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Alternative insecticides to control grain aphids, *Sitobion avenae*, that are resistant to pyrethroids

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CONTENTS

1. Abstract

Cereal aphids, *Sitobion avenae*, have developed resistance to pyrethroids in the last few years, culminating in control failure at some locations in England 2011 and 2012, associated in the latter year with local epidemics of barley yellow dwarf virus (BYDV). Studies by Rothamsted Research and Syngenta have shown this to be due to target site resistance, which can be detected in populations by using a vial bioassay test, and in individual aphids using a DNA diagnostic test. Approximately 35-50% of *S. avenae* tested in the UK in 2012 and 2013 contained genes that confer resistance to pyrethroids, confirming other studies on this species caught in Rothamsted Insect Survey suction traps in those years.

Field trials in autumn 2012 in which plots were inoculated with a clone of *S. avenae* that was resistant to pyrethroids showed that cypermethrin at 25 g a.i./ha and deltamethrin at 7.5 g a.i./ha gave significantly poorer control than chlorpyrifos at 450 g a.i./ha, but not lambda-cyhalothrin at 7.5 g a.i./ha. There were no differences between these products when used against susceptible clones of either *S. avenae* or the bird cherry–oat aphid*, Rhopalosiphum padi.* The rate of lambda-cyhalothrin used was higher than the recommended rate, which might explain why it gave better control.

In two larger field trials to test alternative products against the resistant clone of *S. avenae*, and the consequent spread of BYDV, the carbamate, pirimicarb at 120 g a.i./ha gave moderate control at one site, but good control at another; the neonicotioid, thiacloprid at 72 g a.i./ha gave good control at both sites, while acetamiprid at 50 g a.i./ha was relatively poor. Pymetrozine at 100 g a.i./ha plus adjuvant oil gave good control at the one site it was tested. Chlorpyrifos at 450 g a.i./ha gave best control at both sites.

Secondary spread of BYDV was low in untreated plots at both sites (<2%) in the winter of 2012-13, due to very low temperatures after spray applications, which prevented further primary colonisation by ‘wild’ aphids, and multiplication of those that survived the treatments. However, significant reductions in virus infections were still recorded the following spring, although not enough to affect yield at harvest. There were no significant differences between treatments at either site, but their comparative performance did reflect their efficacy against aphids.

None of the alternatives mentioned above are currently approved for use against aphids in cereals in the autumn, but these results will give regulators some evidence for their activity against resistant grain aphids, should alternatives be required.

2. Introduction

Control of the grain aphid, *Sitobion avenae* has relied heavily upon the use of pyrethroids in recent years, largely because they are cheap, and readily mixable with fungicides in disease control programmes. As a consequence, the majority of cereals are treated every year in the autumn to control aphids carrying barley yellow dwarf virus, often as an insurance, and sometimes twice a year when cereals are also treated with pyrethroids in the summer to control grain aphids or blossom midges. The most recent Defra survey done on pesticide use in the UK showed that 71% of winter barley and 76% of wheat crops were treated with one of five pyrethroids in 2012, although no distinction was made between summer and autumn use (Table 1; Garthwaite *et al*., 2013), and this was largely unchanged since the previous survey in 2010 (Garthwaite *et al*., 2011).

Table 1. Proportion of cereals (% of census area) treated with pyrethroids in the UK in 2012 mostly to control aphids (Garthwaite *et al*., 2013)

Insecticide AI	Winter barley	Spring barley	Wheat
Cypermethrin	31	4	33
Lambda-cyhalothrin	19	6	24
Esvenvalerate	10	3	8
Alpha-cypermethrin	6	-	5
Zeta-cypermethrin	5	2	6
Total	**71**	**15**	**76**

Not surprisingly, this usage has resulted in selection for resistant *S. avenae*. This resistance was first described in 2012 (Foster *et al*., 2013), but they have since been recorded in many sites across the UK following a survey conducted by Dewar Crop Protection Ltd. funded by Syngenta UK Ltd., backed up by further tests using a DNA-based diagnostic assay developed at Rothamsted (Williamson & Foster, In Preparation). In 2012, of 17 samples collected from East Anglia, and tested using a vial test, which requires live aphids, 35% of the samples collected were classified as resistant, after less than 60% of the individuals in vial tests died at a discriminatory dose of insecticide (Table 2). In 2013, 38% of sixteen samples tested in vials were classed as resistant; of these and a further 14 that were collected that year, but tested only using the DNA assay, 50% contained some individuals that carried the *kdr* mutation conferring resistance to pyrethroids. These results correlate well with similar testing of dead *S. avenae* caught in Rothamsted Insect Survey suction traps operating in the same areas, namely the Broom's Barn, Rothamsted and Kirton traps in east and central England (Williamson & Foster, In Preparation).

Table 2. Resistance status of *S. avenae* collected from cereals in the UK in 2012 and 2013

Year	Test method			
	Insecticide-coated vials		DNA-based assay	
	No of samples	% resistant (mortality <60%)	No of samples	% resistant (>50% heterozygotes)
2012	17	35	20	80*
2013	16	38	30	50

- In 17 of these samples tests were done on survivors of the vial test, hence the higher percentage

Thus, resistance has now become a feature of cereal aphid control, but perhaps has not been seen on a catastrophic scale yet because summer epidemics of aphids are relatively rare these days compared to the 1970's, due to the activities of aphid predators. However, there is some circumstantial evidence that the mini-epidemic of BYDV seen in England in the spring of 2012, following a mild winter that would have allowed overwintering aphids to survive quite well, may have been exacerbated by resistant *S. avenae* that survived the traditional autumn sprays of pyrethroids used to control another aphid species, the bird cherry–oat aphid, *Rhopalosiphum padi,* which is regarded as the main vector of BYDV. Many of the samples collected in 2012 came from heavily infected fields.

In response to this situation, experiments were set up to investigate the efficacy of three commonly used pyrethroids against resistant *S. avenae* in winter sown cereals, and to test alternative insecticides that might be useful for controlling them if they become a serious problem in the future.

3. Materials and methods

3.1 Comparison of aphid clones

Two clones of *S. avenae,* one susceptible to insecticides (SS, homozygous susceptible), and one containing a single copy of the kdr gene (i.e. it was heterozygous for the *kdr* mutation- SR), were inoculated into plots of winter barley, cv Cassia, not treated with an insecticidal seed treatment, sown on 21 September 2012 at Brooms Barn Research Centre in Suffolk. These were compared to a clone of susceptible *R. padi.* Each 2 x 6 m plot was inoculated with each of the three clones in a randomised position down the centres of the plot. Inoculation was achieved by placing a tiller of barley infested with 50-100 aphids along a short length of marked row in which at least 8 plants were present. As the tiller dried up, aphids moved from these tillers onto the young seedlings. Treatments were applied on 5 November using a Trials Equipment 'Lunchbox' sprayer with a 2 m offset boom sprayer delivering 200 L/ha through Teejet flat fan nozzles.

3.2 Alternatives to pyrethroids

In two larger trials only the resistant clone of *S. avenae* was used for inoculation. Trials were carried out at two sites, one in the same field at Broom's Barn as the clone trial, and the other at Stetchworth Estates, Cambridgeshire (sown on 29 September), using the same batch of winter barley seed. In these trials there were 6 inoculation points in each plot, 3 m from either end and one in the centre, 1 m in from each side – i.e. two rows of three inoculation points.

In these two trials the inoculation points were inoculated with a small number (5-10) of *R. padi* to initiate the BYDV infection, mimicking what is the likely BYDV epidemiological pathway in the wild in the UK (Plumb, 1995), and then inoculated a second time with larger numbers (50-100) of *S. avenae* 5-7 days later. The latter species was not carrying BYDV when the inoculation took place, and so any spread from the initial foci of infection would have been due to these and subsequently colonising migrant aphids surviving the sprays, and picking up virus from already-infected plants once the latent period has passed. The latent period for BYDV is about two weeks between infection and availability of virus for acquisition (Plumb, 1995).

Insecticides were applied as before, but two passes were made with the sprayer, one up each side of the plot, treating half the plot with each pass. Plots at Broom's Barn were infested on 17 October at GS13 and sprayed on 20 October; plots at Stetchworth were infested on 19 October at GS12 and sprayed on 23 October. Details of applications are shown in Table 2.

3.3 Treatments

In the clone trial, three pyrethroids, lambda-cyhalothrin (Hallmark Zeon from Syngenta), cypermethrin (Toppel 10 from United Phosphorus Ltd) and deltamethrin (Decis Protech from Bayer CropScience) were compared with the organophosphate product, chlorpyrifos (Dursban WG from Dow AgroSciences). In the efficacy trials comparing alternatives to pyrethroids, seven treatments including an untreated control were tested at Broom's Barn, but an additional treatment was included at Stetchworth that had not been made available when the trial at Broom's Barn was sprayed. Treatments included lambda-cyhalothrin and cypermethrin, the carbamate, pirimicarb (Aphox from Syngenta), chlorpyrifos, two neonicotinoids, thiacloprid (Biscaya from Bayer CropScience) and acetamiprid (InSyst from Certis), and, at Stetchworth only, pymetrozine (Plenum from Syngenta). Rates of application are shown in Table 3. The rate used for cypermethrin was that recommended for oilseed rape in autumn, rather than that recommended for cereals (50 ml/ha). The other rates were those recommended for those crops against other pests, or if not approved for barley, a rate already used in other crops. Adjuvant oil was used with pymetrozine.

3.4 Assessments

3.4.1 Aphid counts

In all three trials, aphids were counted on 8 plants at each inoculation point, on three occasions 3, 6-8 and 13-15 days after sprays were applied. Thus 48 plants per plot were examined in the two larger trials.

3.4.2 Virus assessments

BYDV assessments were done in May the following year when symptoms became visible. This was much later than normal due to the relatively cold winter experienced in 2012/13. The actual area visually infected was assessed using a 1 m square quadrat. This area was then converted to % infection within the net plot (3 x 10 m), which was designated to take account of overlapping potential at each end and both sides of the plots due to drift at the time of application, and an allowance for pathways between plots.

3.4.3 Yield

Yield at harvest was measured using small plot harvesters. At Broom's Barn, this was done by NRM Efficacy on 22 July using a 'Claas Compact 25' small plot combine harvester. The grain from a cut of 2.3 x 10m per plot was weighed using a 'Salter 125' electronic scale on the harvester. Grain samples from each plot were tested for moisture content and hectolitre weight using a 'Sinar^{TM} AP 6060 Moisture Analyser'. At Stetchworth, harvesting was done by Suffolk and Cambridge Crop Station (SACCS) using a Deutz M660 cutting a swathe of 2.1 m by 10 m.

3.5 Data analyses

Data were analysed by analysis of variance using Genstat 15. Aphid numbers were transformed (log N+1) prior to analysis. Virus infection data were transformed using square roots before analysis.

Table 1a. Basal treatments applied to trial field at Broom's Barn in 2012/13

Date	Operation/application
7/9/12	Sprayed Glyphosate @ 3l/ha in 100l
19/9/12	Ploughed + pressed N-S @ 20cm
20/9/12	Seedbed Former @ 4cm
21/9/12	Drilled cv Cassia 160kg/ha
25/10/12	Sprayed Liberator @ 0.3l + PDM 330 @ 2l/ha in 100l
21/02/13	Spread Multisulph fertiliser @ 60kg N and 80kg SO^3 /ha
09/04/13	Spread N top dressing @ 100kg N/ha
20/04/13	Sprayed Manganese @ 2.11 l/ha + 3C Chlormequat @ 1.25 l/ha + Moddus @ 0.1 l/ha + Siltra Xpro @ 0.6 l/ha + Ally Max @ 14.82 g/ha in 100 l of water
25/04/13	Spread fertiliser: top dressing @ 40 kg N/ha
30/04/13	Sprayed Axial @ 0.3 l/ha + Adigor @ 0.6 l/ha in 100 l of water
21/05/13	Sprayed Siltra Xpro @ 0.66 l/ha + Vivid @ 0.106 l/ha + Terpal @ 0.33 l/ha in 100 l of water

Table 1b. Basal treatments applied to trial field at Stetchworth in 2012/13

Table 2. Details of spray applications to large field trials in winter barley in autumn 2012.

Site	Broom's Barn	Stetchworth
Date	20 October	23 October
Growth stage	13-21	11-12
Operators(s)	AMD	AMD/AJGD
Start time	2.40 pm	3.20 pm
Finish Time	4.20 pm	4.30 pm
Plot size	4 x 12 m	4 x 10 m
Weather details		
Temperature (^oC)	14.1	13.6
Wind speed (m/s)	0.8	0.5
Wind direction	W	N
Relative humidity (%)	91	89
Cloud cover (%)	100	100
Field details		
Surface moisture	Moist	Wet
Tilth	Fine	Fine
Temperature at 10 cm. (^oC)	15	15
Tillage	Ploughed	Ploughed
Foliage moisture	Droplets	Yes
Comments	Fine afternoon	Misty afternoon

Table 3. Rates of application of insecticides in aphid trials in winter barley in 2012

Active ingredient	Brand name	Formulation	g/a.i.ha	Product/ha
Lambda-cyhalothrin	Hallmark Zeon	100 g/L CS	7.5	75 ml
Cypermethrin	Toppel 10	100 g/L EC	25	250 ml
Pirimicarb	Aphox	50% WG	120	240 g
Chlorpyrifos	Dursban WG	75% WG	450	600 g
Thiacloprid	Biscya	240 g/L OD	72	300 ml
Acetamiprid	Insyst	20% SP	50	250 g
Pymetrozine	Plenum	50% WG	100	200 g
Adjuvant oil (0.75%)	Toil			1.5 L

4. Results

4.1 Comparison of aphid clones

All treatments reduced aphid numbers substantially in each clone 3 days after spraying, but this was surprisingly not significant. However, 8 days after application, all treatments gave significant reductions compared to untreated (Table 4; Fig. 1). In the susceptible clone of *S. avenae* control was over 85% three days after sprays were applied, rising to over 95% 8 days after application, with no significant differences between treatments. Similar results were observed with the susceptible clone of *R. padi*, although deltamethrin gave slightly poorer control at the first assessment. However, with resistant *S. avenae*, control by cypermethrin was significantly poorer than lambda-cyhalothrin and chlorpyrifos eight days after application; the performance of deltamethrin was intermediate between these treatments. Maximum control by cypermethrin was 75% compared with 98% for chlorpyrifos.

4.2 Effect of alternative treatments

4.2.1 Efficacy of treatments against aphids

4.2.1.1 Broom's Barn

The number of aphids per plant in untreated plots was 1.6 per plant three days after application of sprays with 66% of the counted plants infested; these were 99% *S. avenae* - only four *R. padi* were recorded across the whole trial. Numbers were similar seven days after application of treatments, but declined sharply to 0.7 per plant (31% infestation) by 2 November, 13 days after application, due to the occurrence of ground frosts.

All treatments significantly reduced aphid numbers, but best control three days after application (98%), and throughout the sampling period, was given by chlorpyrifos (Table 5; Fig. 2). Pirimicarb, lambda-cyhalothrin and thiacloprid gave next best control, although these were significantly poorer than chlorpyrifos three days after application. However, cypermethrin and acetamiprid gave relatively poor control throughout the assessment period. Indeed, there was no significant control by cypermethrin compared to untreated 13 days after application.

4.2.1.1 Stetchworth

The number of aphids at Stetchworth on 26 October was one per plant three days after application (44% infestation); this declined to 0.6 per plant after 7 days (32% infestation), and only 0.2 per plant after 13 days (19% infestation). All aphids recorded were *S. avenae;* no *R. padi* were seen at this site. Although these populations were smaller than at Broom’s Barn, they still represented a much higher population than is normally recorded in uninoculated winter cereals in the Eastern region, even in a warm autumn.

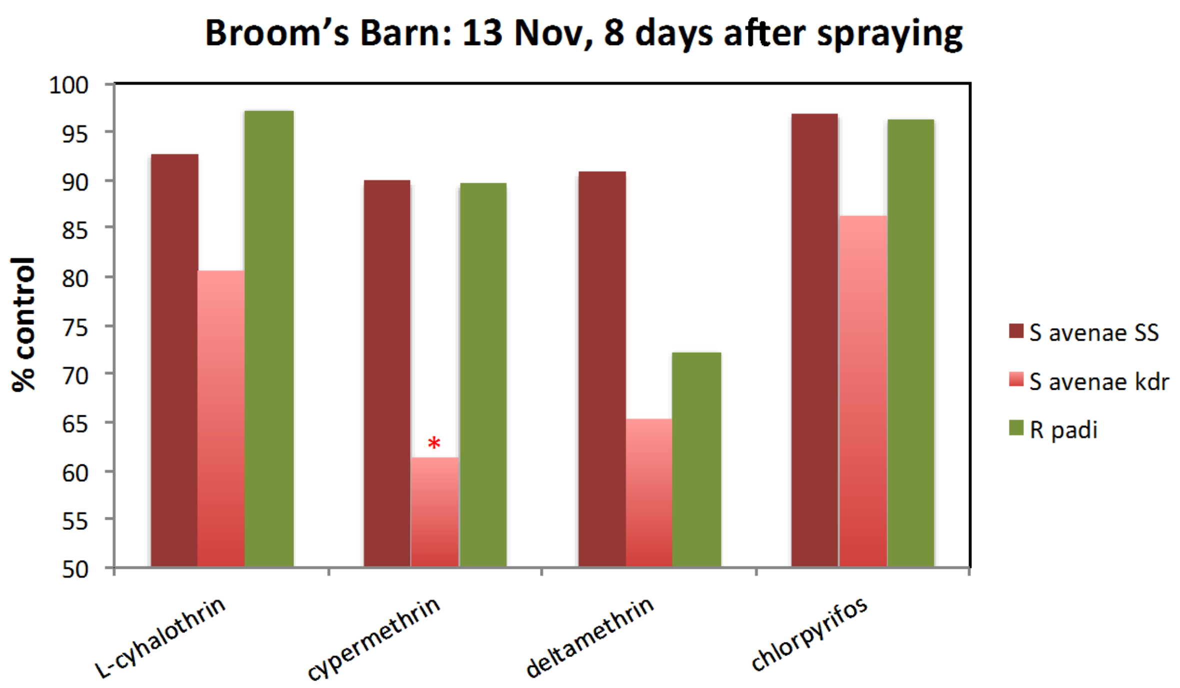
Again all treatments significantly reduced aphid numbers three and eight days after application, but 15 days after application numbers in cypermethrin-treated plots were not significantly lower than in untreated (Table 6; Fig. 3). Best control was again consistently given by chlorpyrifos throughout the assessment period (91-100% control), but in this site it was not significantly better than pirimicarb (90-97% control), lambda-cyhalothrin (68-95% control), acetamiprid (74-92% control) or pymetrozine (72-100 % control); it was significantly better than cypermethrin. The performance of both acetamiprid and pymetrozine improved as the trial progressed.

Table 4. Effect of pyrethroids on the number of aphids per plant of susceptible and resistant *Sitobion avenae,* and susceptible *Rhopalosiphum padi.* on winter barley

Treatment	rate a.i./ha	3 DAA			8 DAA			14 DAA		
		Log (n+1)	Back-trans	% control	Log (n+1)	Back-trans	% control	Log (n+1)	Back-trans	% control
S. avenae susceptible										
Untreated	-	0.650	3.47		0.487	2.07		0.474	1.98	
L-cyhalothrin	7.5	0.132	0.4	90	0.030	0.1	97	0.000	0.0	100
Cypermethrin	25	0.182	0.5	85	0.021	0.1	98	0.000	0.0	100
Deltamethrin	7.5	0.150	0.4	88	0.039	0.1	96	0.000	0.0	100
Chlorpyrifos	450	0.067	0.2	95	0.042	0.1	95	0.021	0.1	97
S. avenae resistant										
Untreated	-	0.595	2.94		0.484	2.05		0.371	1.35	
L-cyhalothrin	7.5	0.199	0.6	80	0.032	0.1	96	0.041	0.1	93
Cypermethrin	25	0.303	1.0	66	0.206	0.6	70	0.127	0.3	75
Deltamethrin	7.5	0.306	1.0	65	0.131	0.4	83	0.076	0.2	86
Chlorpyrifos	450	0.141	0.4	87	0.021	0.1	98	0.011	0.0	98
R. padi susceptible										
Untreated	-	0.852	6.12		0.782	5.05		0.507	2.22	
L-cyhalothrin	7.5	0.070	0.2	97	0.030	0.1	99	0.000	0.0	100
Cypermethrin	25	0.222	0.7	89	0.087	0.2	96	0.011	0.0	99
Deltamethrin	7.5	0.406	1.5	75	0.019	0.0	99	0.000	0.0	100
Chlorpyrifos	450	0.096	0.2	96	0.051	0.1	98	0.011	0.0	99
F Pr.		0.458			0.018			0.288		
Significance		NS			*			NS		
SED (68 d.f.)		0.116			0.081			0.077		
LSD (5%)		0.233			0.162			0.154		

DAA = days after application

Fig.1 Efficacy of pyrethroids against cereal aphids



* Significantly less than chlorpyrifos at P<0.05

Table 5. Effect of insecticides on resistant grain aphids, *Sitobion avenae* on winter barley: Broom's Barn 2012

Treatment	Rate prod g or ml/ha	Aphids per plant											
		23 Oct: 3 DAS				26 Oct: 6 DAS				2 Nov: 13 DAS			
		Log 10 (n+1)	Back-trans	% control	% infested	Log 10 (n+1)	Back-trans	% control	% infested	Log 10 (n+1)	Back-trans	% control	% infested
Untreated		0.415 a	1.60	0	66.2 a	0.412 a	1.58	0	62.5 a	0.230 a	0.70	0	31.3 a
Pirimicarb	240	0.104 c	0.27	83	20.8 c	0.156 bc	0.43	73	22.4 c	0.041 c	0.10	86	6.3 c
L-cyhalothrin	75	0.117 c	0.31	81	21.4 c	0.093 cd	0.24	85	19.3 c	0.019 c	0.04	94	3.7 c
Cypermethrin	250	0.224 b	0.67	58	39.1 bc	0.262 b	0.83	48	47.4 b	0.164 b	0.46	34	27.6 ab
Chlorpyrifos	600	0.017 d	0.04	98	3.1 d	0.004 d	0.01	99	0.5 d	0.000 c	0.00	100	0.0 c
Thiacloprid	300	0.123 c	0.33	80	23.4 c	0.149 bc	0.41	74	22.9 c	0.041 c	0.10	86	7.3 c
Acetamiprid	250	0.244 b	0.76	53	43.7 b	0.202 bc	0.59	62	33.9 bc	0.136 b	0.37	47	21.9 b
Probability & significance		< 0.001 ***			< 0.001 ***	< 0.001 ***			< 0.001 ***	< 0.001 ***			< 0.001 ***
SED (21 df)		0.034			6.668	0.063			8.975	0.030			4.768
LSD (95%)		0.072			13.87	0.131			18.67	0.062			9.92
CV%		30.8			33.9	53.1			46.3	52.52			54.2

* data followed by different letters is significantly different @ P<0.05

Fig. 2 Efficacy of aphicides against grain aphids, *S. avenae,* in winter barley

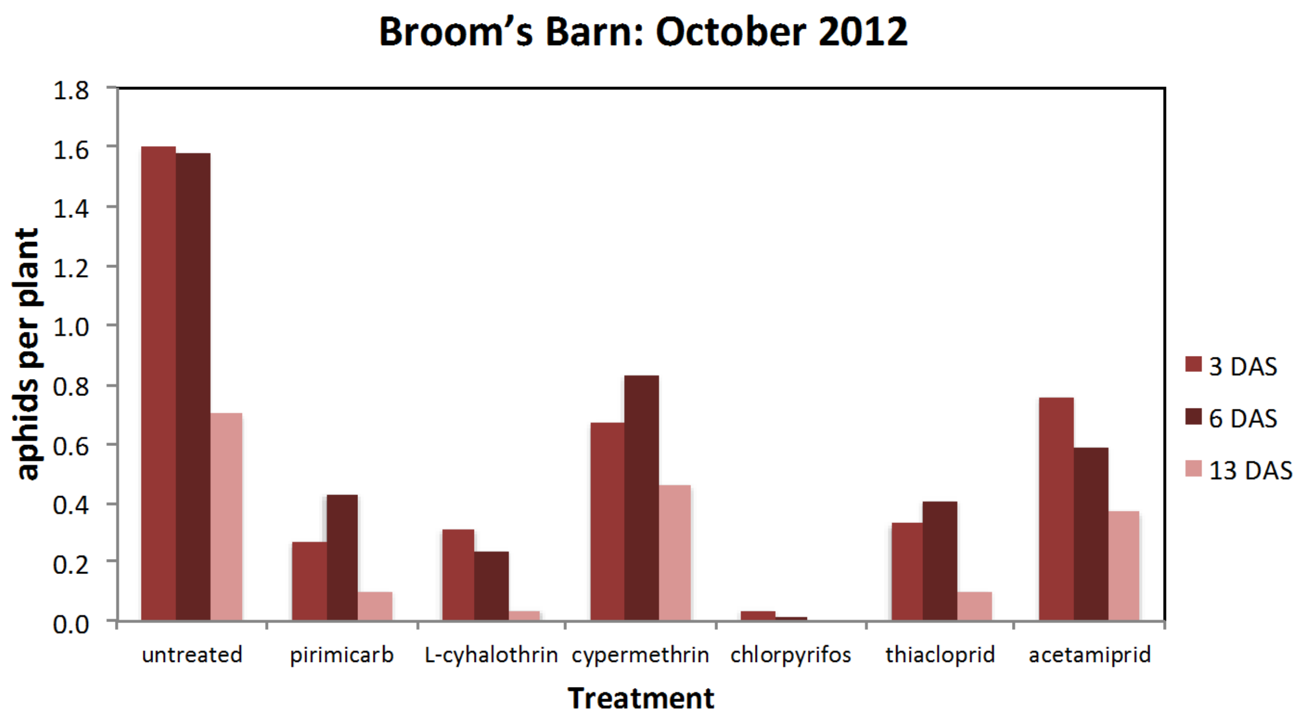
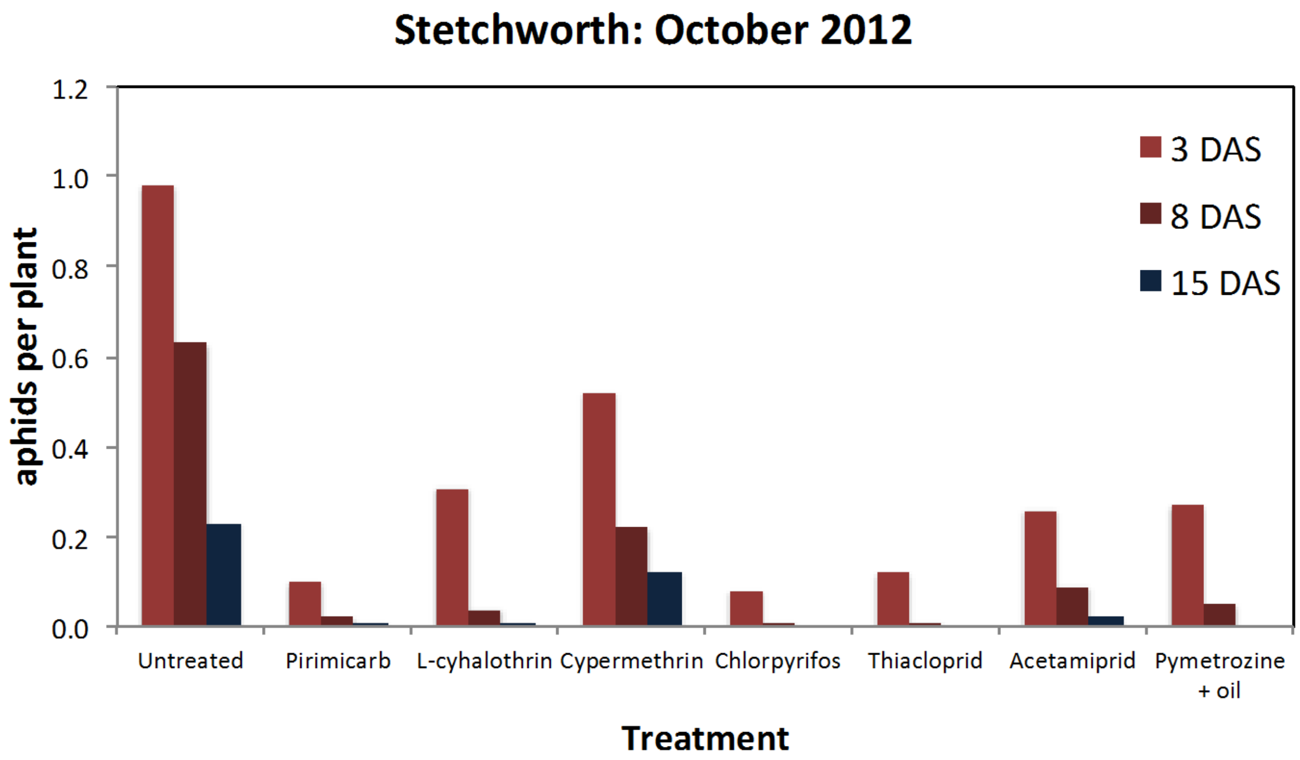


Table 6. Effect of insecticides on resistant grain aphids, *Sitobion avenae* on winter barley: Stetchworth 2012

Treatment	Rate prod g or ml/ha	Aphids per plant											
		26 Oct: 3 DAS				31 Oct: 8 DAS				7 Nov: 15 DAS			
		Log 10 (n+1)	Back-trans	% control	% infested	Log 10 (n+1)	Back-trans	% control	% infested	Log 10 (n+1)	Back-trans	% control	% infested
Untreated		0.297 a	0.98	0	44.3 a	0.213 a	0.63	0	31.8 a	0.090 a	0.23	0	18.8 a
Pirimicarb	240	0.040 c	0.10	90	7.8 c	0.008 bc	0.02	97	1.6 c	0.005 c	0.01	95	1.1 bc
L-cyhalothrin	75	0.117 bc	0.31	68	15.7 c	0.015 bc	0.04	94	3.7 c	0.005 c	0.01	95	1.1 bc
Cypermethrin	250	0.182 b	0.52	47	28.7 b	0.085 b	0.22	66	18.3 ab	0.050 ab	0.12	47	8.4 b
Chlorpyrifos	600	0.035 c	0.08	91	6.8 c	0.002 c	0.01	99	0.5 c	0.000 c	0.00	100	0.0 c
Thiacloprid	300	0.050 c	0.12	88	8.9 c	0.002 c	0.01	99	0.5 c	0.000 c	0.00	100	0.0 c
Acetamiprid	250	0.100 bc	0.26	74	15.1 c	0.037 bc	0.09	86	7.3 bc	0.007 bc	0.02	92	1.6 bc
Pymetrozine	200 +oil	0.105 bc	0.27	72	19.8 bc	0.023 bc	0.05	92	4.2 c	0.000 c	0.00	100	0.0 c
Probability & significance		0.001 ***			< 0.001 ***	< 0.001 ***			0.001 ***	0.003 **			< 0.001 ***
SED (21 df)		0.051			6.169	0.039			6.584	0.022			3.667
LSD (95%)		0.105			12.83	0.081			13.70	0.045			7.63
CV%		78.2			47.5	114.1			109.9	154.2			134.7

* data followed by different letters is significantly different @ P<0.05

Fig. 3 Effect of aphicides against grain aphids, *S. avenae,* in winter barley



4.2.2 Effect of treatments on secondary spread of barley yellow dwarf virus (BYDV) infection

The winter of 2012/13 following the inoculation of plots was particularly cold, for example, with 10 ground frosts being recorded at Broom's Barn in October and 12 in November. These would have slowed aphid development, and also virus multiplication within plants. More severe frosts in December probably had a serious deleterious effect on aphid survival, and thus restricted secondary spread of BYDV, such that the areas infected in untreated plots the following spring were relatively small compared to previous experiments in warmer autumns.

At Broom's Barn, virus infection in untreated plots was only 0.5 m^2, representing only 1.7% of the net plot area (Table 7). However, the effects of treatments on this low level of infection were still apparent. All treatments gave significant reduction in the area infected, and there were no significant differences between them. Best control was given by chlorpyrifos (0.4%), poorest by acetamiprid (0.8%) reflecting their comparative performance against aphids (Table 4; Fig. 4).

At Stetchworth, the area infected was even lower (0.2 m^2), equating to 0.9% of the net plot area, but again, surprisingly, four of the 7 treatments significantly reduced this low level even further (Table 4; Fig. 4). There were no differences between these four, but best control was given by pirimicarb (0.3%) followed by pymetrozine (0.4%), lambda-cyhalothrin (0.5%) and acetamiprid (0.5%). This time cypermethrin, chlorpyrifos and thiacloprid did not significantly reduce virus infection.

4.2.3 Effect of treatments on yield

Yields at Broom's Barn across the trial were around 8 t/ha, quite reasonable given the severe winter conditions. However yield was much less at Stetchworth at circa 7 t/ha.

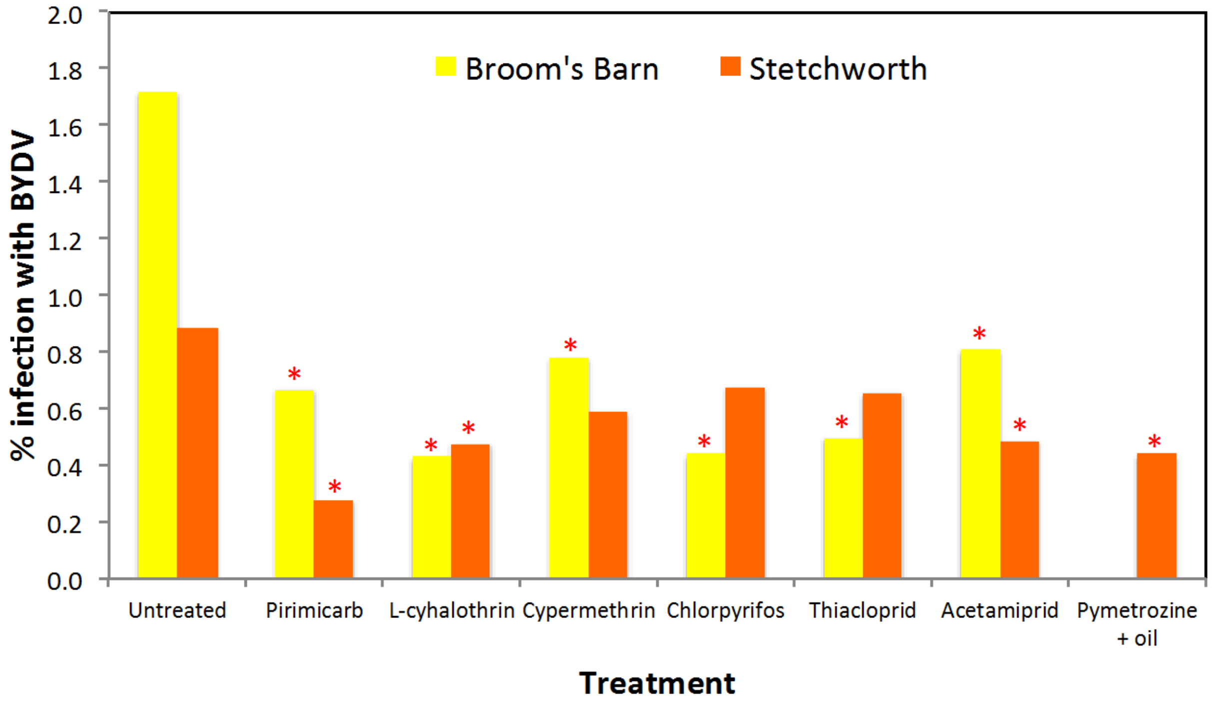
There were no significant effects of treatments on yield or quality of grain at either site, reflecting the low levels of BYDV infection (Table 8).

Table 7. Effect of insecticides on BYDV incidence following inoculation with virus-infective, *Sitobion avenae* on winter barley

Treatment	Rate product ml or g/ha	Broom's Barn			Stetchworth		
		Area infected per plot (m2)	Sqrt area infected per plot (m2)	% infection in net plot (30m2)	Area infected per plot (m2)	Sqrt area infected per plot (m2)	% infection in net plot (30m2)
Untreated		0.52 a	1.23 a	1.72 a	0.21 a	1.10 a	0.89 a
Pirimicarb	240	0.20 b	1.09 b	0.67 b	0.07 b	1.03 b	0.28 b
L-cyhalothrin	75	0.13 b	1.06 b	0.43 b	0.12 b	1.06 b	0.48 b
Cypermethrin	250	0.24 b	1.11 b	0.78 b	0.14 ab	1.07 ab	0.59 ab
Chlorpyrifos	600	0.13 b	1.06 b	0.44 b	0.16 ab	1.08 ab	0.68 ab
Thiacloprid	300	0.15 b	1.07 b	0.50 b	0.16 ab	1.08 ab	0.66 ab
Acetamiprid	250	0.24 b	1.11 b	0.81 b	0.12 b	1.06 b	0.49 b
Pymetrozine + oil	200 + oil	-	-	-	0.11 b	1.05 b	0.44 b
Probability & significance		0.002 **	0.002 **	0.002 **	0.02 *	0.019 *	0.02 *
SED (21 df)		0.083	0.037	0.275	0.035	0.016	0.146
LSD (95%)		0.172	0.076	0.572	0.073	0.034	0.304
CV%		54.2	4.7	54.2	36.8	2.1	36.8

Data followed by different letters are significantly different at $P<0.05$

Fig. 4 Effect of aphicides on incidence of BYDV in winter barley in May 2013



Pymetrozine tested at Stetchworth only
* Significantly less than untreated at P<0.05

Table 8. Effect of insecticides on yield and quality of winter barley following inoculation with virus-infective, *Sitobion avenae*

Treatment	Rate product ml or g/ha	Broom's Barn				Stetchworth			
		Plot yield t/ha	% moisture	Adjusted yield @15% t/ha	Hectolitre weights Kg/HL	Plot yield t/ha	% moisture	Adjusted yield @15% t/ha	Hectolitre weights Kg/HL
Untreated		8.1	12.9	8.27	71.7	6.9	15.1	6.9	65.38
Aphox	240	8.2	12.8	8.34	71.5	6.8	14.9	6.8	68.45
Hallmark	75	8.3	12.8	8.51	72.2	6.9	14.9	6.9	68.75
Toppel	200	8.2	12.9	8.32	71.1	6.8	14.9	6.8	69.25
Dursban		8.3	12.7	8.52	70.9	7.0	15.0	7.0	68.75
Biscaya	600	8.3	12.7	8.47	71.4	7.1	14.9	7.1	69.15
Insyst	300	8.0	12.8	8.13	71.5	7.0	14.9	7.0	69.45
Plenum + oil (St)	200 + oil	Not included in BB trial				6.7	15.0	6.7	68.63
Probability & significance		0.505 NS	0.802 NS	0.444 NS	0.534 NS	0.94 NS	0.933 NS	0.939 NS	0.244 NS
SED (21 df)		0.19	0.13	0.187	0.62	0.31	0.17	0.31	1.532
LSD (95%)		0.39	0.27	0.389	1.28	0.64	0.34	0.64	3.185
CV%		3.2	1.4	3.2	1.2	6.3	1.6	6.3	2.8

NS = not significantly different;

5. Discussion

Indications from the clone trial showed that, for two pyrethroids at least, control of resistant *S. avenae* was significantly poorer than for the susceptible clones of both *S.avenae* and *R. padi*. The fact that lambda-cyhalothrin did not show the same effect as cypermethrin and deltamethrin might be due to the relatively high rate used compared to the recommended rate for this crop – 7.5 g a.i./ha is the rate recommended for aphid control in winter oilseed rape, while 5 g a.i./ha is the rate suggested for wheat.

Of the alternatives tested as potential replacements for pyrethroids, chlorpyrifos was consistently the best, considerably better than thiacloprid. Pirimicarb worked well at one site but not so well at the other; acetamiprid was poor at both. Pymetrozine gave relatively poor control 3 days after spraying at Stetchworth, but eventually gave complete control there, suggesting that it is a slow starter, but comes good later.

The relatively low levels of secondary spread of BYDV infection were due to lack of further primary colonisation by 'wild' aphids, as shown by Rothamsted Insect Survey suction trap catches, and the very cold conditions that prevailed after inoculation. Thus it has not been possible to demonstrate that poor control of resistant grain aphids can lead to BYDV epidemics in this study. The consequences of this were also seen in the total lack of effects on yield. However, in warmer winters, the greater survival of aphids in plots treated with cypermethrin, and deltamethrin as demonstrated in these trials may have had greater adverse consequences on BYDV spread, and subsequent yield, and perhaps this merits further study in such years.

Although chlorpyrifos and thiacloprid are approved for use in cereals, neither is currently approved for use against aphids in the autumn. Neither acetamiprid and pymetrozine are approved at all in cereals. These results will therefore give regulators some useful independent information about the comparative efficacy of these alternative compounds for potential future use should applications for registration be made.

6. References

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7. Acknowledgements

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