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Apple: Evaluation of surfactants for the eradication of primary mildew

Headline

- **Silwet L-77 was the most consistently effective surfactant in reducing primary mildew compared to Activator 90 and LI 700.**
- **In general surfactants at the higher concentration of 3% were more effective in reducing primary mildew.**
- **The addition of the fungicides Nimrod (bupirimate), Systhane (myclobutanil) or Corbel (fenpropimorph) improved the efficacy of the surfactants but there was no difference in the effectiveness between the fungicides.**

Background and expected deliverables

Powdery mildew is one of the most important diseases of apple in the UK, reducing yield and quality on susceptible varieties. All the main UK culinary and dessert varieties are susceptible. Cox and Jonagold are especially susceptible.

The fungus overwinters as mycelium in fruit buds or vegetative buds that emerge as mildewed blossoms at pink bud or mildewed shoot tips at petal fall. Spores from these infect developing flowers, leaves and shoots and initiate the secondary mildew epidemic. During summer mildew spreads to developing shoots and under favourable conditions can infect leaves and produce sporing mildew colonies in about 4-5 days. Mildew colonises fruit buds in about June and vegetative buds at the end of extension growth in late summer where it remains quiescent until the following spring. Control of powdery mildew requires costly season-long fungicide programmes from pink bud in spring to the end of shoot growth in July. The success of these programmes is dependent on maintaining the overwintering primary mildew at a low level. In recent years the incidence of powdery mildew in orchards has increased, especially in the South East, partly through favourable weather in spring and summer and mild winters and partly from a reduction in the number of effective fungicides.

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Thus, in many orchards the incidence of primary mildew has risen, making mildew difficult to control and leading to intensive, costly fungicide programmes. In the 1970s, research at East Malling showed that surfactants applied in the dormant season could eradicate mildew from apple buds and hence eliminate primary mildew from orchards, improving mildew control the following spring and reducing the need for costly fungicide programmes. The research resulted in the development of Dormakill, an ICI product, for use in commercial orchards. Unfortunately this product is no longer available, but this approach to mildew control fits in with the zero pesticide residue strategy, being developed under Defra projects HH2502STF and HH3122STF, by targeting treatment in the dormant season. Recently a number of growers have tried various approved adjuvants as dormant season sprays to eradicate primary mildew, with mixed success. Since the original research at East Malling, considerable development has taken place in types of surfactants, particularly in the development of silicone-based surfactants. These may have increased penetration into the plant and may also be active at lower doses and less phytotoxic.

In year one of the project, eight different surfactants at concentrations of 1.5 or 3% were evaluated for efficacy in eradicating overwintering mildew from apple buds. Silwet L-77 was the most consistently effective surfactant in all three of the trials. Agral, Mixture B, Planet and Activator were also effective. In general, surfactants at the higher concentration of 3% were more effective with no significant effects on tree development or fruit set. There was also an indication that the treatments were more effective when applied at the higher volume of 1000L/ha compared to 500L/ha.

In year two of the project the following were explored:

1. The most effective surfactants (Silwet L-77 and Activator 90) were further evaluated with and without the addition of fungicides (Nimrod (bupirimate), Systhane (myclobutanil), Corbel (fenpropimorph)).

2. In addition LI 700, a penetrant, which was not included in year one evaluations, was tested.

3. The effect of spray volume was also evaluated.

Summary of project and main conclusions

In two replicated small plot orchard experiments, both on cv. Cox, the surfactants Silwet L-77, Activator 90 and LI 700, applied at 1% or 3% and with and without fungicides, were compared for their effectiveness in reducing or eliminating powdery mildew overwintering in buds on apple trees when applied as high volume sprays in January or February when the trees were fully dormant.

The fungicides included were Nimrod (bupirimate), Systhane (myclobutanil) and Corbel (fenpropimorph) (Table 1). In a separate small plot experiment on cv Cox the effect of spray volume (500, 1000 or 2000 L/ha) on efficacy of surfactants Silwet L-77 and Activator 90 was also evaluated.

The incidence of primary mildew was assessed on blossoms and vegetative shoots in May. Phytotoxicity of the treatments was also assessed as effects on tree development and on fruit set. Silwet L-77 was the most consistent of the three surfactants in reducing primary mildew.

In general the surfactants were more effective at 3% concentration. The addition of fungicides increased the efficacy of the surfactants in reducing primary mildew, but there was no difference between the fungicides.

There was no significant effect of spray volume on surfactant efficacy, but unfortunately rain fell (not forecast) soon after treatments were applied in this trial. This probably affected the efficacy of the surfactants and was reflected in the higher incidence of primary mildew overall in this trial compared to the other experiments.

None of the treatments appeared to have any significant effect on stage of tree development or fruit set.

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Table 1. **% buds at green cluster, % fruit set and primary mildew (blossom and vegetative) following treatment of Cox trees with various surfactants in February 2005. The surfactants were applied at 3% concentration and at 1000 L/ha**

Treatment	Conc. %	Fungicide	Fungicide rate L / ha	% fruit buds at green cluster in mid April	% fruit set in mid July	% primary blossom mildew	% veg shoots with primary mildew
untreated	-			44.4	26.0	8.2	8.1
Activator 90	1.0	-		54.8	30.7	11.7	13.4
Activator 90	1.0	Nimrod	1.4	36.9	21.3	**3.0**	4.6
Activator 90	1.0	Systhane	0.45	47.6	22.2	**3.3**	6.7
Activator 90	1.0	Corbel	1.0	51.9	16.1	5.3	6.6
Activator 90	3.0	-		74.2	21.8	**2.3**	5.2
Activator 90	3.0	Nimrod	1.4	36.8	19.1	**2.0**	4.4
Activator 90	3.0	Systhane	0.45	37.5	29.3	**1.3**	**2.5**
Activator 90	3.0	Corbel	1.0	18.2	26.7	**3.0**	**2.6**
Silwet L-77	1.0	-		48.6	19.1	**2.0**	**2.6**
Silwet L-77	1.0	Nimrod	1.4	54.3	21.8	**0.9**	**1.3**
Silwet L-77	1.0	Systhane	0.45	27.0	30.2	**3.0**	**1.0**
Silwet L-77	1.0	Corbel	1.0	43.1	21.8	**1.4**	**0.8**
Silwet L-77	3.0	-		43.3	22.0	**0.03**	**1.6**
Silwet L-77	3.0	Nimrod	1.4	68.2	24.8	**0.1**	**0.1**
Silwet L-77	3.0	Systhane	0.45	46.7	26.8	**0**	**2.4**
Silwet L-77	3.0	Corbel	1.0	28.7	25.7	**0.03**	**0.1**

Treatments in **bold** indicate treatments which show a significant difference (for $p<0.05$) compared to the untreated control

Financial benefits of the project

Effective control of powdery mildew in apple requires season-long fungicide programmes that are costly (approximately £300/ha). Failure to control mildew during the growing season results in a high incidence of primary mildew the following season, further reducing the chances of successful mildew control and leading to reductions in yield and fruit quality. The availability of a method of reducing primary mildew inoculum would enable mildew control to be restored and reduce the need for expensive intensive fungicide use in the growing season.

In addition to the cost of controlling mildew, orchards with a high incidence of mildew usually require fungicide use to continue near harvest with the risk of residues in the fruit. Such residues are usually below the maximum residue level permitted, but to many consumers the presence of any residue is unacceptable.

Under Defra-funded projects HH2502STF and HH3122STF, a zero pesticide residue strategy is being developed for apples. This strategy involves the use of conventional pesticides up to petalfall and after harvest, but only biocontrol agents during the fruit development period. Currently in this programme mildew control during the post blossom period (the main mildew epidemic period) is achieved by the use of sulphur while alternative approaches are being developed. The key to successful disease control in this strategy depends on maintaining overwintering inoculum at a very low level.

The availability of an effective means of eliminating mildew overwintering in the buds would contribute considerably to the success of the zero pesticide residue strategy. One drawback of this approach to mildew control could be cost. Surfactants, particularly organo silicon based products, are expensive. A comparison of the cost of Silwet L-77 versus Activator 90 is given in Table 2. The most consistently effective surfactant in eliminating overwintering mildew was Silwet L-77 applied at 3% and 1000L/ha. This would cost more than £1000 /ha.

These costs have to be considered against the cost of intensive fungicide programmes and/or physical removal to eliminate mildew. The cost of an intensive mildew programme based on mixtures of Stroby with Systhane alternating with Nimrod applied at 5-7 day intervals is around £385/ha. Reducing primary mildew would not eliminate the need to control mildew during the growing season, but would the opportunity to use reduced doses and cheaper products such as sulphur.

Table 2. Cost comparisons for Silwet L-77 versus Activator 90 at various concentrations and spray volumes

Product / Cost	Concentration %	Spray volume L/ha	Cost £ / ha
Silwet L-77 £38/L	1	500	190
	1	1000	380
	1	2000	760
	3	500	570
	3	1000	1140
	3	2000	2280
Activator 90 £6.40	1	500	32
	1	1000	64
	1	2000	128
	3	500	96
	3	1000	192
	3	2000	384

Action points for growers

- Given the costs the most effective treatment is uneconomic at this stage.
- Until the completion of the project there are therefore no action points at present.

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Science Section

Introduction

Powdery mildew is one of the most important diseases of apple in the UK, reducing yield and quality on susceptible varieties. All the main UK culinary and dessert varieties are susceptible. Cox and Jonagold are especially susceptible.

The fungus overwinters as mycelium in fruit buds or vegetative buds that emerge as mildewed blossoms at pink bud or mildewed shoot tips at petal fall. Spores from these infect developing flowers, leaves and shoots and initiate the secondary mildew epidemic. During summer mildew spreads to developing shoots and under favourable conditions can infect leaves and produce sporing mildew colonies in about 4-5 days. Mildew colonises fruit buds in about June and vegetative buds at the end of extension growth in late summer where it remains quiescent until the following spring**.** Control of powdery mildew requires costly season-long fungicide programmes from pink bud in spring to the end of shoot growth in July. The success of these programmes is dependent on maintaining the overwintering primary mildew at a low level. In recent years the incidence of powdery mildew in orchards has increased, especially in the South East, partly through favourable weather in spring and summer and mild winters and partly from a reduction in the number of effective fungicides. Thus in many orchards the incidence of primary mildew has risen, making mildew difficult to control and leading to intensive, costly fungicide programmes. In the 1970s, research at East Malling showed that surfactants applied in the dormant season could eradicate mildew from apple buds and hence eliminate primary mildew from orchards, improving mildew control the following spring and reducing the need for costly fungicide programmes. The research resulted in the development of Dormakill, an ICI product, for use in commercial orchards. Unfortunately this product is no longer available, but this approach to mildew control fits in with the zero pesticide residue strategy, being developed under Defra project HH2502STF and HH32 STF, by targeting treatment in the dormant season. Recently a number of growers have tried various approved adjuvants as dormant season sprays to eradicate primary mildew, with mixed success. Since the original research at East Malling considerable development has taken place in types of surfactants, particularly in the development of silicone-based surfactants. These may have increased penetration into the plant and may also be active at lower doses and less phytotoxic. In year one of the project eight different surfactants at concentrations of 1.5 or 3% were evaluated for efficacy in eradicating overwintering mildew from apple buds. Silwet L-77 was the most consistently effective surfactant in all three of the trials. Agral, Mixture B, Planet and Activator 90 were also effective. In general surfactants at the higher concentration of 3% were more effective and there was there were no significant effects on tree development or fruit set. There was also an indication that the treatments were more effective when applied at the higher volume of 1000L/ha compared to 500L/ha. In year two of the project the most effective surfactants were further evaluated with and without the addition of fungicides. Of the effective surfactants identified in year one it was decided to conduct year two experiments on Silwet L-77 and Activator. In addition LI 700, a penetrant, which was not included in year one evaluations, was tested. The effect of spray volume were also evaluated.

Overall objective: To evaluate the efficacy of surfactants in eradicating powdery mildew overwintering in apple buds

Specific objectives for year 2

1. To evaluate Silwet L-77, Activator 90and LI 700 with and without fungicide for their effectiveness in eradicating powdery mildew overwintering in apple buds.

2. To evaluate the effect of spray volume on the efficacy of surfactants in eradicating mildew.

Materials and Methods

In 2005, surfactants were evaluated in three experiments, all of which were in small plots in orchards. Two experiments were targeted at surfactant and fungicide and the third at the effect of spray volume. Experiments were conducted in January and February 2005 when trees were fully dormant.

Surfactant and fungicide experiments

Two Cox orchards (TL109, Rocks Farm, East Malling and CW120/121, East Malling main) both located at East Malling and known to have a high incidence of powdery mildew in 2004 and therefore expected to have a high incidence of overwintering mildew, were chosen for the experiments.

On 3 February 2005, single tree plots of Cox on MM106 rootstock (orchard TL109) were treated with Silwet L-77, Activator 90 or LI 700 at concentrations of 1 or 3% as shown in Table 1. LI 700 was included with and without bupirimate (Nimrod). An untreated control was included. Treatments were applied at 1000 L/ha using a Hardi MRY (pink Micron restrictor nozzle) motorised knapsack sprayer.

Table 1. Treatments applied to Cox trees in orchard TL109 for evaluation as eradicants of overwintering mildew in February 2005

Treatment	Concentration %	Fungicide	Fungicide rate /ha
1 untreated	-	-	-
2 Activator 90	1.0	-	-
3 Activator 90	3.0	-	-
4 Silwet L-77	1.0	-	-
5 Silwet L-77	3.0	-	-
6 LI 700	1.0	-	
7 LI 700	3.0	-	
8 LI 700	1.0	Nimrod (bupirimate)	1.4 L
9 LI 700	3.0	Nimrod (bupirimate)	1.4 L

On 2 February 2005, single tree plots of Cox on M9 rootstock (CW120/121) were treated with Silwet L-77 or Activator 90, at concentrations of 1 or 3%, with or without fungicides bupirimate (Nimrod), myclobutanil (Systhane) or fenpropimorph (Corbel). Treatments were applied at 1000L/ha using a Hardi MRY motorised knapsack sprayer. An untreated control was included.

In both experiments treatments were replicated four times in a randomised block design.

Table 2. **Treatments applied to Cox trees in orchard CW120/121 for evaluation as eradicants of overwintering mildew in February 2005**

Treatment	Concentration %	Fungicide	Active ingredient	Fungicide rate/ ha
1 untreated	-	-	-	
2 Activator 90	1.0	-	-	
3 Activator 90	1.0	Nimrod	bupirimate	1.4 L
4 Activator 90	1.0	Systhane	myclobutanil	0.45 L
5 Activator 90	1.0	Corbel	fenpropimorph	1.0 L
6 Activator 90	3.0	-	-	
7 Activator 90	3.0	Nimrod	bupirimate	1.4 L
8 Activator 90	3.0	Systhane	myclobutanil	0.45 L
9 Activator 90	3.0	Corbel	fenpropimorph	1.0 L
10 Silwet L-77	1.0	-	-	
11 Silwet L-77	1.0	Nimrod	bupirimate	1.4 L
12 Silwet L-77	1.0	Systhane	myclobutanil	0.45 L
13 Silwet L-77	1.0	Corbel	fenpropimorph	1.0 L
14 Silwet L-77	3.0	-	-	
15 Silwet L-77	3.0	Nimrod	bupirimate	1.4 L
16 Silwet L-77	3.0	Systhane	myclobutanil	0.45 L
17 Silwet L-77	3.0	Corbel	fenpropimorph	1.0 L

Effect of spray volume

On 26 January 2005, in a Cox orchard on M9 rootstock (CW109, East Malling Main), single tree plots were treated with Silwet L-77 or Activator at 3% concentration. Treatments were applied at 500, 1000 or 2000 L/ha using a Hardi MRY motorised knapsack sprayer (Table 3). An untreated control was included. All treatments were replicated four times in a randomised block design.

Assessments

In all trials, primary blossom mildew was assessed at pink bud or late blossom as percentage mildewed blossoms, on the whole tree by recording the total number of blossoms present and the number with powdery mildew. Similarly, at petal fall the percentage vegetative primary mildew was recorded from the total number of vegetative shoots on each tree and the number infected with mildew. In addition, the effect of treatments on tree development was recorded by noting the stage of development of 50 fruit buds on each tree plot prior to flowering. The effect of treatments on fruit set was assessed by recording the total number of flowers on two marked branches and then later in June the resulting number of fruits. Any obvious phytotoxicity resulting from treatments, such as leaf distortion, flower distortion or leaf discoloration, was also noted.

Table 3. Treatments applied to Cox trees in orchard CW109 for effect of spray volume on efficacy of surfactants at 3% concentration as eradicants of overwintering mildew in January 2005

Treatment	Concentration %	Spray volume L/ha
1 untreated	-	-
2 Activator 90	3.0	500
3 Activator 90	3.0	1000
4 Activator 90	3.0	2000
5 Silwet L-77	3.0	500
6 Silwet L-77	3.0	1000
7 Silwet L-77	3.0	2000

Statistical analysis

The data was analysed using ANOVA, following angular transformation.

Results and Discussion

Surfactant and fungicide experiments

Orchard TL109

Overall, the treatments applied significantly reduced the incidence of primary blossom mildew compared to the untreated control (p= 0.015) (Table 4). However, there was no evidence of any overall significant difference (p=0.891) between the surfactant concentrations of 1 and 3%. There was no significant difference (p=0.240) in the incidence of primary blossom mildew between the three surfactants. However, the incidence of primary blossom mildew was much lower on plots treated with Silwet L-77 at 1 or 3% concentration than on plots treated with the other surfactants. The incidence of primary blossom mildew on plots treated with either concentration of Silwet L-77 was also significantly less than that on untreated plots (Table 4).

Overall, treatments applied significantly reduced the incidence of primary vegetative mildew compared to the untreated control (p=< 0.001) (Table 4). There were also significant

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differences in mildew incidence between surfactants (p=0.036) and between surfactant concentration (p=0.010). The incidence of primary vegetative mildew was always least on plots treated with the higher surfactant concentration. The lowest incidence of primary vegetative mildew was recorded on plots treated with Activator 90 at 3% and the highest incidence on plots treated with LI700 + Nimrod (Table 4).

There were no significant effects of treatments on tree development or on fruit set. No signs of phytotoxicity were observed.

<u>Orchard CW120 / 121</u>

Overall, treatments significantly reduced the incidence of primary blossom mildew compared to the untreated control (Table 5) except for plots treated with Activator 90 at 1% concentration. In general the incidence of primary blossom mildew was significantly lower on plots treated with Silwet L-77 compared to Activator 90 (p=<0.001) and generally the higher concentration of Silwet L-77 was more effective. In general, there were no overall differences in the incidence of primary blossom mildew between fungicide treatments (p=0.4). Although not significantly different, the incidence of primary blossom mildew was in general lower where a fungicide had been included with the surfactant.

Overall, the incidence of primary vegetative mildew was significantly reduced on treated plots compared to the untreated control (Table 5). In general plots treated with Silwet L-77 had significantly lower primary vegetative mildew compared to the untreated control and plots treated with Activator 90 (p<0.001). The higher concentration of Silwet L-77 was significantly more effective in reducing primary vegetative mildew than the lower concentration. The addition of fungicide significantly improved the effectiveness of the surfactants (p=0.032).

There was no significant effect of treatments on tree development or fruit set. No obvious signs of phytotoxicity were observed.

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Table 4. **% buds at green cluster, % fruit set and primary mildew (blossom and vegetative) following treatment of Cox trees with various surfactants in February 2005. Figures shown are back-transformed (%) scale and figures in brackets are angular transformations**

Treatment	Conc. %	% fruit buds at green cluster in mid April	% fruit set in mid July	% primary blossom mildew	*No. veg shoots with primary mildew
untreated	-	87.3 (69.1)	16.1 (23.7)	6.7 (15.0)	8.5 (17.0)
Activator 90	1.0	86.7 (68.6)	20.7 (27.1)	3.3 (10.5)	2.6 (9.3)
Activator 90	3.0	91.4 (73.0)	19.2 (26.0)	1.3 (6.6)	0.6 (4.5)
Silwet L-77	1.0	91.3 (72.8)	23.7 (29.1)	0.6 (4.3)	2.5 (9.2)
Silwet L-77	3.0	99.2 (84.9)	15.2 (22.9)	0.6 (4.5)	1.4 (6.8)
LI 700	1.0	91.1 (72.7)	17.3 (24.6)	3.4 (10.6)	2.8 (9.7)
LI 700	3.0	88.1 (69.8)	19.5 (26.2)	2.2 (8.4)	1.9 (7.9)
LI 700 + Nimrod	1.0	85.1 (67.3)	17.2 (24.5)	1.1 (6.1)	4.8 (12.7)
LI 700 + Nimrod	3.0	90.2 (71.8)	15.8 (23.4)	3.6 (10.9)	3.0 (10.0)
F prob		(0.571)	(0.600)	(0.015)	(<0.001)
SED		(6.1)	(3.4)	(2.8)	(1.6)
LSD (p=0.05)		(12.6)	(7.0)	(5.7)	(3.2)

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Table 5. **% buds at green cluster, % fruit set and primary mildew (blossom and vegetative) following treatment of Cox trees with various surfactants in February 2005. Figures shown are back-transformed (%) scale and figures in brackets are angular transformations**

Treatment	**Conc. %**	**Fungicide**	**% fruit buds at green cluster in mid April**	**% fruit set in mid July**	**% primary blossom mildew**	***No. veg shoots with primary mildew**
untreated	-		44.4 (41.8)	26.0 (30.7)	8.2 (16.6)	8.1 (16.5)
Activator 90	1.0	-	54.8 (47.8)	30.7 (33.7)	11.7 (20.0)	13.4 (21.5)
Activator 90	1.0	Nimrod	36.9 (37.4)	21.3 (27.5)	3.0 (10.0)	4.6 (12.3)
Activator 90	1.0	Systhane	47.6 (43.6)	22.2 (28.1)	3.3 (10.5)	6.7 (15.0)
Activator 90	1.0	Corbel	51.9 (46.1)	16.1 (23.7)	5.3 (13.3)	6.6 (14.8)
Activator 90	3.0	-	74.2 (59.5)	21.8 (27.8)	2.3 (8.8)	5.2 (13.2)
Activator 90	3.0	Nimrod	36.8 (37.3)	19.1 (25.9)	2.0 (8.0)	4.4 (12.1)
Activator 90	3.0	Systhane	37.5 (37.8)	29.3 (32.8)	1.3 (6.6)	2.5 (9.1)
Activator 90	3.0	Corbel	18.2 (25.3)	26.7 (31.1)	3.0 (10.0)	2.6 (9.2)
Silwet L-77	1.0	-	48.6 (43.9)	19.1 (25.9)	2.0 (8.1)	2.6 (9.2)
Silwet L-77	1.0	Nimrod	54.3 (47.5)	21.8 (27.8)	0.9 (5.5)	1.3 (6.6)
Silwet L-77	1.0	Systhane	27.0 (31.3)	30.2 (33.4)	3.0 (9.9)	1.0 (5.8)
Silwet L-77	1.0	Corbel	43.1 (41.1)	21.8 (27.9)	1.4 (6.9)	0.8 (5.1)
Silwet L-77	3.0	-	43.3 (41.2)	22.0 (28.0)	0.03 (1.0)	1.6 (7.2)
Silwet L-77	3.0	Nimrod	68.2 (55.7)	24.8 (29.9)	0.1 (2.1)	0.1 (2.2)
Silwet L-77	3.0	Systhane	46.7 (43.1)	26.8 (31.2)	0 (0)	2.4 (9.0)
Silwet L-77	3.0	Corbel	28.7 (32.4)	25.7 (30.5)	0.03 (1.0)	0.1 (1.4)
F prob			(0.983)	(0.657)	(0.003)	(0.012)
SED			(6.9)	(3.6)	(2.9)	(2.6)
LSD (p=0.05)			(13.8)	(7.2)	(5.7)	(5.3)

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Effect of spray volume – Orchard CW109

Treatments were applied on 26 January 2005. Unfortunately, despite a dry forecast there was heavy drizzle in late afternoon following treatment and light rain the following days (see appendix). The overall effect of the surfactants in reducing primary mildew compared to the other trials where conditions following treatment were dry, was therefore very much reduced.

Overall, treatment with surfactants significantly reduced the incidence of primary blossom mildew compared to the untreated, although the actual incidence of primary mildew was still relatively high (Table 6). Silwet L-77 was more effective in reducing primary blossom mildew compared to Activator 90 ($p=0.014$), but there was no significant effect of spray volume on effectiveness of the surfactants. This is in contrast to previous results from 1970s (Bent et al, 1977) and probably due to the rain soon after treatment application.

The results for the effect of treatments on primary vegetative mildew were similar with Silwet L-77 overall more effective in reducing primary mildew than Activator 90. In general there was no significant effect of spray volume on the incidence of primary vegetative mildew but Silwet L-77 at the highest spray volume of 2000L/ha was significantly more effective than other treatments except for Silwet L-77 at 1000L/ha.

There was no significant effect of treatments on tree development or fruit set.

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Table 6. % buds at green cluster, % fruit set and primary mildew (blossom and vegetative) following treatment of Cox trees on M9 rootstock (CW109) with surfactants Activator 90 or Silwet both at 3% concentration at three different spray volumes – 500, 1000 or 2000 L/ha in January 2005 a. Figures shown are back-transformed (%) scale and figures in brackets are angular transformations

Treatment	Spray volume L/ha	% fruit buds at green cluster in mid April	% fruit set in mid July	% primary blossom mildew	% veg shoots with primary mildew
untreated	-	77.7 (61.8)	20.8 (27.1)	13.0 (21.1)	14.1 (22.1)
Activator 90	500	75.9 (60.6)	31.5 (34.1)	9.2 (17.7)	11.5 (19.8)
Activator 90	1000	78.9 (62.7)	14.5 (22.4)	12.2 (20.5)	16.5 (24.0)
Activator 90	2000	80.2 (63.6)	16.3 (23.8)	8.8 (17.2)	14.1 (22.0)
SilwettL-77	500	81.6 (64.6)	16.1 (23.7)	6.4 (14.7)	10.9 (19.3)
Silwet L-77	1000	90.0 (71.5)	19.1 (25.9)	6.4 (14.6)	9.8 (18.2)
Silwet L-77	2000	77.1 (61.4)	18.8 (25.7)	2.6 (9.3)	4.3 (12.0)
F prob		(0.692)	(0.748)	(0.061)	(0.236)
SED		(5.6)	(3.7)	(2.7)	(2.3)
LSD (p=0.05)		(11.8)	(7.7)	(5.7)	(4.9)

General discussion

The experiments conducted in year two confirm the effectiveness of Silwet L-77 as the most effective of the surfactants in reducing primary mildew and that surfactants were more effective at the higher concentration. The use of fungicides improved the efficacy of the surfactants offering the possibility of using the surfactant at lower concentration. Surfactants, especially Silwet L-77 are expensive and concentration and spray volume (Table 7) used will have a significant impact on the cost effectiveness of such treatments.

Table 7. **Cost comparisons for Silwet L-77 versus Activator 90 at various concentrations and spray volumes**

Product/Cost	Concentration %	Spray volume L/ha	Cost £ / ha
Silwet L-77 £38/L	1	500	190
	1	1000	380
	1	2000	760
	3	500	570
	3	1000	1140
	3	2000	2280
Activator 90 £6.40	1	500	32
	1	1000	64
	1	2000	128
	3	500	96
	3	1000	192
	3	2000	384

Conclusions

- The surfactant Silwet L-77 was more effective in reducing primary mildew than Activator 90 and LI 700. LI 700 was less effective than Activator 90, but not significantly so.

- In general surfactants at the higher concentration of 3% were more effective in reducing primary mildew than at 1% concentration.

- The addition of fungicides improved the effectiveness of the surfactants in reducing primary mildew, but there was no difference between fungicides.

- The incidence of primary mildew was lower on plots treated with fungicide and surfactants at the higher concentration but this was not significantly lower than primary mildew incidence on plots treated with fungicides and surfactants at the lower concentration.

- The effect of spray volume on the efficacy of surfactants in reducing primary mildew was inconclusive, although Silwet L-77 (3% concentration) applied at 2000L/ha was the most effective treatment in reducing primary mildew compared to other treatments.

- The importance of dry weather after treatment application for the surfactants to be effective is confirmed.

Future work

- In year three of the project the effect of spray volume on surfactant efficacy in reducing primary mildew will be re-examined in large plot trials as the experiments in 2005 were inconclusive.

- The best surfactant fungicide combinations identified in year two trials will evaluated in large plot orchard trials. Treatments will be applied using tractor trailed orchard airblast sprayers.

Technology transfer

Growers have been informed of the project, but no data has yet been presented as the project is at an early stage.

References

Bent, K J, Scott, P D & Turner, J A W (1977). Control of apple powdery mildew by dormant-season sprays: Prospects for practical use. *Proceedings 1977 British Crop Protection Conference – Pests and Diseases*, pp 331-339

APPENDIX

Weather data for East Malling January and February 2005

METSTD										
DATED	DRY BULB	WET BULB	TEMP MAX	TEMP MIN	GRASS MIN	CONC MIN	_STEMP10	_ETEMP30	_RAINFALL	_SUNSHINE
1-Jan-2005	7.30	5.90	12.00	5.50	-0.90	2.40	5.50	6.20	1.00	0.00
2-Jan-2005	4.50	2.50	7.70	4.10	1.10	1.40	3.00	6.10	0.00	5.00
3-Jan-2005	4.70	4.20	9.90	3.00	-1.60	-0.30	2.00	5.00	0.00	4.50
4-Jan-2005	9.90	7.80	11.00	4.70	0.20	1.80	6.50	5.90	1.60	0.60
5-Jan-2005	1.90	1.80	8.90	1.10	-3.10	-0.60	2.60	5.90	0.40	0.40
6-Jan-2005	6.30	5.70	12.50	1.90	-0.90	0.40	4.10	5.70	0.00	3.10
7-Jan-2005	12.40	10.70	12.90	6.20	3.90	4.40	8.80	6.90	1.60	0.10
8-Jan-2005	10.00	7.40	10.20	9.60	6.50	7.60	8.20	8.00	0.00	4.20
9-Jan-2005	7.80	6.80	12.90	5.10	0.50	2.70	4.20	6.60	0.40	1.40
10-Jan-2005	12.30	10.80	12.30	7.80	5.50	5.60	9.40	7.80	4.80	0.00
11-Jan-2005	9.70	8.70	12.50	8.00	2.70	5.10	7.80	8.00	2.60	0.10
12-Jan-2005	6.80	5.00	10.20	6.30	2.10	3.60	5.30	7.90	0.00	5.60
13-Jan-2005	4.40	3.00	8.60	2.70	-1.60	-0.40	2.30	6.50	0.00	6.60
14-Jan-2005	-1.10	-1.00	8.50	-2.00	-5.20	-2.30	1.50	5.10	0.00	7.00
15-Jan-2005	6.40	5.80	10.00	-1.10	-3.00	-1.20	4.90	5.20	0.20	1.70
16-Jan-2005	3.30	3.20	9.90	1.00	-2.50	-0.60	2.10	5.40	0.00	3.20
17-Jan-2005	9.60	8.20	10.10	3.30	-0.80	0.40	5.20	5.60	2.00	0.30
18-Jan-2005	3.10	2.00	7.60	3.00	0.40	1.80	3.90	6.20	0.00	4.30
19-Jan-2005	4.60	3.00	11.80	2.00	-2.00	-0.60	1.90	5.30	0.00	2.30
20-Jan-2005	11.80	10.10	13.30	4.60	0.10	1.70	6.10	5.90	0.20	1.40
21-Jan-2005	6.10	3.90	8.40	5.40	1.40	2.70	4.40	7.00	0.00	5.60
22-Jan-2005	0.00	-0.40	7.40	-1.90	-6.80	-3.60	2.00	5.80	0.20	5.80
23-Jan-2005	2.10	1.10	6.10	-0.10	-3.50	-1.70	1.70	5.20	0.00	7.40
24-Jan-2005	1.70	0.80	4.00	1.20	-1.20	-0.10	1.60	4.50	0.60	3.30
25-Jan-2005	2.50	2.00	5.50	1.30	-1.20	-0.10	2.20	4.20	0.20	3.80
26-Jan-2005	1.50	0.10	4.50	0.30	-2.50	-1.40	1.00	3.80	0.20	3.00
27-Jan-2005	4.50	3.50	7.00	0.70	-3.80	-1.60	2.40	3.60	1.80	0.10
28-Jan-2005	5.80	5.30	7.00	4.50	3.50	4.10	4.80	4.60	5.20	0.00
29-Jan-2005	4.70	4.20	7.60	4.50	2.70	3.60	4.50	5.10	1.40	1.20

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METSTD										
DATED	DRY BULB	WET BULB	TEMP MAX	TEMP MIN	GRASS MIN	CONC MIN	_STEMP10	_ETEMP30	_RAINFALL	_SUNSHINE
30-Jan-2005	6.20	5.10	7.90	4.70	3.30	4.60	5.10	5.50	0.00	1.00
31-Jan-2005	6.80	5.70	10.40	5.50	1.20	3.40	5.00	5.80	0.20	3.70
1-Feb-2005	6.70	5.40	8.70	6.10	3.60	4.60	6.20	6.60	0.40	2.50
2-Feb-2005	6.10	4.60	8.30	5.90	4.80	5.70	6.30	6.70	0.20	1.00
3-Feb-2005	6.60	6.30	10.10	4.80	-1.10	2.50	5.30	6.40	0.00	0.70
4-Feb-2005	6.90	6.80	9.80	6.20	3.40	5.70	6.60	6.80	0.00	0.40
5-Feb-2005	4.10	3.20	6.80	0.80	-3.00	-0.10	4.50	6.80	0.20	0.60
6-Feb-2005	6.50	5.80	9.70	3.30	-0.70	2.00	5.40	6.30	0.00	4.20
7-Feb-2005	1.60	1.50	9.70	-1.90	-5.40	-2.90	1.80	5.70	0.20	8.40
8-Feb-2005	4.20	4.20	9.80	-1.50	-4.80	-2.10	2.60	4.90	0.20	2.50
9-Feb-2005	6.90	6.60	10.10	2.00	-2.10	0.20	3.60	5.20	0.60	1.70
10-Feb-2005	10.10	8.90	11.10	6.90	3.80	5.30	7.20	6.20	4.40	0.00
11-Feb-2005	6.20	5.60	13.00	5.60	4.70	5.80	7.00	7.20	1.40	0.60
12-Feb-2005	13.00	11.10	14.00	6.20	6.70	7.20	9.70	7.90	3.20	2.00
13-Feb-2005	4.40	2.60	6.40	3.70	1.50	2.80	4.60	7.20	2.00	4.50
14-Feb-2005	3.70	1.20	6.40	2.60	-0.50	0.70	2.70	6.00	0.00	2.40
15-Feb-2005	2.60	1.40	6.30	1.30	-1.60	-0.60	1.80	5.20	0.00	5.40
16-Feb-2005	2.60	1.20	4.00	2.60	0.00	1.10	2.60	5.00	0.00	0.00
17-Feb-2005	1.70	0.20	5.90	-0.80	-3.70	-2.00	1.90	4.50	0.00	0.00
18-Feb-2005	5.80	5.20	9.40	1.70	2.60	2.70	4.80	5.10	1.20	4.60
19-Feb-2005	3.30	1.10	5.40	2.80	-0.60	0.70	3.00	5.50	0.00	4.90
20-Feb-2005	0.80	0.50	4.50	-0.30	-3.00	-1.80	1.00	4.40	0.00	2.90
21-Feb-2005	1.50	0.70	5.40	0.70	-1.30	-0.20	2.00	4.00	1.40	3.00
22-Feb-2005	2.10	0.40	4.00	-0.60	-2.90	-2.20	1.30	4.00	1.40	2.10
23-Feb-2005	-0.20	-0.30	2.10	-0.90	-2.20	-1.40	1.10	3.60	3.00	1.80
24-Feb-2005	0.90	0.70	2.40	-0.30	-0.10	0.30	1.20	3.50	4.20	0.00
25-Feb-2005	0.50	0.00	3.40	-3.00	-5.50	-3.70	0.70	2.90	0.20	4.70
26-Feb-2005	2.10	1.80	6.40	0.00	-1.70	-0.70	1.70	3.10	1.60	2.10
27-Feb-2005	-0.60	-0.70	1.90	-0.90	-1.80	-1.00	1.20	3.50	1.20	3.60
28-Feb-2005	0.10	-0.40	2.90	-5.60	-7.30	-5.80	0.40	2.80	0.00	7.40

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