Project Title:	Neonicotinoid alternatives to chlorpyrifos for raspberry cane midge control 2010
Project Number:	SF 101
Project Leader:	Jerry Cross
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The results and conclusions in this report are based on an investigation conducted over a one-year period. The conditions under which the experiments were carried out and the results have been reported in detail and with accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.

Principal Scientists:

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Authentication

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

J V Cross

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J V Cross

Date ....2 March 2011...

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GROWER SUMMARY

Headline

Half rate Calypso+Silwet and Gazelle+Silwet sprays were of low to moderate (21-58%) efficacy for control of raspberry cane midge, only giving good results when applied curatively a few to several days after egg laying.

Background and deliverables

Raspberry cane midge is a major pest of raspberries in the UK. Growers currently rely on chlorpyrifos sprays for control. If use or registration of chlorpyrifos on raspberry is lost there would be no effective control for cane midge. The pest would increase and severely limit the productivity of raspberry plantations. The sex pheromone of the raspberry cane midge has been identified by EMR and NRI and pheromone traps are now available commercially for monitoring the pest to time spray applications. Work is in progress in HortLINK project HL0175 (SF74) to develop methods of using the pheromone for control of the pest by attract and kill, mass trapping or mating disruption, but mixed results have been obtained to date and it remains uncertain as to whether an effective pheromone based control method can be developed. In project SF59 in 2003-05, EMR conducted three trials to evaluate a wide range of alternative insecticides to chlorpyrifos for control of cane midge. None of the alternative products tested were found to be either suitable or sufficiently effective for commercial purposes. Treatment with Talstar + LI700 (adjuvant) reduced larval populations by 93% in one trial but synthetic pyrethroids have persistent harmful effects on natural enemies and their use is incompatible with IPM. Importantly, recent work in Poland has indicated that the neonicotinoid insecticides acetamiprid (Gazelle) and thiamethoxam (Centric) have significant activity against cane midge. The neonicotinoid, thiacloprid (Calypso), is already approved for use on raspberry and whilst it did not show promise in project SF79, further investigation is warranted. This finding needed to be verified and the most effective product and timing of spray application identified. Use of silicone based adjuvants (e.g. Break Thru 240 S, Silwet L-77) which may aid penetration of insecticides into splits also needed to be investigated.

The expected deliverables from this project were:

- Identify an effective neonicotinoid insecticide for control of raspberry cane midge.
- Ascertain the optimum timing of spray application in relation to pheromone trap catches.
- Determine whether the addition of a silicone based adjuvant significantly improves the performance of insecticides against cane midge.

Approval may be needed for some of the products identified.

Summary of the project and main conclusions

A replicated field experiment further investigated the effect of varying the timing of application of the neonicotinoid insecticides Calypso and Gazelle (used at half rate in admixture with a silicone adjuvant) on efficacy for control of raspberry cane midge, in comparison with the standard product chlorpyrifos. Work in 2009 had shown that applications of these neonicotinoid insecticides at half rate in admixture with a silicone adjuvant gave good control of the midge when applied curatively 6 days after artificial splits were made in primocanes, but gave poor results when applied preventively 6 days before artificial splits were made in primocanes.

In 2010, a wider range of application times relative to egg laying in artificial splits were investigated. Two experimental sprays were applied during the second generation of cane midge activity. The first was applied on 10 June 2010 during the first half of the generation. The second was applied on 17 June 2010, during the second half of the generation. Artificial splits were made in primocanes both before and after these spray applications were made. These split canes were then collected for examination periodically up until 32 days after the first split was made. The following conclusions were drawn:

- Half rate Calypso+Silwet and Gazelle+Silwet sprays were of low to moderate efficacy (21-58%) for control of raspberry cane midge. They were of considerably lower efficacy than the standard chlorpyrifos treatment (87 – 88% efficacy).

- The timing of their application was more critical and the time period of their efficacious effect was also much narrower than for the chlorpyrifos.

- They only worked well when sprays were applied a few days after the splits were made. Egg laying is known to occur mainly in fresh splits so they acted curatively, probably mainly against young larvae.

- They were used at half the normal recommended rate, to comply with the requirement to do so when they are used in admixture with a silicone adjuvant.

- Several applications of half rate Calypso or Gazelle with a silicone adjuvant would be required to get a good standard of commercial control and timing of application would be critical.

- Sex pheromone traps give a good indication of the period of risk, which for the second generation (the most damaging) lasts about 3-4 weeks. To cover this period, a programme of 3-4 sprays at weekly intervals would be required. This would be a significant increase in the number of applications and in cost compared to a single chlorpyrifos treatment, but may be less harmful to IPM and the environment.

- Further work is required to investigate the efficacy of such programmes of sprays, comparing targeting of the first with targeting of the second generation.

- A considerable improvement in timing and efficacy could probably be achieved if there was a greater knowledge of the timing of occurrence of natural splits. Most modern varieties have a low propensity to split. Splits probably mainly occur in periods of windy weather, or when mechanical operations are undertaken in the plantation. A simple split risk simulation model may greatly improve the targeting of sprays and hence overall efficacy.

- If approval for use of chlorpyrifos is lost, further work on this topic will become important.

Financial benefits

Chlorpyrifos is relied on for control of cane midge in the UK but its future approval status is uncertain. If alternatives to control these pests cannot be found, raspberry production would become uneconomic in the UK. Finding alternative treatments is crucial to the raspberry industry. At current prices, treatment of 1 ha of raspberry at the recommended dose with Lorsban, Calypso or Tracer costs £14, £39 and £50 respectively.

Action points for growers

- Half rate Calypso+Silwet and Gazelle+Silwet sprays were of low to moderate efficacy (21-58%) for control of raspberry cane midge. They were of considerably lower efficacy than the standard chlorpyrifos treatment (87 – 88% efficacy).

- The timing of their application was more critical and the time period of their efficacious effect was also much narrower than for chlorpyrifos.

- They only worked well when sprays were applied a few days after egg laying so they acted curatively, probably mainly against young larvae.

SCIENCE SECTION

(EMQA GEP ORETO study no. 10/002)

Introduction

Background

Raspberry cane midge is a major pest of raspberries in the UK. Growers currently rely on chlorpyrifos sprays for control. If use or registration of chlorpyrifos on raspberry is lost there would be no effective control for cane midge. The pest would increase and severely limit the productivity of raspberry plantations. The sex pheromone of the raspberry cane midge has been identified by EMR and NRI and pheromone traps are now available commercially for monitoring the pest to time spray applications. Work is in progress in HortLINK project HL0175 (SF 74) to develop methods of using the pheromone for control of the pest by attract and kill, mass trapping or mating disruption, but mixed results have been obtained to date and it remains uncertain as to whether an effective pheromone based control method can be developed.

In project SF 59 in 2003-05, EMR conducted three trials to evaluate a wide range of alternative insecticides to chlorpyrifos for control of cane midge. None of the alternative products tested were found to be either suitable or sufficiently effective for commercial purposes. Treatment with Talstar + LI700 (adjuvant) reduced larval populations by 93% in one trial but synthetic pyrethroids have persistent harmful effects on natural enemies and their use is incompatible with IPM.

Importantly, recent work in Poland has indicated that the neonicotinoid insecticides acetamiprid (Gazelle) and thiamethoxam (Centric) have significant activity against cane midge. The neonicotinoid, thiacloprid (Calypso), is already approved for use on raspberry and whilst it did not show promise in project SF79, further investigation is warranted. This finding needs to be verified and the most effective product and timing of spray application identified.

Use of silicone based adjuvants which may aid penetration of insecticides into splits also needs to be investigated. Work in 2009, the first year of this project, showed that applications of the neonicotinoid insecticides Calypso and Gazelle, at half rate in admixture with a silicone adjuvant, gave good control of the midge when applied curatively 6 days after artificial splits were made in primocanes, but gave poor results when applied preventively 6 days before artificial splits were made in primocanes. Excellent results were also obtained with Centric, but this product is no longer available for use in fruit crops, so further investigation of it is not warranted.

Objectives

The objective in 2010 was to conduct a replicated field experiment twice to further investigate the effect of varying timing of application of the neonicotinoid insecticides Calypso and Gazelle (used at half rate in admixture with a silicone adjuvant) on efficacy for control of raspberry cane midge, in comparison with the standard product chlorpyrifos. Work in 2009 had shown that applications of these neonicotinoid insecticides at half rate in admixture with a silicone adjuvant gave good control of the midge when applied curatively six days after artificial splits were made in primocanes, but gave poor results when applied preventively six days before artificial splits were made in primocanes.

Materials and methods

Site

The trial was done in four tunnels containing in total eight 64 m long rows of the variety Maravilla at Kenward Road Yalding, Kent ME18 6JP, by kind permission of Robert Pascal, Clockhouse Farm, Linton. The plantation was managed by James Dearing and deputy manager Nick Deppe. Each tunnel contained two rows of raspberries, spaced 2.8 m apart, one row in each tunnel being divided into eight 8 m long plots, the other row acting as a guard.

Raspberry cane midge sex pheromone monitoring traps

Two standard white delta traps (20 x 20 cm base), each containing a rubber septa lure loaded with 10 µg of the raspberry cane midge sex pheromone racemate, were deployed in the tunnels adjacent to the experimental site on 12 April 2010. They were spaced > 20 m apart and held at the standard height of 0.5 m. The numbers of midges captured in each trap was recorded weekly until 12 July. Lures were renewed every four weeks, in accordance with standard practice. The mean weekly catch of midges per trap was calculated.

Treatments

Treatments were single sprays of Calypso + Silwet L-77, Gazelle + Silwet L-77 or chlorpyrifos in comparison with a double replicated untreated control. The experiment was done twice, on 10 and 17 June, respectively, in the same overall experiment using different plots for the two timings of spray treatment but with the same untreated controls (Table 1). These application dates were in the first half of the second generation flight of the midge. The two spray application times have been regarded as separate experiments, for ease of interpretation of the experimental results, although the data for all treatments were analysed together.

Table 1 Treatments

Trt no	Product	Experiment no.	Date of application
1	Calypso + Silwet L-77	1	10 June
2	Gazelle + Silwet L-77	1	10 June
3	Chlorpyrifos	1	10 June
4	Calypso + Silwet L-77	2	17 June
5	Gazelle + Silwet L-77	2	17 June
6	Chlorpyrifos	2	17 June
7, 8	Untreated	1,2	-

Products and their doses of application are shown in Table 2.

Table 2 Product formulations and dose rates of application The spray volume was 1000 l/ha.

Product	Active ingredient and formulation	Dose rate (/ha)
Calypso	480 g/l thiacloprid SC	125 ml
Gazelle	20 % w/w acetamiprid	250 g
Chlorpyrifos	Chlorpyrifos 48 EC	1.5 l
Silwet L-77	Silicone adjuvant	500 ml

Note: The Silwet L-77 label states ‘on edible crops provided that the statutory conditions of use for the pesticide are followed and that the pesticide is not used at more than 50% of the maximum approved rate for that application, 0.05% (0.5 ml/l)’

Treatment application

Sprays were applied at a volume of 1000 l/ha using a Birchmeier motorised air assisted back pack sprayer by EMR staff. They were targeted to the base of the canes. The accuracy of application of each treatment was estimated by measurement of the amount of spray that had actually been applied (calculated from the initial minus the final volume of sprayate left in the tank, minus the amount that should have been left had the spray been applied at exactly the correct volume rate). All applications were within 10% of required (Table 3).

Table 3 Accuracy of spray application estimated from the amount of sprayate remaining in the spray tank after spray application

Date	Treatment	Accuracy of application (%)
10 June 2010	1	109
	2	102
	3	94
17 June 2010	1	100
	2	110
	3	99

Experimental design and layout

A randomised complete block experimental design with four replicate plots of each treatment was used. Each plot was an ~ 8 m length of a single row, though assessments were only done on the central 6 m of each plot. Randomisation of treatments to plots is given in Table 4. A screen was used between the plots to minimise inter-plot contamination by spray drift.

Table 4 Randomisation of treatments to plots

Block 1		Block 2		Block 3		Block 4	
Plot no.	Trt	Plot no.	Trt	Plot no.	Trt	Plot no.	Trt
101	6	201	8	301	6	401	7
102	5	202	5	302	5	402	1
103	8	203	3	303	2	403	6
104	1	204	6	304	8	404	2
105	7	205	1	305	3	405	8
106	4	206	2	306	1	406	3
107	3	207	7	307	4	407	4
108	2	208	4	308	7	408	5

Meteorological records

Wet and dry bulb temperature with aspirated psychrometer, wind speed and direction before and after spraying (Table 5) were recorded. In addition, a USB-502 logger was used to take hourly temperature and humidity readings inside a polytunnel (Appendix 1).

Table 5 Weather conditions at the time of spray application

Date		Time	^oC dry	^oC wet	% RH	Kph	DIR
10 June 2010	Start	08:26	16	16	100	0	-
	Finish	10:16	16	16	100	0	-
17 June 2010	Start	11:45	18	17	94	2	N
	Finish	13:00	19	18	95	4	N

Assessments

In each plot, ten artificial cane splits, each ~ 10 cm long, were made, each in a previously unused primocane on the dates shown in Table 6. Splits were collected 13-15 days after they are made and the number of eggs, young and old larvae in each split was counted under a binocular microscope in the laboratory at East Malling Research. The length of each split was measured to the nearest mm and the numbers larvae per 100 cm length of split were calculated.

Table 6 Dates splits were made and collected in for assessment on all plots

Date splits made	Date collected	Interval between splits made and collection (days)
07 Jun	22 Jun	15
14 Jun	28 Jun	14
22 Jun	05 Jul	13
28 Jun	11 Jul	13

Statistical analysis

The numbers of eggs plus larvae per 100 cm of split were calculated for each sample and ANOVA was done with time as a split plot factor, combining the data from experiments 1 and 2 into a single analysis. Log_{10} (no. eggs & larvae / 100 cm split + 1) transformation of the data was used to stabilize variances. Comparison of means was done by LSD (P = 0.05) testing.

Results

Raspberry cane midge sex pheromone monitoring traps

The sex pheromone trap catch records indicated that the experiments were done when the raspberry cane midge adult populations were rising sharply. The artificial splits, made on 7, 14, 22 and 28 June occurred in this period of second generation activity.

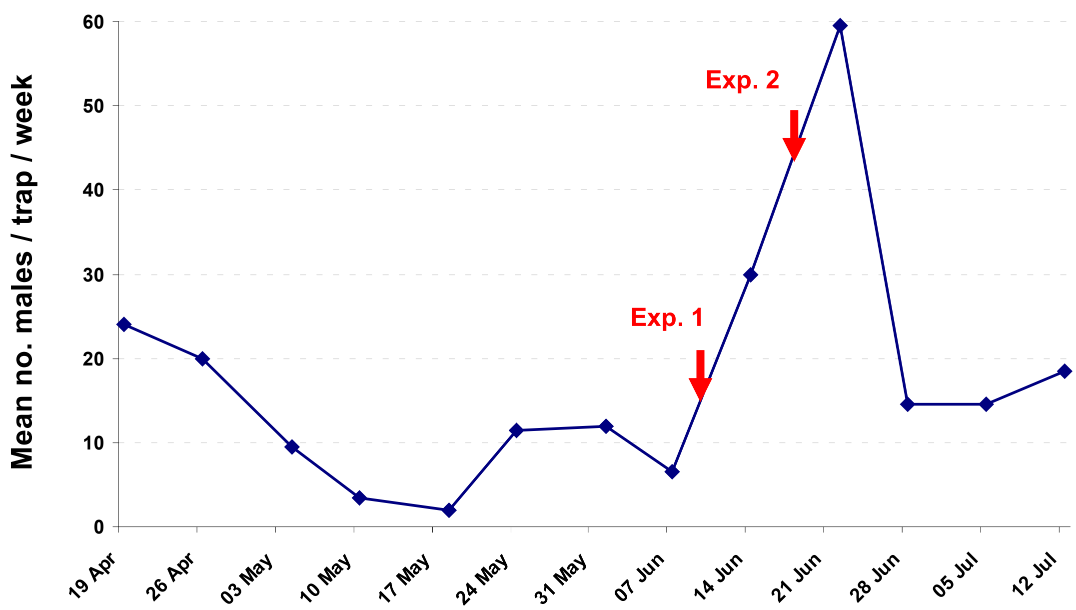


Figure 1 Average weekly catches of raspberry cane midge males in two sex pheromone monitoring traps deployed nearby the experimental site. The dates of spray application in the two experiments are indicated.

Experiment 1 sprayed 10 June 2010

The periods (days) of artificial splitting to assessment relative to insecticide treatment evaluated were -3 to 12, 4 to 18, 12 to 25 and 18 to 32 days (Table 7). The ANOVA of the $\log_{10}$ (n/100 splits + 1) transformed data revealed highly significant Time (P = 0.007) and Treatment effects (P = <0.001) with the Time.Treatment interaction close to standard statistical significance (P = 0.095) (Table 7). The chlorpyrifos treatment significantly reduced the number of eggs and larvae in splits for all the splitting to assessment periods except the last (19 to 32 day) period (Table 7, Figure 2). The Calypso + Silwet and Gazelle + Silwet treatments did not reduce the numbers of eggs and larvae in splits significantly for any of the individual periods except for Calypso + Silwet for the first period (-3 to 12 days), though these treatments gave overall reductions of 21 and 54% respectively compared to the untreated control (Table 8). Looking at trends in the data, only for the first period (-3 to 12 days) did these two neonicotinoid insecticide treatments appear to reduce numbers of eggs and larvae in splits, though the reduction was only significant statistically for Calypso + Silwet.

Table 7 Mean and mean Log_{10} (n+1) transformed numbers of eggs and larvae recorded per 100 cm of split in the experiment treated on 10 June 2010. Fprob (P) and LSD (P = 0.05) values provided from ANOVA on transformed data. Untreated controls were double replicated and thus have maximum replication.

Treat	Time				Mean
DAT splits made	-3	4	12	18	
DAT assessed	12	18	25	32	
	Number of eggs plus larvae /100 cm split				
Calypso + Silwet	8.1	93.2	68.1	65.6	58.8
Gazelle + Silwet	13.8	40.6	54.3	20.7	32.3
Chlorpyrifos	1.1	8.4	8.2	15.7	8.3
Untreated	38.3	86.3	172.6	44.0	85.3
	Log_{10}(Number of eggs plus larvae /100 cm split + 1)				
Calypso + Silwet	0.760	1.864	1.687	1.616	1.482
Gazelle + Silwet	0.955	1.233	1.394	1.203	1.151
Chlorpyrifos	0.252	0.610	0.382	1.095	0.585
Untreated	1.454	1.664	1.904	1.427	1.612
		Time	Treat	Time.Treat	Time.Treat*
Fprob (P)		0.007	<0.001	0.095	0.095
LSD (P = 0.05) - Min rep			0.4504	0.8821	0.8919
Max - Min		0.3153	0.3901	0.7639	0.7724
Max rep				0.6237	0.6307

*Comparing means with same level of Treat

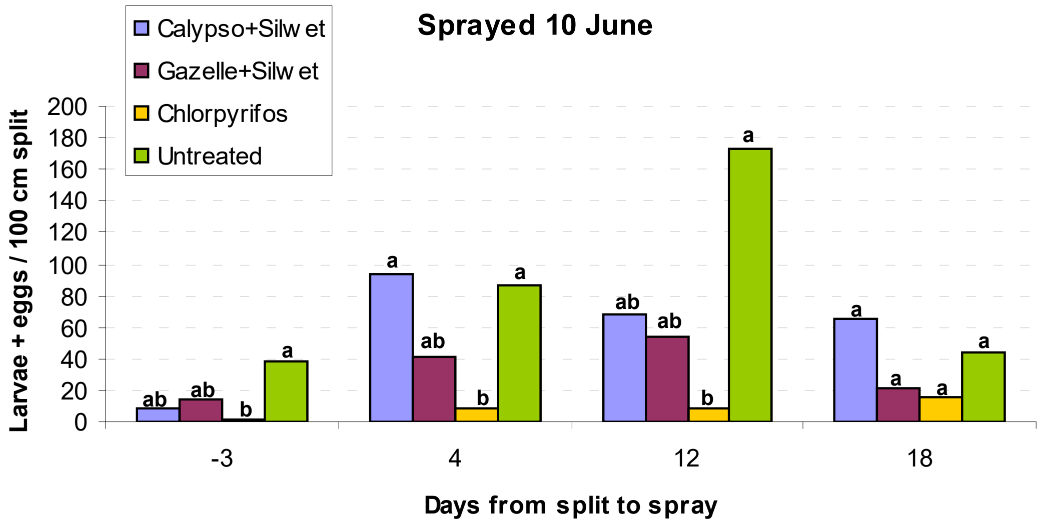


Figure 2 Mean and numbers of eggs and larvae recorded per 100 cm of split in the experiment treated on 10 June 2010. Bars in any group marked with the same letter do not differ significantly in LSD (P = 0.05) test.

Table 8 Back transformed grand mean numbers of raspberry cane midge eggs and larvae per 100 cm of split and % reduction in numbers compared to the untreated control for experiment 1 sprayed 10 June 2010.

Treatment	Back transformed grand mean no. eggs and larvae per 100 cm split	% reduction compared to untreated control
1. Calypso + Silwet	3.65	21
2. Gazelle + Silwet	2.11	54
3. Chlorpyrifos	0.57	88
7,8. Untreated	4.61	

Experiment 2 sprayed 17 June 2010

The periods (days) of artificial splitting to assessment relative to insecticide treatment evaluated were -10 to 5, -3 to 11, 5 to 18 and 11 to 25 days (Table 9). The ANOVA of the $\log_{10}$ (no. / 100 splits + 1) transformed data (for both experiments combined) gave results as described for the first experiment The chlorpyrifos treatment again significantly reduced the number of eggs and larvae in splits for the first three splitting to assessment periods (-10 to 5, -3 to 11 and 5 to 18 days) but not for the last period (11 to 25 days) (Table 9, Figure 3). The Calypso + Silwet and Gazelle + Silwet treatments only reduced the numbers of eggs and larvae in splits significantly for the -3 to 11 day period but not for the -10 to 5, 5 to 18 or the 11 to 25 day periods. These treatments gave overall reductions of 58 and 57% respectively compared to the untreated control (Table 10).

Table 9 Mean and mean $Log_{10}(n+1)$ transformed numbers of eggs and larvae recorded per 100 cm of split in the experiment treated on 17 June 2010. Fprob (P) and LSD (P = 0.05) values provided from ANOVA on transformed data. Untreated controls were double replicated and thus have maximum replication.

Treat	Time period (days)				Mean
DAT splits made	-10	-3	5	11	
DAT assessed	5	11	18	25	
	Number of eggs plus larvae /100 cm split				
Calypso + Silwet	41.7	12.9	75.1	8.2	34.5
Gazelle + Silwet	27.8	1.3	136.1	39.3	51.1
Chlorpyrifos	0.9	0.0	21.6	28.2	12.7
Untreated	38.3	86.3	172.6	44.0	85.3
	Log_{10}(Number of eggs plus larvae /100 cm split + 1)				
Calypso + Silwet	1.291	0.711	1.684	0.798	1.121
Gazelle + Silwet	0.839	0.265	1.552	1.527	1.046
Chlorpyrifos	0.170	0.000	0.793	1.110	0.518
Untreated	1.454	1.664	1.904	1.427	1.612
		Time	Treat	Time.Treat	Time.Treat*
Fprob (P)		0.007	<0.001	0.095	0.095
LSD (P = 0.05) - Min rep			0.4504	0.8821	0.8919
Max - Min		0.3153	0.3901	0.7639	0.7724
Max rep				0.6237	0.6307

*Comparing means with same level of Treat

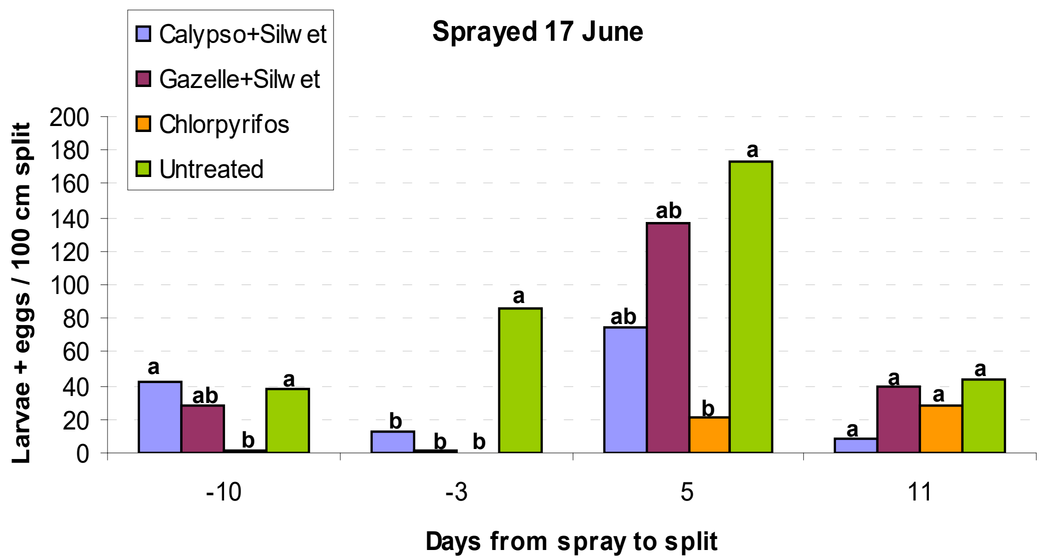


Figure 3 Mean and numbers of eggs and larvae recorded per 100 cm of split in the experiment treated on 17 June 2010. Bars in any group marked with the same letter do not differ significantly in LSD (P = 0.05) test.

Table 10 Back transformed grand mean numbers of raspberry cane midge eggs and larvae per 100 cm of split and % reduction in numbers compared to the untreated control for experiment 2 sprayed 17 June 2010.

Treatment	Back transformed grand mean no. eggs and larvae per 100 cm split	% reduction compared to untreated control
4. Calypso + Silwet	1.95	58
5. Gazelle + Silwet	2.00	57
6. Chlorpyrifos	0.58	87
7,8. Untreated	4.61	

Discussion

These results indicate that the Calypso + Silwet and Gazelle + Silwet treatments were of considerably lower efficacy than the standard chlorpyrifos treatment. The timing of application of the neonicotinoids was more critical and the time period of their efficacious effect was also much narrower than for the chlorpyrifos treatment: They only worked reasonably well when sprays were applied a few days after the splits were made. Egg laying is known to occur mainly in fresh splits so they acted curatively, probably mainly against young larvae. However, they were used at half the normal recommended rate, to comply with the requirement to do so when they are used in admixture with a silicone adjuvant.

These results imply that several applications of half rate Calypso or Gazelle with a silicone adjuvant would be required to get a good standard of commercial control and that timing of application would be critical. The sex pheromone traps give a good indication of the period of risk, which for the second generation (the most damaging) lasts about three to four weeks. To cover this period, a programme of three to four sprays at weekly intervals would be required. This would be a significant increase in the number of applications and in cost compared to a single chlorpyrifos treatment, but may be less harmful to IPM and the environment.

Further work is required to investigate the efficacy of such programmes of sprays, comparing targeting of the first with targeting of the second generation. A considerable improvement in timing and efficacy could probably be achieved if there was a greater knowledge of the timing of occurrence of natural splits. Most modern varieties have a low propensity to split. Splits probably mainly occur in periods of windy weather, or when mechanical operations are done in the plantation. A simple split risk simulation model may greatly improve the targeting of sprays and hence overall efficacy. If approval for use of chlorpyrifos is lost, this work will become important.

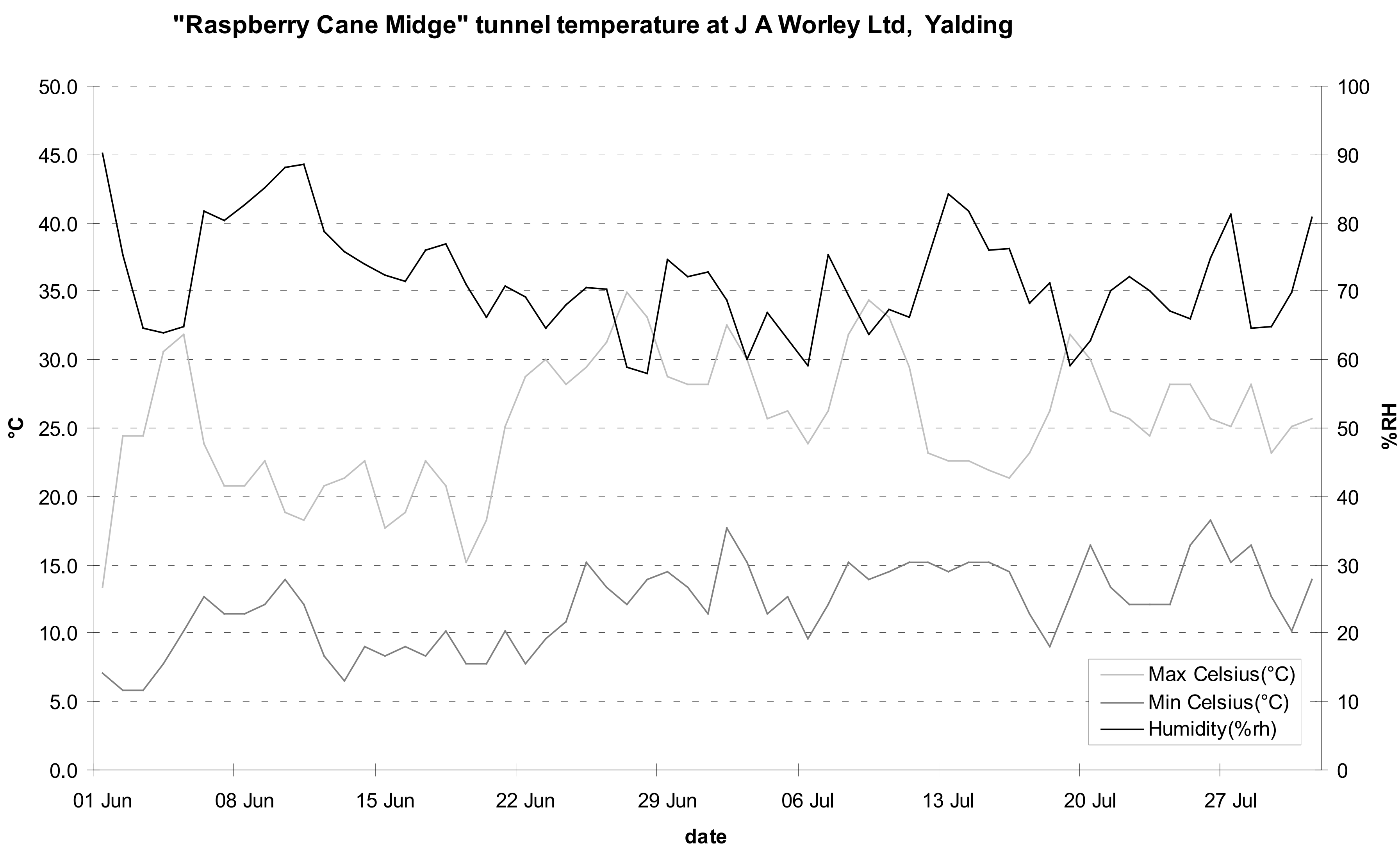
Conclusions

- Half rate Calypso + Silwet and Gazelle + Silwet sprays were of low to moderate efficacy (21-58%) for control of raspberry cane midge. They were of considerably lower efficacy than the standard chlorpyrifos treatment (87 – 88% efficacy).
- The timing of their application was more critical and the time period of their efficacious effect was also much narrower than for the chlorpyrifos.
- They only worked well when sprays were applied a few days after the splits were made. Egg laying is known to occur mainly in fresh splits so they acted curatively, probably mainly against young larvae.
- They were used at half the normal recommended rate, to comply with the requirement to do so when they are used in admixture with a silicone adjuvant.
- Several applications of half rate Calypso or Gazelle with a silicone adjuvant would be required to get a good standard of commercial control and that timing of application would be critical.
- Sex pheromone traps give a good indication of the period of risk, which for the second generation (the most damaging) lasts about three to four weeks. To cover this period, a programme of three to four sprays at weekly intervals would be required. This would be a significant increase in the number of applications and in cost compared to a single chlorpyrifos treatment, but may be less harmful to IPM and the environment.
- Further work is required to investigate the efficacy of such programmes of sprays, comparing targeting of the first with targeting of the second generation.
- A considerable improvement in timing and efficacy could probably be achieved if there was a greater knowledge of the timing of occurrence of natural splits. Most modern varieties have a low propensity to split. Splits probably mainly occur in periods of windy weather, or when mechanical operations are done in the plantation. A simple split risk simulation model may greatly improve the targeting of sprays and hence overall efficacy.
- If approval for use of chlorpyrifos is lost, further work on alternative treatments for cane midge control will be important

Acknowledgements

We are grateful to Robert Pascal, James Deering and Nick Deppe, Clockhouse Farm, Coxheath, for assisting us and providing the site for the trial. We are grateful to Stephanie Cheesman, Gloria Endredi and Cecylia Faltis, East Malling Research, who did the practical work. Gillian Arnold gave biometrics advice and assistance.

Appendix 1


"Raspberry Cane Midge" tunnel temperature at J A Worley Ltd, Yalding
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
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°C
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20
10
0
%RH
01 Jun
08 Jun
15 Jun
22 Jun
29 Jun
06 Jul
13 Jul
20 Jul
27 Jul
date
Max Celsius(°C)
Min Celsius(°C)
Humidity(%rh)