Project Title: Preventing red berry disease by monitoring and control of blackberry mite

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East Malling Research is an officially recognised efficacy testing station and this work is registered as study number ORETO 2010/007

DISCLAIMER

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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GROWER SUMMARY

Headline

Blackberry mite can be effectively controlled by sprays of Codacide oil and Dynamec. Red berry disease is caused only in part by blackberry mite and can be partially controlled by acaricides.

Background and deliverables

Red berry disease is causing serious damage and losses in commercial blackberry plantations in the UK, especially in high value crops grown in tunnels. A proportion of drupelets, often those at the base of the fruits around the calyx, remain green or red and hard whilst the remaining drupelets ripen normally attaining their normal black colouration at maturity. Red berry disease is thought to be caused by the blackberry mite, *Acalitus essigi* (Eriophyidae), which feeds on the flowers (and foliage) injecting toxic saliva into the developing drupelets. The problem has been known for many years but was not significant until recently when the incidence of damage in most UK commercial blackberry plantations dramatically increased and became the most serious problem in commercial production. The upsurge in damage coincided with the loss of the fungicide tolylfluanid (Elvaron Multi), a fungicide with known acaricidal properties against Eriophyid mites, including pear leaf blister mite and apple and pear rust mites.

Blackberry mites over-winter beneath bud scales and invade the new growth, living and increasing on the flower buds, petioles and leaves. At blossom time they enter the flowers and feed on the developing drupelets, especially those sheltered by the calyx. As fruits mature they become less suitable for mite feeding and at harvest it is often difficult to find mites in the damaged fruits. For this reason it is often difficult to diagnose blackberry mite as the cause of the problem, as uneven ripening may also be caused by poor pollination. The extent of blackberry mite infestation in UK blackberry crops needs to be determined and effective means of monitoring and controlling this pest need to be developed.

Summary of the project and main conclusions

In 2011, a replicated experiment was done in a protected blackberry plantation at Belks Farm, Otham, Maidstone, to evaluate the efficacy of acaricide spray treatments for control of blackberry mite, red berry disease and effects on yield. Treatments were:

1. Fortnightly programme of sulphur from bud burst until mid May
2. Fortnightly programme of Codacide oil from mid May to mid ripe fruit (mid July)
3. Two sprays of Dynamec + Break Thru S 240, at 5% flower and 2 weeks later
4. Combination of treatments 1+2
5. Combination of treatments 1+2+3
6. Untreated control (double replicated)

Sprays were applied at 1,000 l/ha with a knapsack sprayer. The number of mites present at the shoot bases and in the petioles was assessed on 1 August 2011. The incidence of red berry symptoms was assessed through the harvest period. The yields of red berry affected and unaffected fruit on each plot were recorded by the grower. The main conclusions of the study were:

- Blackberry mites were only found at the bases of the shoots or in the leaf petioles.

- All the spray treatments evaluated gave very good control of blackberry mite, there being no statistically significant and consistent differences between treatments. All reduced mite numbers by 96% on average.

- There was a high incidence of red berry symptoms, an overall mean of 17.3% of fruit being affected by red berry symptoms on the untreated control plots. None of the treatments significantly reduced the incidence of red berry symptoms.

- A mean of 129 punnets of blackberry fruits were harvested from the untreated control plot (8 m length of row) by the grower from 17 picks between 12 August and 11 October 2011. 41% of fruits were categorised as being outgrade (not suitable for marketing as first quality, mainly due to red berry symptoms) on these plots by the pickers. None of the treatments reduced the yield or the % outgrade fruit significantly.

- Overall, these results confirm the findings of the project in year 1, that blackberry mite is not the sole cause of red berry symptoms and in this crop it was at best a minor cause. Control of the mites to a high standard did not result in a significant reduction in symptoms.

Financial benefits

A typical 12 tonne / ha crop of raspberries was worth more than £60,000 at typical 2010 prices of £5,000/tonne. The large losses caused by red berry disease, which this work shows can be in excess of 30% of the crop, is clearly a huge financial loss to UK blackberry growers. The very substantive reductions in losses due to red berry disease (by up to 70% depending on plantation) recorded in this work and the large increases in marketable yield achieved demonstrate this research is of huge potential financial benefit to UK blackberry growers.

Action points for growers

- Blackberry growers should apply acaricide sprays for control of blackberry mite and avoid the worst ravages of red berry disease, but the sprays are unlikely to completely eliminate the problem as the mites are not the only cause.

- A fortnightly programme of sprays of Codacide oil, starting from May onwards, supplemented with two sprays of Dynamec at 5% flower and 2 weeks later is likely to be the best choice. Sulphur can also give good control but in the first year's work was phytotoxic, and left unsightly deposits on the foliage and fruit.

SCIENCE SECTION

Introduction

Background

Red berry disease is causing serious damage and losses in commercial blackberry plantations in the UK, especially in high value crops grown in tunnels. A proportion of drupelets, often those at the base of the fruits round the calyx, remain greenish or reddish and hard whilst the remaining drupelets ripen normally attaining their normal black colouration at maturity. Red berry disease is thought to be caused by the blackberry mite, *Acalitus essigi*, which feeds on the flowers (and foliage) injecting toxic saliva into the developing drupelets. Mites overwinter beneath bud scales and invade the new growth, living and increasing in numbers on the flower buds, petioles and leaves (Davies et al., 2001). At blossom time they enter the flowers and feed on the developing drupelets, especially those sheltered by the calyx. As fruits mature they become less suitable for mite feeding and at harvest it is often difficult to find mites in the damaged fruits. For this reason it is often difficult to diagnose blackberry mite as the cause of the problem, as uneven ripening may also be caused by poor pollination. The extent of blackberry mite infestation in UK blackberry crops needs to be determined and effective means of monitoring and controlling this pest need to be developed.

Previous advice was to spray blackberry crops with endosulfan in late April-early May with two more sprays before flowering (Alford, 1979). However, this organochlorine insecticide and acaricide was withdrawn over 10 years ago, and no effective replacement treatment has been identified. Screening trials in Poland in the 1980s (Labonowska and Suski, 1990) showed that bromopropylate (Neoron), cyhexatin (Plictran) and azocyclotin (Peropal) were partially effective but more modern acaricides do not appear to have been evaluated. Selective acaricides are needed because naturally occurring predatory mites help regulate blackberry mite populations (Szendrey et al., 2003).

In 2010, the first year of the project, a survey of populations of blackberry mite in dormant buds from 28 commercial blackberry plantations and an acaricide trial evaluating acaricide treatments for control of blackberry mite and red berry disease were conducted. The acaricide treatments evaluated were:

1) a full season fortnightly spray programme of sulphur
2) a full season fortnightly programme of sprays of Codacide oil
3) two sprays of Dynamec at the start of flowering and 2 weeks later
4) treatment 1+3 combined
5) treatments 2+3 combined
6) untreated control (double replicated)

The trial was conducted in polytunnel protected crops of four different blackberry varieties (Loch Tay, Carmel, Chester Thornless, Loch Ness), two at each of two farms (Salmans Farm, Penshurst, Kent; Belks Farm, Otham, Kent). The main findings and conclusions of the first year's work are summarised below.

Overwintering blackberry mites were found in only 10 of 28 samples of 50 dormant buds collected from 28 commercial blackberry plantations in February-March 2010. The highest number found was 0.36 mites/bud. The mites were found mainly beneath the outer bud scales. Numbers were not related to the very considerable losses of fruit due to red berry disease suffered by growers in the preceding season. Results suggest that a larger sample of 100 or more buds per plantation, taken from the tops of the canes, would be preferable and that presence or absence of mites under the outer scale of each bud, to give a % buds infested value, might be more useful and cost-effective and reliable.

In the acaricide trials, there was no obvious relationship between the numbers of mites found in the overwintering buds and the populations that developed subsequently on untreated controls. The blackberry mites remained mainly beneath the outer scales of the overwintering buds and were found there in largest numbers throughout the season. Only when mite numbers started to increase in May/June were any mites found at the base of the petioles further up the shoots, and then only in very small numbers. No mites were found at any time in the flowers or fruits in any of the varieties, even in the variety Carmel which had the highest mite numbers. All the acaricide treatments performed equally well in reducing blackberry mite on the three infested varieties (Loch Tay, Carmel, Chester Thornless), and in reducing red berry disease and increasing yield but no individual spray treatment had consistently the lowest numbers of mites, so no optimum treatment was apparent. None of the treatments eliminated the mites. This is not surprising because the acaricides tested are contact acting and most of the mites were present under the bud scales where they would be inaccessible directly to sprays.

Of the treatments tested, the Codacide spray programme appears to be the best for growers, though early applications, when mites are still under the bud scales, may be of little benefit. Sulphur leaves unsightly deposits, might be phytotoxic, and should not be used, especially during fruiting. Dynamec is probably harmful to predatory Phytoseiid mites which are likely to be important natural enemies of blackberry mite and may exacerbate the problem in the longer-term. The sulphur deposits that resulted from the full season's fortnightly programme of sulphur sprays substantively detracted from the visual quality of the fruit whereas the full season's Codacide spray programme enhanced it, compared with the untreated control. From this point of view, a full spray programme of sulphur sprays is not acceptable, though a small number of applications well before harvest may be acceptable. Measurements of plant growth and fruit size were not taken, but it is suspected that the sulphur spray programmes may have been reducing leaf size and berry weight.

All the spray treatments reduced the % fruits with red berry disease significantly on Loch Tay, Carmel and Chester Thornless, but there was no reduction on Loch Ness. The reduction was by ~70% on the Loch Tay and Carmel, but only by 33% on the Chester Thornless at Belks Farm. Furthermore, 33% of Loch Ness at Belks Farm had red berry symptoms, but this was not reduced by the treatment (note that no blackberry mites were recorded in this plantation). At Belks Farm, the spray treatments significantly increased the yield of marketable fruit by 45% and 106% on the Chester Thornless and Loch Ness, respectively, the latter being despite almost no blackberry mites being detected in the plantations during the growing season. On Chester, the increase in yield is consistent with the hypothesis that blackberry mite is the causal agent of red berry disease and that the disease is reduced by control of its causal agent, but it is not consistent with this hypothesis on Loch Ness.

The positive linear regressions between the mean percentages of fruits with red berry symptoms and the mean numbers of mites found per shoot at the first ripe fruit stage, together with the high level of red berry disease on Loch Ness where no blackberry mite was found, corroborate the hypothesis that there is more than one cause of red berry disease: blackberry mite infestation and at least one other unknown cause. The form and slope of the relationships indicate that the varieties Loch Tay, Chester Thornless, and especially Carmel,were highly sensitive to blackberry mite: small numbers of mites causing large percentages of red berry disease. These findings indicate that, unless very small numbers of mites that cause a hypersensitive reaction were being missed by the visual inspection assessment method used (which seems unlikely in view of the large number of samples examined), there is another major cause of red berry disease, other than infestation by the blackberry mite, and that this other cause is of variable influence in different plantations and it is not affected by the acaricide spray treatments.

The results of year 1 of the project provided useful pointers to the effects of blackberry mite on red berry disease and its control. In 2011, a further acaricide trial was done to validate the findings and conclusions of 2010.

Objectives

The aim of this project is to develop effective and practical methods for monitoring and control of blackberry mite so preventing red berry disease. Specific objectives were to;

1. Identify effective acaricide products and best time(s) of treatment

Materials and methods

Pre-season assessment

Samples of 100 dormant buds were collected from No 5 blackberry plantation at Belks Farm, Otham, Maidstone on 1 March 2011. The buds were examined under the microscope scale by scale for the presence of mites and any found recorded.

Efficacy evaluation

A small plot replicated experiment was done in No 5 Blackberry plantation at Belks Farm, Otham, Maidstone in 2011 to evaluate the efficacy of acaricide spray treatments for control of blackberry mite, red berry disease and effects on yield.

Sites

The experiment was done in a commercial blackberry plantation at:
Belks Farm, Otham, Maidstone, Kent ME15 8RL; (by the kind agreement of Tim Chambers).
Located at National Grid Reference *TQ 188 802526*
Chester No 5, 1 tunnel 6.5 m x 6 m x 20 bays = 0.08 ha (4 reps)
National grid reference TQ 802526, Area 1.16 ha

Treatments

Treatments were programmes of sprays of products which experience in California, Koppert, the Netherlands, and the previous year's study had suggested were likely to be effective against red berry mite (Table 1).

Table 1. Treatments (spray volume 1000 l/ha)

Trt No.	**Product (s)**	**Timing†**
1	Sulphur	2 wk prog bud burst to mid-May
2	Codacide	2 wk prog mid-May to mid-ripe fruit‡
3	Dynamec + Break Thru S 240	2 sprays, the 1st at 5% flower the 2nd 2 weeks later
4	1+2	Both Treatment numbers 1 and 2
5	1+2+3	Both Treatment numbers 1, 2 and 3
6,7	Untreated	

† Interval to be adjusted according to blackberry mite numbers and incidence of red berry damage
‡ Cessation of programme to depend on degree of blackberry mite infestation, extent of red berry damage and occurrence of spray deposits on fruits, if any.

Products, their active ingredients and formulations and rates of use are given in Table 2. Numbers of sprays and their dates of application on the different varieties are given in Table 3.

Table 2. Products, their active ingredients and formulations and rates of use

Product	Active substance and formulation	Product dose rate (/ha)	Product concentration	Harvest interval (days)
Headland Sulphur	Sulphur 800 g/l SC	10 l	10 ml/l	0
Dynamec +	Abamectin 18 g/l EC	500 ml	0.5 ml/l	3
Break Thru S 240	Silicone wetter	1 l	1 ml/l	0
Codacide	Rape seed oil	25 l	25 ml/l	0

Table 3. Numbers of sprays and their dates of application in 2011

Farm	Belks Fm		
Variety	Chester		
	Sulphur	Dynamec	Codacide
No. sprays	4	2	5
Application dates	31 Mar 12 Apr 27 Apr 13 May		
			17 May
		1 Jun	1 Jun
		15 Jun	15 Jun
			29 Jun
			14 Jul

Experimental design and statistical analyses

A randomised complete block designs with four replicates of seven treatments including a double replicated untreated control were used. Plots were 8 m lengths of row arranged end to end in a block, two blocks per row. Because of difficulties of access for spraying, where there are three rows per tunnel, only the central row was sprayed, the other two rows acted as unsprayed guards.

Treatment application

Treatments were applied at a volume rate of 1000 l/ha using a CP15 knapsack sprayer with a hand lance (not air-assisted). This minimised inter-plot contamination by spray drift. 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). Applications were generally within 10% of required (Table 4). Though some larger deviation occurred, applications were all within 13% of target.

Table 4. Accuracy of spray application estimated from the amount of sprayate remaining in the spray tank after spray application

Date	A.I.	Accuracy of application (%) Trt No.				
		1	2	3	4	5
31 Mar	Sulphur	95			95	95
12 Apr	Sulphur	93			93	93
27 Apr	Sulphur	89			89	89
13 May	Sulphur	95			95	95
17 May	Codacide		87		87	87
01 Jun	Codacide		92		92	92
01 Jun	Abamectin			95		95
15 Jun	Codacide		92		92	92
15 Jun	Abamectin			93		91
29 Jun	Codacide		92		92	92
14 Jul	Codacide		90		90	90

Meteorological records

Dry and wet bulb temperature, wind speed and direction were recorded before and after each spray occasion (Table 5). RH% was estimated from the dry and wet bulb temperature readings. In addition, USB-502 loggers were used to take hourly temperature and humidity readings inside the polytunnel (Appendix 1).

Table 5. Weather conditions at the time of spray application

Date	Time	^{o}C dry	^{o}C wet	% rh	Kmph	DIR
31 Mar	11:40	12.5	12.5	100	2	SW
12 Apr	12:30	14.0	10.5	65	0	N/A
27 Apr	10:10	11.5	9.0	70	0	N/A
13 May	14:36	19.0	14.0	58	0	N/A
17 May	11:45	16.0	14.0	81	4	SW
01 Jun	10:07	17.5	12.5	55	0	N/A
15 Jun	09:00	17.5	15.0	81	0	N/A
29 Jun	09:15	17.0	14.0	72	0	N/A
14 Jul	10:15	16.5	14.0	76	0	N/A

Growth stage development

The growth stage of the crops was recorded fortnightly for the duration of the experiment (Table 6).

Table 6. Recording of growth stage of crops

Date	Growth stage
31 Mar	Dormant
12 Apr	Bud break
27 Apr	Full leaf
13 May	5% leaf
17 May	Pre flower
01 Jun	5% flower
15 Jun	50% flower
29 Jun	1st green fruit
14 Jul	50% green fruit
10 Aug	1st ripe fruit

Assessments

Mite population development on untreated: The development of the *A. essigi* populations on the untreated plots was monitored once in June, and all plots were assessed in August.

Effects of treatments on incidence of red berry disease: The percentage berries in each plot affected by red berry disease was estimated on six occasions through the harvesting period. Typical red berry disease symptoms are shown in Figure 1.

Figure 1. Typical red berry disease symptoms on cv Chester

Effects of treatments on yield and quality: At harvest the host grower picked the fruit from each plot and recorded the weight of marketable and discarded fruit.

Results and discussion

Efficacy of blackberry mite control

On 1 August 2011 at the first ripe fruit stage when counts were made, blackberry mites were found on all of the of Chester plots. Means of 13.03 and 9.40 mites were found per leaf petiole and per shoot base in the untreated plots, respectively (Table 7, Figure 2). ANOVA of the $\log_{10}(n+1)$ data showed highly significant treatment affects for both the mites per petiole and mites per shoot base data ($P < 0.001$). All the spray greatly reduced the mean numbers of mites per shoot and per petiole compared to the untreated controls but no individual spray treatment had consistently the lowest numbers of mites, so no obvious best treatment was apparent. The treatments on average reduced the numbers of mites per shoot base and per petiole by 96%.

Table 7. Mean no of blackberry mites found on shoot bases and on petioles at first ripe fruit on 1 August 2011.

	No. mites / shoot base	
	n	$Log_{10}(n+1)$
1. Sulphur	0.1	0.030*
2. Codacide	1.25	0.119*
3. Dynamec	0.1	0.030*
4 1+2	0	0.00*
5. 1+2+3	0.35	0.063*
6. Untreated	9.4	0.626
	Fprob	<0.001
	SED (131 df) – comparisons with control	0.0961
	SED (131 df) – other comparisons	0.1110
	LSD (P = 0.05) – comparisons with control	0.1901
	LSD (P = 0.05) – other comparisons	0.2195

No. mites / petiole		
	n	$Log_{10}(n+1)$
1. Sulphur	1.1	0.176*
2. Codacide	0.75	0.163*
3. Dynamec	0.1	0.030*
4 1+3	0.3	0.069*
5. 1+2+3	0.6	0.108*
6. Untreated	13.03	0.829
	Fprob	<0.001
	SED (131 df) – comparisons with control	0.0994
	SED (131 df) – other comparisons	0.1147
	LSD (P = 0.05) – comparisons with control	0.1965
	LSD (P = 0.05) – other comparisons	0.2270

*Significantly less than untreated control (P = 0.05)

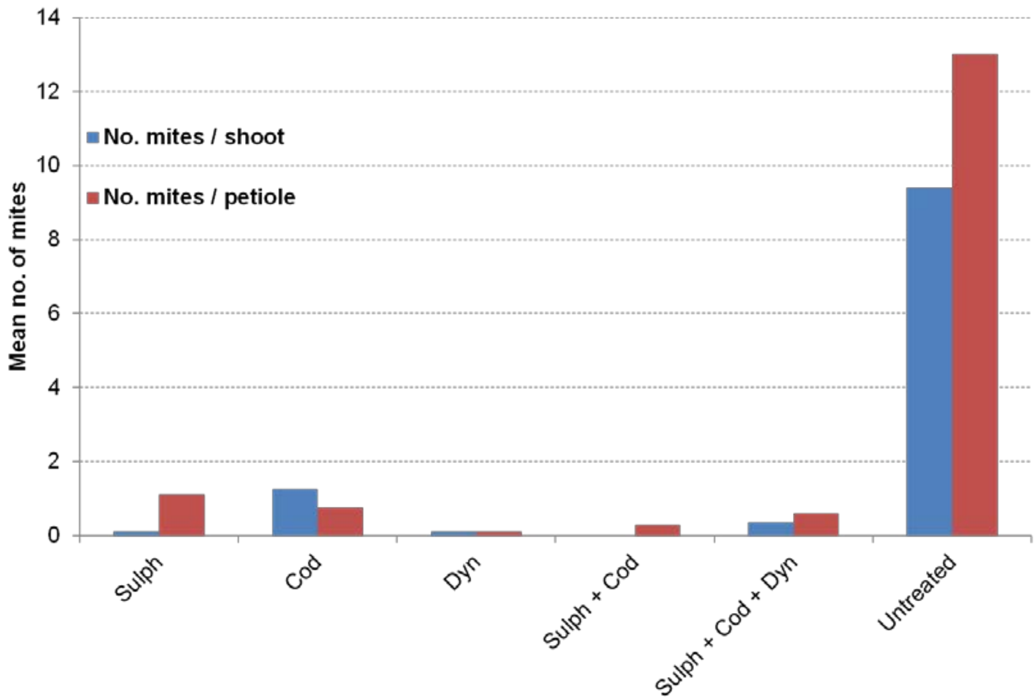

Figure 2. Mean no of blackberry mites found on shoot bases and on petioles at first ripe fruit on 1 August 2011.

Effects of treatments on incidence of red berry disease

The mean percentages of berries on the untreated control plots were 22.9, 16.4, 11.8, 10.4, 13.6 and 18.5% on 10, 22 August, 9, 23 September, 11 and October, respectively, and overall 17.3% of fruits on the untreated control showed red berry symptoms (Table 8). However, none of the treatments reduced the incidence of the disease on any assessment date or overall, as confirmed by the ANOVAs of the angular transformed data which had Fprob values all >>0.05 (Table 8). None of the treatments thus had any effect on the incidence of red berry symptoms.

Effects of treatments on yield and quality harvested by grower

A mean total of 127.9 punnets of blackberry fruits were harvested over 17 picks by the grower's staff between 12 August and 11 October 2011 on the untreated control plots. A mean of 41.3% of these had red berry symptoms (Table 9). However, none of the treatments significantly reduced the amounts of fruit harvested per plot or the % fruit which had red berry symptoms.

Table 8. Mean and mean angular transformed percentages of fruit showing red berry symptoms on six assessment dates between 10 August and 25 October 2011, and overall mean values.

Trt	10 August	22 August	9 September	23 September	11 October	25 October	Mean
			Mean percentage fruits showing red berry symptoms				
1. Sulphur	13.0	10.4	24.4	12.1	25.4	22.2	20.1
2. Codacide	29.1	22.0	11.3	11.0	19.7	9.4	20.7
3. Dynamec	9.0	18.6	17.1	10.3	20.5	6.0	15.5
4 1+3	33.7	15.0	21.6	10.1	33.9	17.4	24.5
5. 1+2+3	9.0	12.6	13.3	23.4	14.3	14.4	15.8
6. Untreated	22.9	16.4	11.8	10.4	13.6	18.5	17.3
			Angular transformed mean percentage fruits showing red berry symptoms				
1. Sulphur	17.2	15.5	28.7	19.3	27.9	24.2	25.0
2. Codacide	30.8	24.1	16.6	19.2	25.3	17.2	26.5
3. Dynamec	12.5	22.8	21.2	17.5	24.7	13.1	21.2
4 1+3	34.0	22.4	26.7	18.2	34.0	24.4	29.1
5. 1+2+3	15.1	18.0	18.6	27.6	20.8	19.4	22.3
6. Untreated	25.4	21.5	17.1	17.1	19.6	22.6	23.3
Fprob	0.238	0.936	0.526	0.372	0.417	0.534	0.723

Table 9. Mean % and angular transformed % punnets with red berry symptoms in total over 17 grower harvests between 12 August and 11 October

Treatment	Total punnets with red berry	Total no. punnets without red berry	Total no. of punnets	% punnets with red berry	Angular transformed % punnets with red berry
1. Sulphur	46.9	79.9	126.8	36.9	37.4
2. Codacide	45.9	90.9	136.8	33.9	35.6
3. Dynamec	48.6	82.9	131.5	37.3	37.6
4 1+3	54.6	71.6	126.2	43.5	41.2
5. 1+2+3	58.0	74.1	132.1	45.4	42.2
6. Untreated	50.4	77.5	127.9	41.3	39.9
Fprob			0.967	0.523	0.549

Conclusions

Blackberry mites were only found at the bases of the shoots or in the leaf petioles.

All the spray treatments evaluated gave very good control of blackberry mite, there being no statistically significant and consistent differences between treatments. All reduced mite numbers by 96% on average

There was a high incidence of red berry symptoms, an overall mean of 17.3% of fruit being affected by red berry symptoms on the untreated control plots. None of the treatments significantly reduced the incidence of red berry symptoms.

A mean of 129 punnets of blackberry fruits were harvested per untreated control plot (8 m length of row) by the grower between from 17 picks between 12 August and 11 October 2012. 41% of fruits were categorised as having red berry symptoms on these plots by the pickers. None of the treatments reduced the yield or the % fruits with red berry symptoms significantly.

Overall, these results confirm the findings of the project in year 1, that blackberry mite is not the sole cause of red berry symptoms and in this crop is was at best minor cause.

Control of the mites to a high standard did not result in a significant reduction in symptoms.

Acknowledgments

We are most grateful to Tim Chambers for hosting the trial and taking the harvest yield records.

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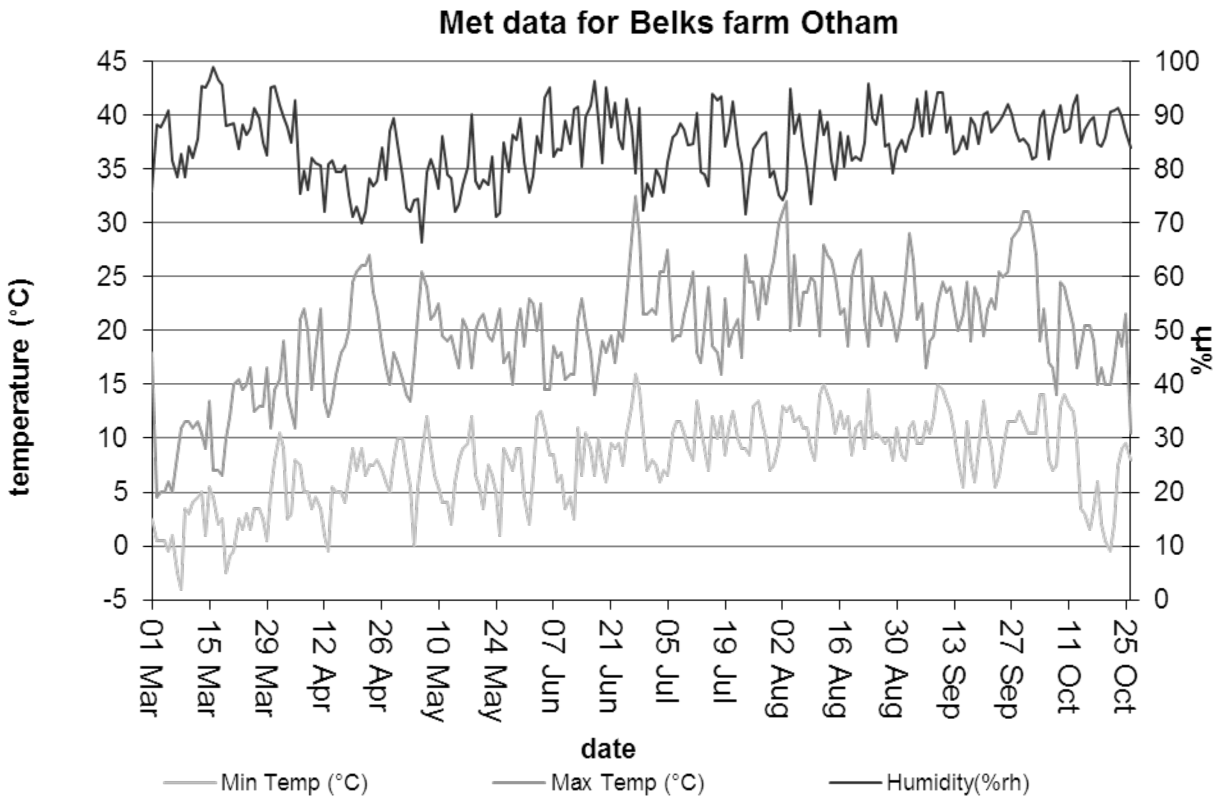
Appendix 1



Daily max/min temperature and relative humidity in tunnels at Belks Farm