta growers meeting, Evesham
9 Mar 2006	Syngenta growers meeting, Lancashire
28 Jun 2006	HDC Grower Event
18 Jan 2007	Industry workshop on lettuce aphid biology and control
6 Mar 2007	Seminar – aphid control in brassica crops

Publications and posters

Prince, G., Chandler, D., Collier, R. (2005). Fungal control of aphids in lettuce and brassica crops. Poster presentation at the Royal Entomological Society's Aphid Special Interest Group Meeting, London, UK, 6 July 2005.

Prince, G., Chandler, D., Collier, R. (2005). Fungal control of aphids in lettuce and brassica crops. Proceedings of the British Mycological Society Conference "Exploitation of fungi", Manchester, UK, 5-8 September 2005.

Regular updates on the project have been given every 6 months at meetings of the UK Insecticide Resistance Action Group.

The resistance status of M. persicae captured in key suction traps run by the Rothamsted Insect Survey was posted on the HDC Pest bulletin web pages in 2005 and 2006.

References to published material

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