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Effect of bactericides, phosphonates and nutrient amendments on blast of dormant flower buds of pear: a field evaluation for disease control

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Abstract

Blast of dormant flower buds (BDFB) of pear is a disease of economic importance in the major pear production areas of Europe. To obtain information concerning control measures and disease origin, chemical control trials were performed which included bactericides (kasugamycin and copper), phosphonates (fosetyl–Al and ethephon), and nutrient amendments (boron, calcium, and microelements). Although Cu levels in bactericidal treatments and microelements in nutrient amendments increased significantly in trees, there was no significant effect on disease control. However, incidence of disease was reduced significantly with phosphonate derivative compounds, and effects were observed only the year after the treatment was performed. Additional field trials were done to determine optimum dose and application timing, and a schedule consisting of three spray applications of fosetyl–Al (240 g a.i. hl^{-1}) during May and June was the most effective treatment. This schedule was evaluated in 31 field trials performed in commercial orchard plots from 1989 through 1998. In the year after the treatment, average disease incidence decreased in 30 of 31 trials. The decrease of disease incidence was significant in 71% of the trials (average decrease of 46%). Neither the presence nor the population levels of *P. syringae* were consistently related to disease levels nor to the fosetyl–Al treatment effects on blast incidence of dormant flower buds.

Introduction

Blast of dormant flower buds (BDFB) of pear is a disease of complex origin characterized by a partial or complete necrosis of flower buds during tree dormancy or budbreak (Montesinos and Vilardell, 1991a,b). Necrosis may affect internal primordial flowers, leaves and scales, and usually starts at the tip part of the bud and progresses to the base. Depending on disease severity, flowers per cluster may be reduced, buds may produce abnormal flowers, or buds may be killed completely. Later, axilary buds appear at the base of necrotic flower buds or bud scars. When disease incidence is high, vegetative growth of trees is delayed. Then, trees become alternate bearers annually. These symptoms are similar to those described for blossom blast of pear and stone fruits (English et al., 1980). The disease caused severe production losses in Europe in some years and has been reported in Spain (Montesinos and Vilardell, 1987; 1988), France (Giraud M, CTiFL, pers. comm.) and Italy (Miglio G, pers. comm.). Certain cultivars, especially young trees of Conference, Doyenne du Comice, Abate Fétel, and General Leclerc are very susceptible. Others, such as Williams (sin. Bartlett), Passe Crassane, and Alexandrine are less susceptible.

The aetiology of the disease is complex. *Pseudomonas syringae* pv. *syringae* and associated ice nucleation active bacteria have been related to symptom development in cold years, and Koch's postulates have been completed for *P. syringae* (Montesinos and Vilardell, 1987; 1991b). It has been suggested that abiotic stresses are also associated with the disease. The nutritional state of trees during dormancy and

budbreak, with respect to boron and water soluble sugar contents, and heat-induced leaf burn during summer appeared to be related to a higher disease incidence (Montesinos et al., 1992). However, in a more extensive study during a ten year period, neither population levels of *P. syringae* nor nutrient levels in trees were significantly correlated to the amount of disease (Montesinos and Vilardell, 1996). Other causes including insufficient tree chilling, unmet dormancy requirements, incompatibility between scion and cultivar, and other plant pathogens or pests may be involved but these have not been studied.

Due to the economic impact of the disease, pear growers need control methods to restrict its negative effect on production and pear quality. No comparison of control methods has been published, but there is considerable experience from growers and extension services which indicates a lack of efficacy of available control methods. Sprays of copper compounds applied during autumn–winter, as the typical treatments used for control of several bacterial diseases of fruit trees, were not effective. However, certain phosphonate derivatives including fosetyl–Al showed variable degrees of disease control during the year following the treatment (Montesinos and Vilardell, 1991a; 1996). Fosetyl–Al was moderately effective, but inconsistent, in the control of bacterial diseases such as fire blight of pear (Paulin et al., 1990), citrus canker (McGuire, 1988), and some bacterial diseases of ornamental plants (Chase, 1993). In addition, several phosphonates such as potassium phosphonate, fosetyl–Al and ethephon were effective at high doses for control of infections of *P. syringae* pv. *syringae* on pear in controlled environments (Moragrega et al., 1998).

The objectives of this work were (i) to evaluate several control methods, (ii) to determine the optimum dose, timing and frequency of application of fosetyl–Al, (iii) to test the effect of fosetyl–Al on population levels of *P. syringae*, and (iv) to evaluate the performance of fosetyl–Al in commercial orchard plots over a nine-year-period.

Materials and methods

Disease control trials

Field trials were conducted in the fruit-tree growing area of Girona in Catalunya, in the Northeastern part of Spain, where the disease has affected pear production for many years. Trials were performed in experimental plots located in commercial orchards and at the Mas Badia Agricultural Experiment Station. The study included the most susceptible pear cultivars Conference, Doyenne du Comice, Abate Fétel and General Leclerc. Tree age ranged from 4 to 10 years.

To obtain information concerning, suitable control measures and disease origin, field trials consisted of the following treatments: (1) antibacterial treatment based on the antibiotic kasugamycin and copper compounds, (2) nutrient amendment with boron, calcium and microelements, and (3) phosphonate derivatives. The antibacterial treatment consisted of one kasugamycin (Kasumin 8%, Lainco-Hokko, Barcelona, Spain), and four copper oxychloride sprays (Curenox 50% Cu, Industrias Químicas del Vallés, SA, Barcelona, Spain). Nutrient amendments consisted of micronutrient solution (B 0.35%, Cu 0.15%, Fe 1.5%, Mn 1.25%, Mo 0.025%, and Zn 0.25%; Micro-Luqsa, Luqsa, Spain), boron (Solubor 17.4% B, Borax España, SA, Barcelona, Spain), and calcium chloride (Stopit 12% Ca, Phosyn, Barcelona, Spain). Treatments with phosphonates consisted of aluminium tris-o-ethylphosphonate (fosetyl–Al 80%, Aliette 80W, Rhone-Poulenc Agro SA, Madrid, Spain) and/or 2-chloroethylphosphonate (ethephon, Ethrel 48, Etisa, Barcelona, Spain). The application timing and dates of spray are indicated in Tables 4–6. Rates in g of active ingredient per hectoliter were as follows: fosetyl–Al (80, 160, 240, and 320 g a.i. hl^{-1}), ethephon (75 g a.i. hl^{-1}), micronutrients (200 ml hl^{-1}), boron (34 g a.i. hl^{-1}), calcium chloride (24 g a.i. hl^{-1}), kasugamycin (4 g a.i. hl^{-1}), and copper oxychloride (200 g Cu hl^{-1}). Treatments were applied with an engine operated 15-liter hand sprayer (Stihl model SR400, Waiblingen, Germany) until runoff.

Two types of field trials were performed to optimize fosetyl–Al efficacy and to determine the proper dose and application schedule. In one type, a schedule consisting of three applications (May 7, May 20, and June 7) was tested at the rates of 0, 80, 160, 240, and 320 g of active ingredient per hectoliter (g a.i. hl^{-1}). In another type, a dose of 240 g a.i. hl^{-1}, was applied in the following six spray schedules: one application in May (May 7), two applications in May (May 7, May 20), three applications between May and June (May 7, May 20, June 7), four applications between May and July (May 7, May 20, June 7, July 15), four applications in spring and one in September (May 7, May 20, June 7, July 15, September 9), and three applications in autumn (September 5, September 24, October 10).

To test the consistency and efficacy of fosetyl–Al treatments for disease control under a wide range

of orchard conditions, a total of 31 field trials were performed in commercial orchard plots of cultivars Conference, Abate Fétel, Doyenne du Comice and General Leclerc during 1989–1998. There was a range of 7–10 days in the date of each spray application due to the differences from year to year, or from orchard to orchard. Treatments consisted of fosetyl–Al at 240 g a.i. hl^{-1} at May 7–14, May 20–30, and June 7–14. In all the field trials, the experimental design consisted of 3–5 replicates per treatment, with 4–10 trees per replicate depending on orchard plot.

Nutrient analysis in plant material

Leaves, dormant buds and current year shoots were selected at random within each sampled tree. Samples consisted of each separated type of plant material pooled from all trees corresponding to each treatment repetition. The plant material was washed first with a distilled water solution containing Tween 20 (0.1%) and then twice with distilled water. After washing, the plant material was placed in paper bags and dried for 24 h at 80 °C in a drying oven. Then, the samples were ground using a stainless steel mill. N was analyzed by the Kjeldahl method, P by the vanadate–molybdate yellow method, B by the azomethine H method, K by flame photometry, and Ca, Mg, Na, Fe, Mn, Zn, and Cu by atomic absorption spectrophotometry according to standard methods (AOAC, 1970).

Assessment of bacterial population levels on dormant flower buds

In 1989 and 1996, seven orchard plots were selected for testing the effect of fosetyl–Al treatments (applied in 1989 and 1996, respectively) done at the standard schedule and doses, on population levels of *Pseudomonas* in relation to disease incidence. Samples were taken before budbreak, during either November, January or February at the phenological state A–C of Fleckinger (Fleckinger, 1965), depending on trial. A bulk sample of 50–100 buds was collected from trees of each treatment replicate in each orchard plot. Samples were placed in plastic bags and transported to the laboratory. Buds were cut accross the longitudinal axis into two pieces and the proportion of diseased flower buds was determined for each sample. Approximately 3 g of bud material was processed for each sample to determine population levels of bacteria. Bud material was placed in 20 ml of sterile 0.1% peptone water and shaken on a rotary shaker for 30 min. The supernatant was used for 10-fold serial dilutions in sterile Ringer's solution. Bacterial populations were determined by plating 50 µl of sample extract dilutions onto King's B agar plates and incubated at 22 °C for 2 days. Fluorescent colonies under ultraviolet light were counted and tested for oxidase. Fluorescent colonies which were negative for the oxidase test were considered as *P. syringae*, since in previous surveys about 95% of these were found to be *P. syringae* (Montesinos and Vilardell, 1991b). Results were expressed as CFU per gram of fresh weight of bud tissue.

Disease assessment in commercial orchard plot trials

Disease was assessed in April–May at the phenological stage D–E of Fleckinger (Fleckinger, 1965) during the year after the treatments were done. Buds remaining in stage A were considered as diseased, and cut open for confirmation. Disease assessment was not performed at full bloom because blasted buds usually abscised by full bloom. Disease incidence was measured as the percentage of flower buds blasted per tree. All dormant flower buds were counted on each of four selected branches per tree and the disease incidence per tree (80–200 buds) was calculated from the overall count. Mean disease incidence of all trees for each replicate was used for statistical analysis. Treatment efficacy was calculated as the ratio between the difference in disease incidence between non-treated controls and treatment, and disease incidence in non-treated controls, and expressed as a percentage.

Data treatment and statistical analysis

Effect of treatments was determined with ANOVA using the GLM procedure (SAS Institute, Cary, Inc., NC) and Tukey-Kramer means separation test at a 0.01 probability level. Before analysis, data were log-transformed to normalize and homogenize the variance.

Results

Chemical treatments evaluated in orchard plots

Neither the antibacterial treatments (kasugamycin plus copper) nor the nutritional amendments had significant

Table 1. The effect of chemical treatment on incidence of BDFB on 'Conference' pear in orchard plots

Treatment[x]	Orchard trial/year					
	Casadella 1990	Casadella 1991	Baguda 1997	Baguda 1998	Mas Badia 1998	Mas Badia 1999
Non-treated	66.7 a[y]	42.3 a	42.2 a	84.4 a	89.5 a	57.1 a
Antibacterial	61.8 a	48.4 a	—	—	—	—
Nutritional	74.8 a	—	47.2 a	72.1 a	83.4 a	—
Fosetyl–Al	30.8 b	11.0 b	18.3 b	40.4 c	45.4 c	15.9 c
Ethephon	—	—	—	53.4 b	—	24.7 bc
Fos + Ete	—	—	—	36.4 c	39.9 c	18.9 c

[x]Antibacterial: Copper oxychloride at 200 g Cu hl^{-1} (May 30, June 16, November 5, November 20) and kasugamycin at 4 g a.i. hl^{-1} (July 9). Nutritional: Six sprays of a mixture of micronutrients solution (Cu, Fe, Mn, Mo, and Zn, at 200 ml hl^{-1}), and Ca (24 g hl^{-1}), B (40 g a.i. hl^{-1}) performed in April 25, May 2, May 15, May 30, June 16, July 9). Fosetyl–Al: 3 sprays of fosetyl–Al (240 g a.i. hl^{-1}) in May–June (May 7, May 20, June 7). Ethephon: 1 spray of ethephon (75 g a.i. hl^{-1}) before leaf fall (September 19–October 10). Fos + Ete: combined fosetyl–Al and ethephon at rates and timing as when used alone.
[y]Means within the same column and followed by the same letter(s) do not differ significantly ($p = 0.05$) according to Tukey's mean separation test.

Table 2. Levels of nutrients in ppm[x] in several tree organs in Sant Iscle orchard

Treatment[y]	Leaves					Dormant flower buds		Bark		
	Mn	Cu	B	Zn	Fe	Cu	B	Cu	B	Fe
Non-treated	20.2 b[z]	5.4 b	25.4 b	16.6 b	79.2 ab	19.8 c	20.4 c	35.2 c	28.2 b	31.4 b
Antibacterial	20.4 b	5.2 b	25.8 b	16.4 b	68.2 b	170.2 a	19.4 c	245.0 a	34.3 ab	37.2 ab
Nutritional	43.8 a	7.6 a	44.2 a	21.8 a	107.2 a	89.8 b	40.4 a	112.0 b	47.2 a	42.8 a
Fosetyl–Al	19.6 b	4.8 b	29.0 b	17.6 b	101.8 a	19.2 c	25.2 bc	35.4 c	33.8 ab	44.4 a

[x]Leaf analysis was performed during July–August (120–130 days from F2) of the current year when treatments were performed. Dormant flower bud and bark analysis were done during February the year after the treatments.
[y]Antimicrobial: Copper oxychloride at 200 g Cu hl^{-1} (May 30, June 16, November 5, November 20) and kasugamycin at 4 g a.i. hl^{-1} (July 9). Nutritional: Six sprays of a mixture of micronutrients solution (Cu, Fe, Mn, Mo, and Zn, at 200 ml hl^{-1}), Ca (24 g hl^{-1}), and B (40 g a.i. hl^{-1}) performed in April 25, May 2, May 15, May 30, June 16, July 9). Fosetyl–Al: 3 sprays of fosetyl–Al (240 g a.i. hl^{-1}) in May–June (May 7, May 20, June 7).
[z]Means within the same column and followed by the same letter(s) do not differ significantly ($p = 0.05$) according to Tukey's mean separation test.

effects on disease control (Table 1). Only fosetyl–Al and ethephon significantly affected the disease control during the year following the treatment. No improvement in disease control was obtained by combining treatments of fosetyl–Al during spring with tree defoliation with ethephon before natural leaf fall in autumn.

Nutritional amendments and bactericidal treatments increased the levels of some chemical elements in the plant material. The antibacterial treatment increased significantly (almost 10 times) the Cu levels in buds and bark. Nutritional amendments significantly increased the Mn, Cu, Fe, Zn, and B levels in leaves, Cu and B in dormant flower buds, and Cu, B, and Fe in bark (Table 2). Fosetyl–Al treatment did not affect nutrient levels in general compared to non-treated controls; only a slight increase in Fe in leaf and bark tissue was observed. No significant effect of the treatments on N, P, Ca, and K was observed in comparison to non-treated controls.

Dose and application timing of fosetyl–Al

The best results in disease control were obtained with a dose of 240 g a.i. hl^{-1}, and no significant improvement was obtained at higher doses (Table 3).

The timing of application during the vegetative growth period of pear trees at the optimal dose of 240 g a.i. hl^{-1} was critical (Table 4). Increasing the number of applications during spring–summer or combining

Table 3. Effect of application dose of fosetyl–Al for control of BDFB of 'Conference' pear in commercial orchard plots at Sant Iscle (Girona) at a three spring spray schedule[x]

Dose (g a.i. hl^{-1})	Disease incidence (%)[y]	
	Trial 1	Trial 2
0	30.1 a[z]	5.5 a
80	21.8 ab	3.5 ab
160	18.9 b	2.2 bc
240	9.1 c	1.6 bc
320	13.7 bc	2.0 bc

[x]Three applications of fosetyl–Al between May and June (May 7, May 20, June 7).
[y]Disease was assessed the year after the treatments were applied, and was determined in April–May (stage D–E of Fleckinger).
[z]Means within the same column and followed by the same letter(s) do not differ significantly ($p = 0.05$) according to Tukey's mean separation test.

Table 4. Effect of spray application timing of fosetyl–Al on control of BDFB of 'Conference' pear in commercial orchard plots at Sant Iscle (Girona)

Treatment[x]	Disease incidence (%)[y]	
	Trial 1	Trial 2
Non-treated control	40.5 a[z]	5.4 ab
Spring 1	29.0 b	3.2 abc
Spring 2	32.5 ab	3.5 abc
Spring 3	11.6 c	1.2 d
Spring–summer 4	11.0 c	2.1 bc
Spring–autumn 5	12.7 c	1.7 cd
Autumn 3	—[w]	6.4 a

[x]Fosetyl–Al (240 g a.i. hl^{-1}). Spring 1, one application in May (May 7); Spring 2, two applications in May (May 7, May 20); Spring 3, three applications between May and June (May 7, May 20, June 7); Spring–summer 4, four applications between May and July (May 7, May 20, June 7, July 15); Spring–autumn 5, four applications in spring and one in September (May 7, May 20, June 7, July 15, September 9); Autumn 3, three applications in autumn (September 5, September 24, October 10).
[y]Disease was assessed the year after the treatments were applied, and was determined in April–May (stage D–E of Fleckinger).
[z]Means within the same column and followed by the same letter(s) do not differ significantly ($p = 0.05$) according to Tukey's mean separation test.
[w]Not tested.

spring schedule with applications during autumn did not improve results. Treatments done only during autumn had no significant effect on disease control. The best disease control with the lowest number of sprays was obtained during May–June (by spraying trees three times).

Efficacy of fosetyl–Al treatment in commercial orchard plots

Disease incidence in non-treated control plots in 31 orchards, ranged from 3.3 to 89.5%. In 71% of the trials (22 out of 31) a significant difference between treated and non-treated controls was observed (Table 5). However, in other (9 out of 31) no significant effect of fosetyl–Al treatments was observed. Efficacy ranged from non-significant to 89% and mean values were $46.0 \pm 12.2\%$. No significant relationship was detected between efficacy of fosetyl–Al treatments and disease incidence in non-treated controls ($p = 0.316$), suggesting that control failures were not due to high or low disease levels in orchard plots.

Relationships between population levels of Pseudomonas syringae*, disease incidence and fosetyl–Al treatments*

Neither the presence nor the population levels of *P. syringae* were related to disease levels nor were they related to the treatment effects on incidence of BDFB (Table 6). However, significantly lesser disease incidence was observed in the second sampling date in six out of seven trials of the treated cases. Among the six trials with significant disease control only in one case (Gorga orchard) the levels of *P. syringae* decreased significantly and coincided with a disease reduction in treated trees. *P. syringae* was not detected in two trials but disease levels were significantly reduced by the treatment (Baguda and Mas Badia orchards). In Mas Oller orchard, population levels were higher in the treated trees in the second sampling date, but disease levels were significantly reduced by the treatment. In Frigola orchard, population levels were higher but not significantly different between treated and non-treated trees. In Llambilles orchard, *P. syringae* was detected but disease levels were not significant. In Sibina orchard, *P. syringae* was detected in the first sampling date but not in the second, however, disease levels significantly decreased in the treated trees. Total fluorescent *Pseudomonas* slighly decreased in all the treated plots compared to non-treated, but only in one case, the difference was significant.

Discussion

Antibacterial treatments (copper and kasugamycin) were not effective for control of blast of dormant flower

Table 5. Incidence of BDFB on four pear cultivars treated[x] with three applications of fosetyl–Al in commercial orchard plots in Girona, Spain, between 1989 and 1999

Pear cultivar	Orchard	Year of disease assessment	Disease incidence (%)[y]		$p > F$[z]
			Non-treated	Treated	
Conference	Mas Badia	1989	38.4	33.3	0.253
	Sant Pere	1989	56.9	10.9	<0.001
	Palau Sator	1990	36.9	44.5	0.456
	Sant Iscle	1990	66.6	30.7	0.003
	Sant Iscle	1991	42.3	11.6	0.001
	Sand Andreu	1992	81.0	53.0	0.005
	Mas Oller	1992	5.3	1.2	0.009
	Can Miró	1993	56.3	22.1	0.012
	Can Calonge	1994	21.5	5.3	<0.001
	Mas Badia	1995	42.6	24.7	0.001
	Mas Badia 1	1997	36.6	24.0	0.134
	Mas Badia 2	1997	34.2	7.8	<0.001
	Bagudà	1997	42.2	18.3	0.004
	Lleida	1997	5.5	4.0	0.357
	Ullà	1998	84.4	40.4	0.010
	Mas Badia	1998	89.5	45.4	0.008
	Mas Badia	1999	57.1	15.9	<0.001
Abate Fétel	Mas Oller	1992	24.8	12.5	0.011
	Mas Oller	1993	19.8	10.7	0.009
	Mas Oller	1994	6.2	2.8	0.013
	Mas Oller	1995	5.7	2.2	0.011
Doyenne	Sant Gregori	1989	65.8	47.8	0.156
du Comice	Mas Badia	1989	38.8	36.4	0.735
	Sant Pere	1989	38.2	12.1	0.007
	Palau Sator	1990	37.0	36.7	0.850
	Can Vidal	1992	6.8	1.0	<0.001
	Sant Andreu	1992	46.7	44.9	0.536
	Roman	1992	3.3	1.2	0.010
General Leclerc	Mas Badia	1989	24.4	13.7	0.009
	Sant Pere	1989	10.5	4.2	0.008
	Palau Sator	1990	17.0	16.6	0.352

[x]Treatments corresponded to three applications of fosetyl–Al at 240 g a.i. hl^{-1} between May and June (May 7–14, May 20–30, June 7–14).
[y]Disease was assessed the year after the treatments were applied, and was determined in April–May (stage D–E of Fleckinger) depending on the pear cultivar.
[z]Significance of the difference between non-treated control and treated according to ANOVA.

buds of pear. However, Cu levels in bactericide treatments increased in trees. It could be that copper resistant strains of *P. syringae* are involved in the disease, but they should be controlled by the simultaneous application of kasugamycin in the antibacterial spray. Therefore, these results do not support the hypothesis that BDFB is caused by *P. syringae*.

Nutritional amendments (boron, calcium, and microelements) were ineffective for control of blast of dormant flower buds of pear. However, most microelements provided in nutrient amendments readily increased in trees. Therefore, the hypothesis of a nutritional disorder as the cause of BDFB is not supported by our experiments.

Both results including antibacterial treatments and nutritional amendments agree with the experience of commercial pear orchadists having had only unsuccessful trials for control BDFB disease over the years.

In contrast, preventive applications of fosetyl–Al in one year had a significant effect on disease control in the subsequent year. The reasons for its effect are not well understood. The efficacy of fosetyl–Al against BDFB of pear agrees with reported activity

Table 6. Effect of fosetyl–Al treatment[x] on population levels of total fluorescent *Pseudomonas* and *P. syringae* in flower buds in relation to BDFB incidence in seven orchard trials

Orchard	Date of sampling	Fluorescent *Pseudomonas* ($\log_{10}$ CFU g f.w.$^{-1}$)			*P. syringae* ($\log_{10}$ CFU g f.w.$^{-1}$)			Disease incidence (% buds)		
		NTC[x]	T	$p > F$[y]	NTC	T	$p > F$	NTC	T	$p > F$
Llambilles	Jan 1997	6.75	6.07	0.689	3.50	nd[z]	0.055	2.6	2.9	0.919
	Feb 1997	6.28	5.47	0.001	3.92	2.78	0.435	1.4	0.0	0.356
Mas Oller	Jan 1997	7.31	6.82	0.208	3.38	nd	0.055	8.9	5.9	0.378
	Feb 1997	7.37	6.56	0.058	nd	2.89	0.310	13.8	3.9	0.024
Sibina	Jan 1997	7.70	7.06	0.023	3.39	4.52	0.599	6.9	5.2	0.702
	Feb 1907	7.24	6.50	0.114	nd	nd	—	12.0	7.1	0.046
Gorga	Nov 1996	4.93	4.58	0.426	nd	nd	—	2.5	1.3	0.670
	Jan 1997	8.19	8.03	0.171	3.42	nd	0.041	22.9	8.5	0.018
Baguda	Nov 1996	2.63	3.44	0.157	nd	nd	—	3.8	0.0	0.168
	Feb 1997	7.29	7.03	0.203	nd	nd	—	21.0	8.0	0.017
Mas Badia	Nov 1996	4.06	3.94	0.722	nd	nd	—	1.2	1.3	0.972
	Feb 1997	7.76	7.59	0.389	nd	nd	—	16.8	2.6	0.007
Frigola	Jan 1990	8.43	8.13	0.459	5.45	4.73	0.550	80.7	52.3	0.023

[x]Treatments corresponded to three applications of fosetyl–Al at 240 g a.i. hl^{-1} between May and June (May 7–14, May 20–30, June 7–14) the year before sampling and disease assessment. NTC, non-treated controls; T, treated.
[y]Significance of the difference between the non-treated control and treated orchard according to ANOVA. When *P. syringae* was not detected in any of the repetitions, the comparison was performed using the detection level value.
[z]Not detected. Below detection level of 2.5 $\log_{10}$ (CFU/g f.w.).

of this compound to control of infections by *Erwinia amylovora* (Paulin et al., 1990) and *P. syringae* on pear (Moragrega et al., 1998), *Xanthomonas citri* on citrus (McGuire, 1988), and other bacterial diseases in ornamentals (Chase, 1993). This chemical or its derived metabolites produced by the plant such as phosphonate had a very low *in vitro* activity against bacterial plant pathogens (Moragrega et al., 1998). It has been suggested that fosetyl–Al could act against bacteria by an indirect mechanism mediated by the plant. The fact that fosetyl–Al has an activity *in planta* against bacterial infections and that it is moderately effective against BDFB of pear, points to a possible bacterial origin of the disease. However, neither the presence nor the population levels of *P. syringae* were consistently related to disease levels in the orchards studied, and fosetyl–Al treatment did not consistently decrease *P. syringae* levels. Thus, these results do not provide definitive evidence in favor of a bacterial origin of the disease.

Control of BDFB of pear with fosetyl–Al requires a relatively high dose and number of applications to get significant disease control, and there is a specific short period of activity of applications restricted to spring (May–June). This may be related to a high activity of sap flow, photosynthesis and metabolism of trees during the vegetative period from bloom to growth cessation, and to foliar canopy absorption properties of the compound (El-Hamalawi et al., 1995). It also may be due to an increased activity of the pathogen playing a role in the disease, or due to the most favorable conditions for bud colonization or infection during spring (Ercolani, 1969; Gross et al., 1983).

Combination of spring fosetyl–Al treatments with an application of ethephon during autumn before natural leaf fall did not improve disease control. However, ethephon alone is quite effective. The activity of ethephon agreed with a previous report showing that it is one of the most effective phosphonates for control of *P. syringae* infections on pear plants under controlled conditions (Moragrega et al., 1998). For this reason we tested a combined schedule with fosetyl–Al. However, the lower efficacy and the non-target effects of ethephon due to its activity as a plant regulator restrict its use to applications only in autumn before leaf fall to avoid negative effects on tree development.

In spite of the moderate efficacy of control of BDFB of pear with fosetyl–Al and the observation of certain control failures, this method is the only one available at this time. Moreover, in many situations, disease control level was acceptable and led to a sufficient number of flower buds on trees to adequately maintain a commercial pear production.

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