Project title	Apples: Increasing the efficacy of potassium hydrogen carbonate (potassium bicarbonate) for powdery mildew control by a range of adjuvants and sulphur.
Project number:	TF 186
Project leader:	James Carew, Farm Advisory Services Team Ltd.
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DISCLAIMER:

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GROWER SUMMARY

Headline

- Effective control of apple powdery mildew can be achieved through a combination of the use of potassium bicarbonate's eradicant properties with the protectant properties of a *Bacillus subtilis* product.

Background and expected deliverables

Powdery mildew (*Podosphaera leucotricha*) in apple is a regular problem in many orchards. Conventional control relies on synthetic fungicides and cultural practices such as cutting out primary mildew. These methods can be time consuming and expensive, so alternative methods of control are being sought.

One alternative method is the use of potassium bicarbonate which has eradicant properties. Experience of its use in other crops suggests that repeated applications are required as it is not persistent and offers no protection from infection.

The aim of this project was to assess the efficacy of potassium bicarbonate at eradicating powdery mildew infection on apple.

The expected deliverables from the project include:

- The assessment of the efficacy of potassium bicarbonate at controlling apple powdery mildew.

- The assessment of the physical compatibility of potassium bicarbonate with a range of adjuvants and alternative protectant fungicides.

- The assessment of the effect of different combinations of products and adjuvants at gaining effective control of apple powdery mildew.

Regarding this final point, improving the use and efficacy of potassium bicarbonate may help to give greater control of powdery mildew in apple orchards. This naturally occurring substance has a low risk of pathogen resistance because it acts by dehydrating the mildew mycelia and is therefore likely to be used in the long term. If increased control of powdery mildew is achieved through the use of adjuvants or sulphur, this will help to protect potassium bicarbonate from resistant strains of powdery mildew arising.

Summary of the project and main conclusions

The first part of the project assessed the physical compatibility of potassium bicarbonate with Flowable Sulphur, Nu-Film-17 (pinolene based), Nu-Film-P (pinolene based) and Slippa (silicon based). At label recommended rates, no physical incompatibility problems occurred with any of the products tested.

The second part of the project assessed the effect of combinations of these adjuvants and products, along with a *Bacillus subtilis* product, on the occurrence of powdery mildew over two seasons, using Cox as the standard variety. Sixteen treatment combinations (Table 1) were applied to a Cox orchard and the effect on powdery mildew was recorded.

Potassium bicarbonate and sulphur applications were made at pink bud and petal fall (as recommended in HDC project CP 48). The *Bacillus subtilis* product was applied at the same time and also one week after petal fall.

Each treatment was applied to blocks of five trees and replicated four times in a randomized block experiment.

Table 1: Treatment combinations

	None	Nu-Film-17 (1ml/L)	Nu-Film-P (1ml/L)	Slippa (1ml/L)
Potassium bicarbonate (15g/L)	1	2	3	4
Potassium bicarbonate (15g/L) + Flowable Sulphur (5.5ml/L)	5	6	7	8
Potassium bicarbonate (15g/L) + *Bacillus subtilis* product (20ml/L)	9	10	11	12
None	13	14	15	16

Assessments of powdery mildew were made weekly until the end of July. In the first year, leaves were selected randomly and assessed for the presence or absence of mildew. In the second year, the percentage of new shoots showing symptoms of mildew was recorded.

In all treatments, powdery mildew levels increased throughout the season. However those treatments that did not include potassium bicarbonate had greater levels of the disease present at the first observation (4-5%) than the treatments where potassium bicarbonate was applied (0-2%). Treatments where the *Bacillus subtilis* product was applied with potassium bicarbonate had the lowest initial levels of inoculum present (0-1%).

The addition of Flowable Sulphur to potassium bicarbonate did not improve control compared to potassium bicarbonate alone. In both cases incidence increased equally to the end of the assessments. For these two treatments, the use of any of the adjuvants did not appear to enhance the action in reducing mildew.

Where a *Bacillus subtilis* product was added to potassium bicarbonate, a reduced incidence of mildew was observed, but only in the first year of the project. Potassium bicarbonate is an eradicant with no protectant properties whereas the *Bacillus subtilis* product acts as a protectant. The initial reduction in mildew levels due to the potassium bicarbonate was enhanced by use of a protectant which resulted in a continued low level of infection rather than an escalating one.

Disease levels were greatest where potassium bicarbonate was not applied at all and only the individual adjuvants were applied. There was an indication that where the two pinolene products (Nu-Film-P and Nu-Film-17) were applied, initial levels of mildew were reduced compared to where the silicon based product (Slippa) was applied and to the control where nothing was applied. However, this difference was not statistically significant.

It is apparent that potassium bicarbonate has an effect on the observed incidence of powdery mildew in apple, effectively reducing incidence of the disease. It is also apparent from the results that although initial levels are controlled, after the use of potassium bicarbonate has stopped, incidence of the disease can then increase as the potassium bicarbonate offers no protectant action.

The addition of sulphur, Nu-Film-P, Nu-Film-17 or Slippa did not increase efficacy of potassium bicarbonate in controlling powdery mildew. However the use of a Bacillus subtilis product increased control of the disease.

From these results it can be seen that it is important to reduce initial disease inoculum through the use of potassium bicarbonate early in the season. Additional use of a *Bacillus subtilis* product as a protectant can help to reduce disease levels through the season.

It is surmised that effective control of powdery mildew can be achieved by continued use of potassium bicarbonate to eradicate inoculum coupled with a protectant product (*Bacillus subtilis*) later into the season to maintain protection.

Financial benefits

Good control of apple powdery mildew is essential if apple producers are to attain the necessary yields of Class 1 fruit to remain commercially viable. The results of this project have identified sustainable control measures.

Action points for growers

- Use potassium bicarbonate to eradicate occurrences of powdery mildew in apple.

- Use a *Bacillus subtilis* product as a protectant for powdery mildew in apple.

- The *Bacillus subtilis* product Serenade ASO currently has a Specific Off-Label Approval (SOLA) for use on apples. This expires in November 2012.

SCIENCE SECTION

Introduction

Powdery mildew is one of the most serious and important diseases of all temperate fruit crops. It is widespread and is a perennial problem for apple growers in the U.K. Commercial control has been achieved through the regular use of a range of fungicides at 7 to 10d intervals combined with cultural control such as pruning out mildewed shoots. However, pressure from retailers to reduce pesticide use and the potential loss of registered fungicides, together with the cost of these control methods, gives the aim of residue free control of mildew an urgency that wasn't present 10 years ago.

One alternative method of control is through the use of potassium bicarbonate, which acts as an eradicant fungicide. However repeated applications are required as potassium bicarbonate is not persistent and has no protectant properties. The project described here therefore aimed to determine the efficacy of potassium bicarbonate on its own or in combination with sulphur or Serenade on the presence of powdery mildew of apple using the variety Cox.

The efficacy of potassium bicarbonate against powdery mildew has been investigated for a range of horticultural crops including apple (HDC Project CP 48) and recommendations on spray volume and timing were made. However it has been found that control is often less than 100%. As there were no specific recommendations for the addition of adjuvants in apple there is potential to improve the efficacy of potassium bicarbonate in the control of powdery mildew.

The life cycle of powdery mildew in apple has been well described. In spring the overwintered mildew can be seen developing on newly expanded leaves from which conidia disperse in air and initiate sites of secondary infections on growing shoots (Burchill, 1960). Secondary infections then effectively continue to develop as leaf wetness is not required for development of infection (Butt, 1978). Powdery mildew can infect apple leaves, flowers and fruit but the foliage of new terminal shoots are particularly sensitive where the disease is first seen on the underside of the leaves as grey felt like patches (Grove *et al*., 2003).

The importance of mildew is not only that it is so widespread but also that the effect on yield can be significant. For example, Yoder (2000) tested the effect of controlling mildew using fungicides on yield in the apple variety ‘Ginger Gold’ which was selected as it is particularly sensitive to mildew. The combination of fungicides which resulted in the greatest reduction in mildew severity also caused the greatest increase in yield, an increase of around 200% when compared to the untreated control trees. The effect on yield is partly due to loss of marketable fruit. With pressure from retailers reducing the allowable level of russet, this will only become more important. Mildew also reduces the efficiency of photosynthesis. A reduction in rate of photosynthesis from 13 to 5mg$CO^2dm^2hr^{-1}$ has been observed when trees are inoculated with powdery mildew (Ellis *et al*., 1981). In this study it was shown that whilst the tree may appear to resume normal growth following treatment, the photosynthesis rate of individual leaves never did. This supports the argument that prevention is better than cure.

There have been a number of reports of the effect of potassium bicarbonate on mildew in various crops recently but only a few have examined its effect on apple powdery mildew. Cromwell and Morgan (2009) working with the apple variety “Empire” compared the effect of potassium bicarbonate with conventional fungicides. The effect was limited with marketable yield only being 40% of the fungicide treatment. In work on cucurbit species potassium bicarbonate did affect the severity of powdery mildew but repeated applications were necessary and conventional fungicides were still four times as effective (McGrath and Shishkoff, 1999). In grape potassium bicarbonate reduced powdery mildew of grape leaves during the two weeks following application. Disease severity was reduced by 39% after one week and by 80% after two weeks. It is possible though that this reduction was more due to an increase in the control level of powdery mildew two weeks following application when compared to the unsprayed control (Schilder *et al*., 2008). So in the limited published data available potassium bicarbonate has been shown to affect the development of powdery mildews in a range of crops but sufficient data is not available to optimize its use in apple.

This project firstly assessed the physical compatibility and then efficacy against powdery mildew of potassium bicarbonate with a range of adjuvants and sulphur to affect an improved control of powdery mildew in apple. In addition to these treatments a *Bacillus subtilis* treatment (Serenade) was applied in combination with potassium bicarbonate to provide protectant and eradicant modes of action.

Improved efficacy of potassium bicarbonate would give greater control of powdery mildew in apple orchards. This naturally occurring substance has a low risk of the development of pathogen resistance and therefore is likely to be used in the long term, particularly if greater control of powdery mildew is achieved through the use of adjuvants or sulphur.

Materials and Methods

In 2008 the physical compatibility of potassium bicarbonate with Flowable Sulphur, Nu-Film-17 (pinolene based), Nu-Film-P (pinolene based) and Slippa (silicon based) was determined.

Sixteen treatment combinations were applied to a Cox orchard and the effect on powdery mildew was assessed. Sixteen treatment combinations (Table 2) were applied to a Cox orchard and the effect on powdery mildew was observed. The sixteen combinations were laid out as a randomised block experiment with four blocks of five trees per treatment. Combinations of three products and wetters were combined with a control as shown in Table 1.

The Potassium bicarbonate and sulphur application was at pink bud and petal fall as recommended in the HDC Project CP48. Serenade applications were made at these timings and also 1 week after petal fall. In the first year of the project (2008) the *Bacillus subtillus* product Sentry S was applied but as this product is no longer available, another similar *Bacillus subtillus* product, Serenade ASO, was used in the second year (2009). The adjuvants used were Nu-Film-M (Formerly Nu-Film-17 but changed to Nu-Film-M at approval), Nu-Film-P, Slippa.

	None	**Nu-Film-17**	**Nu-Film-P**	**Slippa**
Potassium bicarbonate	1	2	3	4
Potassium bicarbonate + Flowable sulphur	5	6	7	8
Potassium bicarbonate + Serenade	9	10	11	12
None	13	14	15	16

Table 1. Treatment combinations of products.

Treatment	**2008**	**2009**
1	Potassium bicarbonate	Potassium bicarbonate
16	Potassium bicarbonate + Sentry S + Slippa	Potassium bicarbonate + Serenade ASO + Slippa

The timings and rates of application are shown in Table 2.

Assessments

In the first year of the project, 10 leaves were selected at random from each tree and assessed for the presence or absence of mildew. However, because the primary mildew will affect the new growing shoots, this methodology was altered to concentrate on the vegetative shoots in line with the Apple Production Best Practice Guide and EPPO guidelines. Five shoots per tree were assessed for the presence of mildew on each tree. Assessments were made for a total of five weeks after applications were made. Presence of mildew was determined by mycelium presence. The percentage infection was then calculated.

The rates of application and product details are given in Table 2.

Trade name	Active ingredient	Application rate	Application regime	Approval status	Number of applications
Potassium bicarbonate	Potassium bicarbonate	15g/L	Pink bud Petal fall	Approved	2
Headland flowable sulphur	Sulphur	5.5ml/L	Pink bud Petal fall	Approved	2
Sentry S (2008) Serenade ASO (2009)	*Bacillus subtillus*	10L/Ha	Pink bud Petal fall 1wk after petal fall	Not approved SOLA	3
Nu-Film-17(M)	di-1-p-Menthene	1ml/L	As determined by treatment combination	Approved	As determined by treatment combination
Nu-Film-P	96.0 % w/w poly-1-p-menthene	1ml/L	As determined by treatment combination	Approved	As determined by treatment combination
Slippa	64.0 % w/w polyalkylene oxide	1ml/L	As determined by treatment combination	Approved	As determined by treatment combination

Results

Physical compatibility

Table 3: Physical compatibility of potassium bicarbonate.

	Physical incompatibility (precipitate)
Flowable sulphur	No
Nu-Film-17	No
Nu-Film-P	No
Slippa	No

As can be seen from Table 3, there were no physical compatibility issues when mixing potassium bicarbonate with any of the tested products.

Occurrence of Mildew

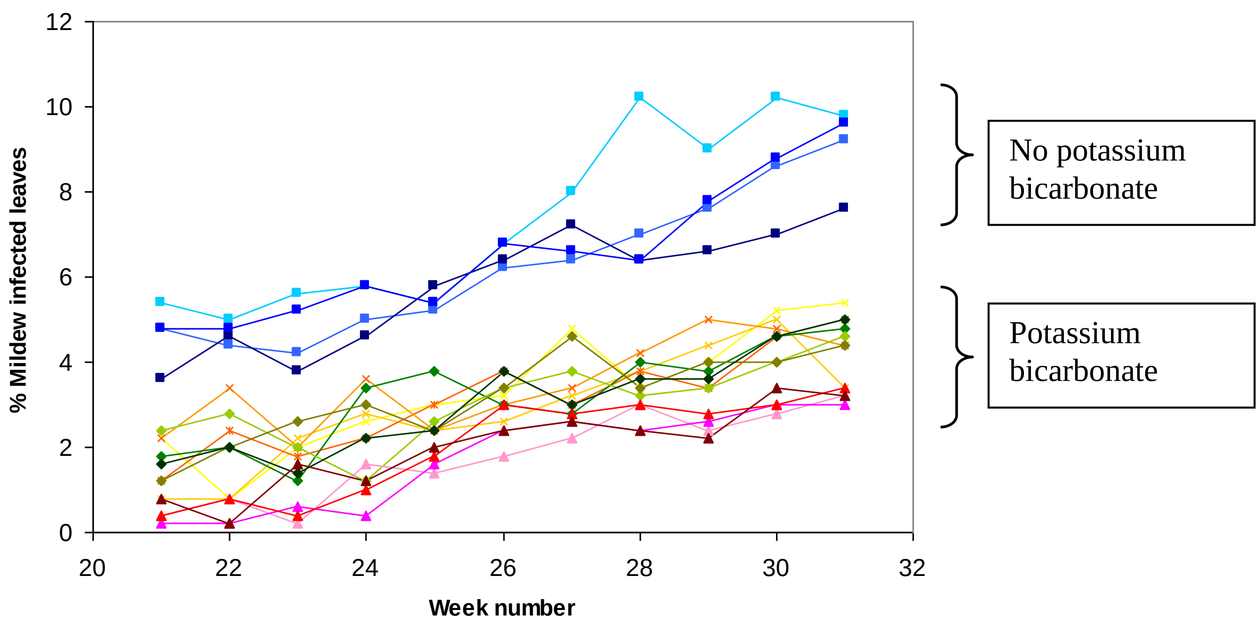

Figure 1: Occurrence of powdery mildew throughout the season related to treatment (% of leaves infected). Data from 2008. Note. Treatment details are not

shown due to the number of treatments and data points. The effect of potassium bicarbonate in combination is shown compared to the trees which received no potassium bicarbonate.

Figure 1 shows the effect of potassium bicarbonate, sulphur and serenade on powdery mildew of Cox in 2008. It can be seen that in all cases powdery mildew levels increased throughout the season. However, those treatments that did not include potassium bicarbonate had greater levels of the disease present at the first observation (4-5%) than the treatments where potassium bicarbonate was applied (0-2%). This pattern continued throughout the duration of the trial with the difference between those trees treated with potassium bicarbonate and the untreated treatment increasing. Treatments where Sentry S (Serenade) was applied had the lowest initial levels of inoculum present (0-1%). There was a general trend of incidence increasing over the assessment period in all treatments. Mildew levels at the end of the season were far greater where initial levels of mildew were not reduced as the rate of increase in mildew level was much greater.

Figure 2 show the main effects of treatments for potassium bicarbonate, sulphur and Serenade with the data being averaged for the adjuvants due to their effect not being significant. Shown in this way the effect of the potassium bicarbonate, serenade and sulphur becomes clear. The data is shown in this way purely to facilitate clearer analysis of the results. The level of mildew was lowest in the potassium bicarbonate+ serenade treatment. The effect of potassium bicarbonate + sulphur and potassium bicarbonate alone treatments were similar. All three caused a reduction in the level of mildew.

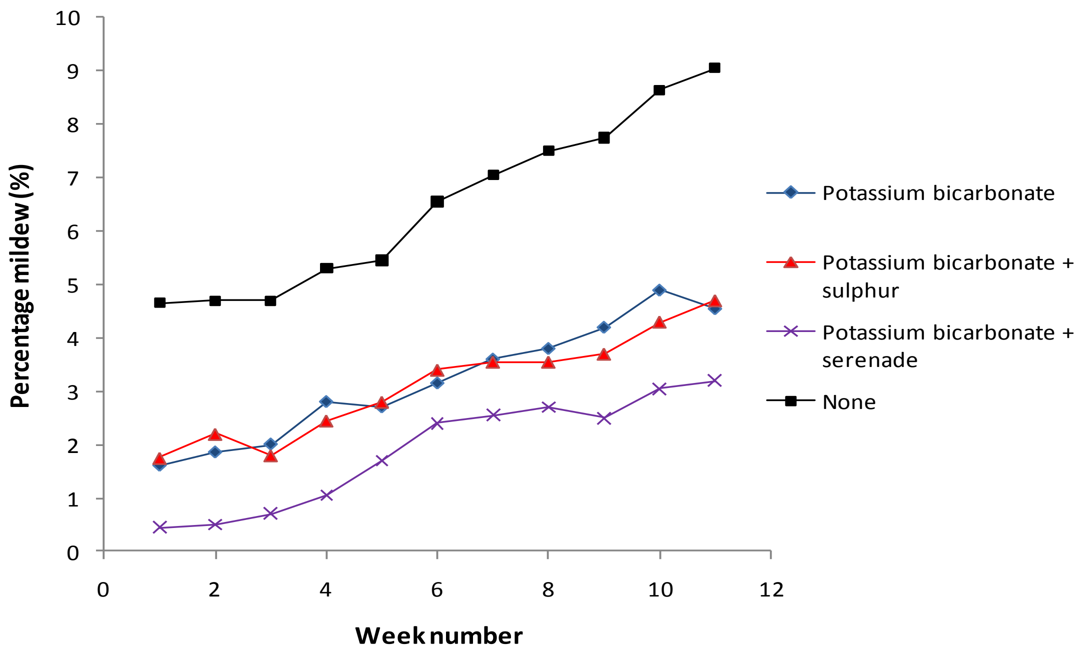

Figure 2. The effect of potassium bicarbonate, sulphur and serenade on mildew incidence severity. Data from 2008.

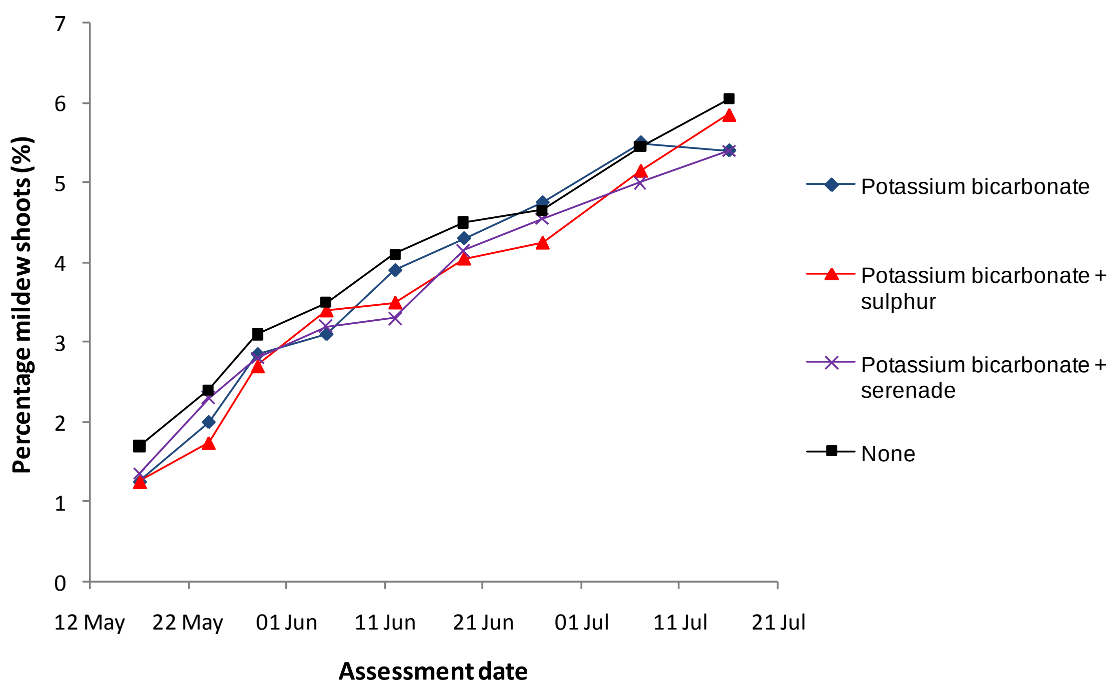

Figure 3. The effect of potassium bicarbonate, sulphur and Serenade on mildew incidence severity. Data from 2009.

The data shown in figure 3 is the combination of adjuvant treatments to show the main effects of potassium bicarbonate, sulphur and Serenade. In 2009 the effect of potassium bicarbonate treatments was not significant (Figure 3). The level of mildew increased throughout the duration of the experiment. The rate of increase was high but there was little difference between treatments in this rate of increase. Initially the level of mildew in the untreated trees was slightly higher than the treated trees but this difference was small and it did not continue for the duration of the trial. The impact of the treatments did not result in any difference in the level of mildew at the end of the assessment period. This was not likely considering the similar levels of the mildew in each treatment at the start of the assessment period.

The average daily temperatures and humidity for the duration of the assessment period is shown in Figures 4 and 5. The data is taken from a weather station around two miles from the experimental site. The aim here is to test whether the combination of temperatures and humidity would have resulted in a different level of disease pressure in the two years. In 2008, temperatures during May were slightly higher with the average daily temperature increasing to just less than 20^{o}C. However, this was followed by a rapid decline in temperature which meant that for about a week, temperatures in 2009 were actually higher. Later on in June two similar periods occurred where temperature in 2008, was higher than 2009.

Although the humidity was similar, it was generally higher in 2008 than in 2009. For example, the humidity in the first 10 days of June was around 5-10% higher in 2008 than 2009. There are obviously exceptions to this such as the period in mid May where humidity in 2009 was higher.

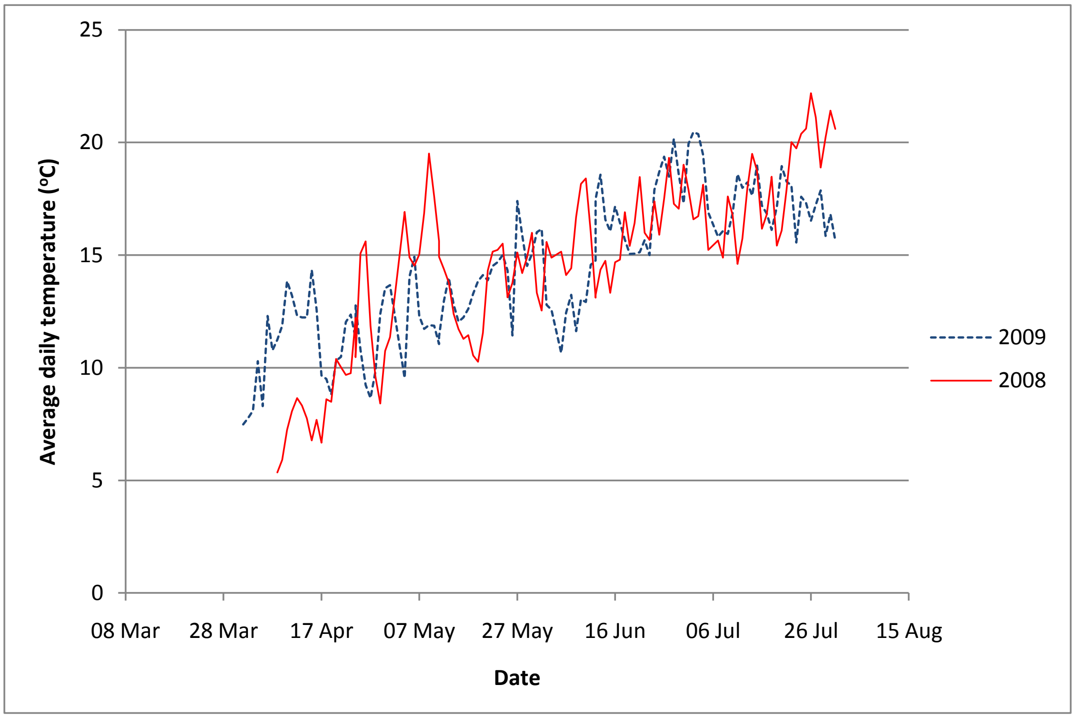

Figure 4. Average daily temperatures for the assessment periods in 2008 and 2009.

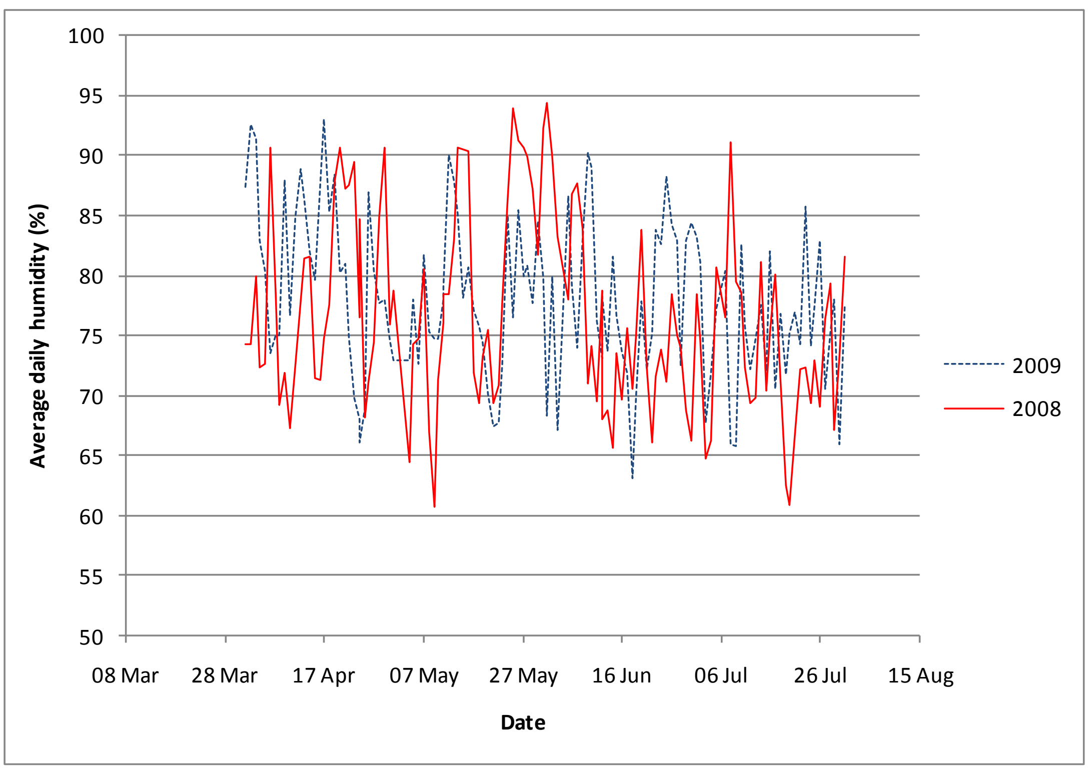

Figure 5. Average relative humidity for the assessment periods in 2008 and 2009.

The difference in rainfall during the assessment periods in 2008 and 2009 is shown in Figure 6. There was considerably more rain during 2008 than 2009 with a total difference during the period of around 34mm, increasing from 65mm to 99mm. This may have impacted the humidity and also reduced the severity of mildew and perhaps the efficacy of potassium bicarbonate.

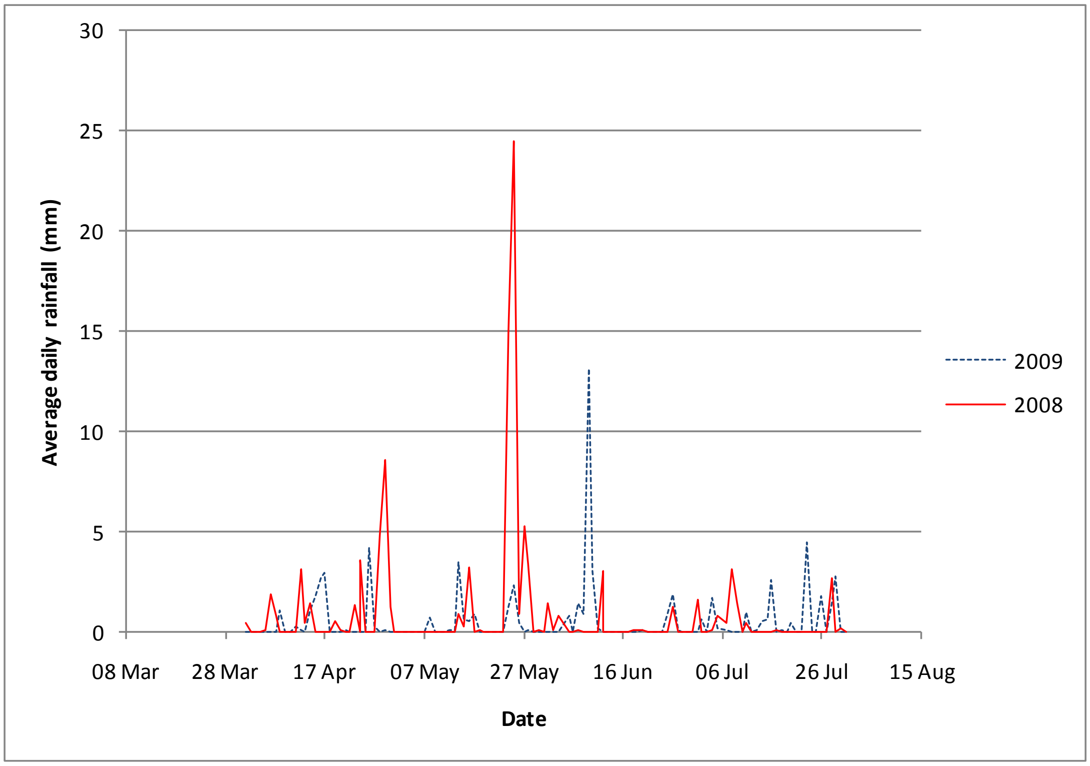

Figure 6. Average daily rainfall for the assessment periods in 2008 and 2009.

Discussion

Potassium bicarbonate alone was effective at initially reducing levels of mildew compared to treatments where potassium bicarbonate was not applied although this was more apparent in year 1 than year 2. The addition of Flowable Sulphur to the tank mix did not however improve control over the disease, in both cases incidence then increased equally to the end of the assessments. For these two chemical applications, the use of any of the adjuvants did not appear to enhance the action in reducing mildew.

Where a *Bacillus subtilis* product was added to the treatment, a reduced incidence of mildew was observed throughout the experiment. Potassium bicarbonate is an eradicant with no protectant properties whereas the *Bacillus subtilis* product acts as a protectant. The initial reduction in mildew levels due to the potassium bicarbonate was enhanced by use of a protectant which resulted in a continued low level of infection rather than an escalating one.

From the data shown here it is not possible to assess whether the level of mildew and the difference in the effect of treatments were due to the difference in weather between the two years. However, the experience of growers and advisors is that the overall level of mildew was higher in 2009. This may have contributed to the lower efficacy of the products. This would have been exacerbated by using the same site for two years, meaning that there were carried over effects from one year to the next, thereby complicating the results. There was a difference in the method used to collect the data. In the first year, leaves were recorded as showing symptoms and in year 2, new growing shoots were used as the measure. However, it seems clear that potassium bicarbonate did reduce the level of mildew in the apple trees tested and it certainly shows potential for reducing the overall level of mildew in apple.

A number of reports have tested the effect of potassium bicarbonate in apple and show varying success. For example, Cromwell and Morgan (2009) working with the apple variety “Empire” compared the effect of potassium bicarbonate with conventional fungicides. Potassium bicarbonate did affect the level of mildew but the marketable yield was only 40% of that from the fungicide treatment. Work on other species has shown that repeated applications are necessary and that the effect of the potassium bicarbonate prolongs for only about 2 weeks. (Kelderer *et al*., 1999; McGrath and Shishkoff, 1999; Schilder *et al*., 2008). This does seem likely as potassium bicarbonate does not offer any protectant properties but solely acts as an eradicant.

Conclusions

So from the data presented here and the limited published data available, it appears that potassium bicarbonate, when applied around flowering, can reduce the level of mildew in suitable weather conditions. Efficacy may be improved when applied with a protectant such as *Bacillus subtilis* product as well. The addition of sulphur, Nu-Film-P, Nu-Film-17 or Slippa did not increase efficacy of potassium bicarbonate in controlling powdery mildew.

The efficacy though will decline if the overall level of mildew becomes too high and it may be necessary to resort to conventional fungicides in these cases. It may also be necessary to use repeated applications in these circumstances with published research suggesting that applications at 7-10 day intervals are necessary.

The level of mildew increased dramatically during the experiment in both years. There is therefore great importance in reducing the initial inoculum by the use of potassium bicarbonate to control levels of the disease later in the season. It may be that applications of conventional fungicides which are still more effective would be useful early on during growth to reduce the level of inoculum, followed by applications of potassium bicarbonate after this when residues start to become an issue.

It could be surmised that methods of effective control of powdery mildew could be achieved by continued use of potassium bicarbonate to eradicate inoculum or use of potassium bicarbonate coupled with a protectant *Bacillus subtilis* product such as Sentry S or Serenade ASO later into the season to confer protection into the season. Using potassium bicarbonate as part of a conventional fungicide programme would also seem sensible.

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Controlling powdery mildew in euonymus with polymer coatings and bicarbonate solutions Ziv, O.,Hagiladi, A.
1993
Powdery mildew in euonymus (Euonymus japonica Thunb.) plants, caused by Oidium euonymi-japonica (Arcang.) Sacc., was controlled by applying various polymer coatings or an aqueous solution of sodium or potassium bicarbonate plus horticultural Sun Spray (SS) Ultra Fine Oil 1% (v/v) to plant foliage. The combined treatment (bicarbonate + oil) was more effective than either of the two materials alone. The results indicate that sodium or potassium (but not ammonium) bicarbonate solutions mixed with SS seems to be a useful biocompatible fungicide for controlling powdery mildew in euonymus plants. Some of the polymer coatings effectively reduced disease levels when applied immediately after the symptoms first appeared
HortScience 28: 124-126

In work on apple scab in Turkey sodium bicarbonate effectively inhibited spore germination and germ tube elongation of *Venturia inaequalis*. An application rate of 1% was required at intervals of 10d. The effect was comparable with the effect of applications of tebuconazole (Ilhana *et al*., 2006).

Fallik *et al*. (1997) found Potassium bicarbonate to be effective on powdery mildew of pepper in Israel.

Travis *et al*. (2005) found there to be a difference in efficacy on mildew in different parts of the plant with effectiveness on leaf mildew being greater to efficacy on cluster powdery mildew.

Interesting work by Kelderer *et al*. (Unpublished) has described very positive effects of a Potassium based product Armicarb on apple scab with total control being achieved with repeated 7 day applications. Compared to this the application of straight Potassium bicarbonate had significantly less efficacy suggesting that the additions to Armicarb had significant implications for efficacy.

On *Gerbera* Millstop (Potassium bicarbonate) was effective in reducing powdery mildew but not as effective as the fungicide program of Heritage (Azoxystrobin) alternated with Eagle (Myclobutanil).

Integrated control of powdery mildew on apple trees by foliar sprays of mono-potassium phosphate fertilizer and sterol inhibiting fungicides

References and further reading may be available for this article. To view references and further reading you must purchase this article.

Moshe Reuveni†, , Dov Oppenheim‡ and Reuven Reuveni§ Crop Protection
Volume 17, Issue 7, September 1998, Pages 563-568
Foliar sprays of 0.5–1% solutions of KH2PO4 (plus Triton X-100), commercial systemic fungicides, and an alternating treatment of phosphate fertilizer and systemic fungicides inhibited development of the powdery mildew fungus, Podosphaera leucotricha (Ell. & Ev.) E. S. Salmon, on shoots and leaves of apple trees. The effectiveness of alternating an appropriate systemic fungicide with a 1% solution of mono-potassium phosphate (MKP) was similar to that of the commercial treatment with the systemic fungicides. However, application of the systemic fungicides only, omitting the phosphate treatments when they were scheduled, was significantly less effective than either the phosphate or the alternation treatments. These results indicate that the use of phosphate fertilizer has a significant role in disease control, enabling reduced numbers of fungicide treatments against powdery mildew by up to 50%. These results were confirmed in large-scale demonstration trials conducted in commercial orchards in 1996 and 1997. In these trials, the tank-mix of 1% mono-potassium phosphate solution with a half rate of an appropriate fungicide was as effective or superior to that obtained by the standard fungicide treatment. Phosphate solutions were not

phytotoxic to plant tissue. The inhibitory effectiveness of mono-potassium phosphate fertilizer makes it a potential major component of an integrated pest management program.

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Abstract In a field experiment conducted over two growing seasons, the effectiveness and phytotoxicity of inorganic fungicides such as sulphur, lime sulphur, copper, silicon and Armicarb (a new formulation of potassium bicarbonate) was compared with water for the control of primary apple scab infections in Belgium on high, medium and low scab-susceptible cultivars (cvs 'Pinova', 'Pirouette' and 'Reinette des Capucins', respectively). In order to drastically reduce the amount of fungicide applied in the orchard, two approaches were used: (1) a strategy involving spraying during the infection process, before fungal penetration and (2) a tunnel sprayer machine for treatment applications. Under field conditions highly favourable for disease, low rates of elemental sulphur (31.8 and 38.6 kg ha−1 year−1 in 2005 and 2006, respectively) combined with low rates of copper (2.1 kg ha−1 year−1 in both years) provided the best scab control and reduced scab severity on the fruits of cv. 'Pinova' by 97 and 98% compared with water control in 2005 and 2006, respectively. Lime sulphur was much more effective than wettable sulphur and appeared to be efficient at temperatures below 10°C, but its effectiveness against apple scab decreased if the treatments were applied 12–24 h later than in the 'during-infection' spray strategy. Armicarb used alone significantly reduced apple scab severity on the leaves and fruits of the three cultivars compared with the water control. Its effectiveness was as good as wettable sulphur applied using the same timing

and dosage. Silicon reduced apple scab on fruits very slightly, but not on leaves. The amounts of wettable sulphur, lime sulphur, copper, silicon and potassium bicarbonate used in this experiment to control apple scab were not phytotoxic, did not increase fruit russet, did increase the yield of each cultivar and did not affect summer density of the beneficial Typhlodromus pyri. The potential and limitations of 'during-infection' spraying as a protection strategy against apple scab in organic farming are discussed

Efficacy of fungicides for control of powdery mildew on delphinium
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Powdery mildew (pm), caused by the fungi Golovinomyces cichoracearum, Erysiphe polygoni, and Podosphaera xanthii, is a serious disease of delphinium. In 2002, eleven products including conventional, reduced risk, organic, and biological fungicides were tested for efficacy against delphinium powdery mildew (dpm) in a field experiment at the South Coast Research and Extension Center in Irvine, CA. Test seedlings of a susceptible cultivar were inoculated in the greenhouse with pm spores from field-collected plants and transplanted 10 d later into beds on 16 Sept. Bed spacing was 1 m with 0.25 m between plants in a row. Fungicides were applied at 7 or 10 d intervals according to label rates from 29 Oct to 20 Dec using a hand-held carbon dioxide-pressurized sprayer. A randomized complete block design with 4 replications was used. Disease severity (ds) (0-5 scale) and incidence (percent) were measured on 22 Nov, 9 Dec, and 24 Dec. Propiconazole and chlorothalonil applied every 10 d reduced ds by up to 95 and 77 percent, respectively. Jojoba oil and potassium bicarbonate applied every 7 d reduced ds by up to 54 and 45 percent, respectively. The results from this study suggest that environmentally benign products such as Jojoba oil and potassium bicarbonate can control dpm, but not as effectively as the best conventional fungicides.

