Effect of Dolomitic Lime on Production of Asci and Pseudothecia of *Venturia inaequalis* and *V. pirina*

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ABSTRACT

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An autumn application of dolomitic lime to infected leaves on the orchard floor resulted in a decrease in the percentage of apple and pear leaves with pseudothecia, the number of pseudothecia per leaf, and the number of asci per pseudothecium of *Venturia inaequalis* and *V. pirina*. A dolomitic lime application of 5.08 metric tons per hectare reduced the ascospore dose the following spring up to 88% for pear and 92% for apple.

Apple scab, caused by *Venturia inaequalis* (Cooke) G. Wint., and pear scab, caused by *V. pirina* Aderhold, are present in all apple- and pear-growing districts in Oregon. An important practice for managing apple scab in an integrated program is reduction of primary inoculum. Several nonchemical sanitation procedures are effective and include shredding of leaves (18) and application in the fall of nitrogenous fertilizers such as urea (3,10). Only one report describes the effect of lime on *V. inaequalis* (15). In that study, an autumn application of lime caused a reduction in the number of ascospores discharged the following spring, but urea was more effective than lime. No research has been published on the effect of lime on *V. pirina*.

In the spring of 1993, weather was favorable for scab in the Hood River Valley, and seven moderate or high scab infection periods occurred during April and May. In addition, over 14% leaf scab occurred the previous year in the research orchard at the Mid-Columbia Agricultural Research and Extension Center (MCAREC). Despite favorable spring weather and a high primary inoculum potential, leaf scab infection in unsprayed apple and pear trees was less than 3% (R. A. Spotts, unpublished data). The only practice that was done differently from previous years was an appli-

cation of dolomitic lime at 5.08 metric tons per hectare to all research orchards on 19 October 1992.

The purpose of this study was to determine the effect of an autumn application of dolomitic lime on *V. inaequalis* and *V. pirina* in scab-infected leaves on the orchard floor during the following spring. The study was conducted for two seasons with one rate of dolomitic lime for apple leaves and three rates for pear leaves.

MATERIALS AND METHODS

Pear (*Pyrus communis* L.) leaves with scab lesions were collected from trees in a commercial orchard in the lower Hood River Valley at early leaf drop on 21 October 1993 (cv. d'Anjou) and 21 October 1994 (cv. Bosc). Apple (*Malus pumila* L.) Mill. 'Golden Delicious') leaves with scab lesions were collected on 21 October 1993 and 24 October 1994. On the day of collection, leaves were placed between two layers of nylon mesh and placed in the herbicide strip on the orchard floor at MCAREC, Hood River. Prior to the positioning of the upper mesh cover, dolomitic lime (National Mineral Products, Salinas, CA) containing 22.7 and 11.8% of elemental calcium and magnesium, respectively, was applied evenly over the surface of the leaves with a flour sifter. Rates of dolomitic lime of 1.27 and 2.54 metric tons per hectare were applied to pear leaves and 5.08 metric tons per hectare to pear and apple leaves. Control leaves of apple and pear received no lime. One group of apple or pear leaves covering about 0.35 m² was treated with each lime concentration. The six plots were spaced along a 10-m linear distance of the herbicide strip.

Five to 10 leaves were removed at bi-weekly intervals from bud swell in mid-March through mid-June 1994 and from late February to early June 1995. Ascospore development was assessed in five pseudothecia per leaf with the differential

count method of Gadoury and MacHardy, in which asci are classified as immature, mature, or empty (8), and the number of asci per pseudothecium was determined. The number of pseudothecia per leaf was determined with a dissecting microscope at $\times 12.5$, and the mean of the biweekly observations was calculated.

On 24 April, 10 and 24 May, and 7 June 1995 for pear and 9 and 23 May and 6 June 1995 for apple, the area of each leaf or leaf piece evaluated for production of asci and pseudothecia was determined with an area meter (model LI-3000, Li-Cor, Inc., Lincoln, NE). The averages of the leaf area values were calculated and used in *t* test (apple) or regression (pear) analyses.

RESULTS

As the concentration of dolomitic lime applied to leaves increased, the percentage of leaves with pseudothecia, the number of pseudothecia per leaf, and the number of asci per pseudothecium decreased. This effect was observed in both pear (Table 1) and apple (Table 2) leaves in 1994 and 1995. For pear, four of the six regressions of averages of biweekly pseudothecial data on lime concentration were significant ($P = 0.05$; Table 1). Similarly, the effects of dolomitic lime on pseudothecia in apple leaves were significant ($P = 0.01$; Table 2).

Based on the percentage of leaves with pseudothecia, the number of pseudothecia per leaf, and the number of asci per pseudothecium, the ascospore dose of each lime treatment was calculated and compared with the nonlimed control. Ascospore dose was reduced 46 to 88% for pear and 55 to 92% for apple (Table 3). The effects of dolomitic lime on ascospore dose appeared greater in 1994 than in 1995. Within 1 week after the autumn, 1994, dolomitic lime application, 22 cm of rain fell and removed much of the visible lime deposit from the leaf surfaces, possibly reducing the effect of the lime the following spring. Application of dolomitic lime also resulted in reductions in leaf area of 11, 29, and 34% for pear with 1.27, 2.54, and 5.08 metric tons of lime per hectare, respectively, and the regression of leaf area on lime concentration was significant at $P = 0.05$ (Table 3). For apple, lime treatment resulted in an 18% reduction in leaf area, which was significant at $P = 0.02$ (Table 3).

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DISCUSSION

Only one previous, published study has been on the effects of lime on apple scab (15), and none has dealt with pear scab. Miller and Rich (15) reported that an autumn application of 0.17 metric tons of lime per hectare caused a reduction of 7, 32, and 56% in the number of ascospores discharged in April, early May, and late May, respectively, of the following year. They found that nitrogenous fertilizers (10-10-10 at 0.14 metric tons per hectare and urea at 0.03 metric tons per hectare) caused a greater reduction in ascospore discharge than lime. The effect was attributed to an increase in the bacterial population of the apple leaves (5). The most important biological agent that removes apple leaves from the orchard floor is the earthworm *Lumbricus terrestris* (16,17). Urea and other nitrogenous compounds increase the softening rate of leaf litter and, thus, their palatability to earthworms (4). The effect of lime on softening of leaves has not been studied, but earthworms were excluded from the leaves in our study. The amount of lime applied by Miller and Rich (15) was considerably less than that applied in our study. Our application rates were based on local extension recommendations.

Liming enhances microbial activity, resulting in more rapid decomposition of leaf litter (6,19). We found that 5.08 metric tons of dolomitic lime per hectare reduced leaf area 18 and 34% for apple and pear, respectively. A study of beech leaf decomposition on German forest soils showed that decomposition was higher in lime soils than in acid soils (12). In a study done in acidic peat bogs in upland Britain, decomposition of plant litter was positively correlated with the calcium concentration of litter components (11). Lignin and tannin concentrations had a negative effect on decomposition, and a complex interaction of calcium, phosphorus, and organic molecules was described with multiple regression analysis (11). In another study, leaves of 19 tree species were inoculated with a forest humus suspension and the rate of decomposition from 2 to 6 months was most closely related to the excess base content of the litter (2). Excess base in soil neutralizes soil acidity (2).

The reductions that we observed in leaf area were considerably less than the reduction of ascospore dose that occurred following the application of dolomitic lime (55 to 92% for apple, 46 to 88% for pear). Thus, factors other than leaf decomposition must be involved. Cook (7), using phosphate buffers applied to detached scabby apple leaves, showed that the number of pseudothecia per cm² decreased sharply as the pH on the leaf surface approached 7.0. Urea also may suppress pseudothecial development by raising the leaf pH to an alkaline level (7). Dolomitic lime undoubtedly

increases the pH of apple and pear leaves, but the extent of the increase has not been determined.

The number of pseudothecia per leaf in this study was quite low, even in the absence of lime. We have counted as many as 64 to 204 pseudothecia per leaf for d'Anjou and Bartlett pear, respectively (R. A. Spotts, unpublished data). Infected apple leaves have a mean of 21.6 mature pseudothecia per fertile lesion, but low lesion fertility often results in pseudothecial density (mature ascocarps per visible lesion) values of less than 2.0 (9). The values reported herein (2.0 to 2.7 pseudothecia per leaf for nonlimed pear leaves and 2.5 to 3.7 for apple leaves) may be the result of several factors, including a high percentage of sterile lesions, poor leaf contact with the ground because of the underlying nylon mesh, and periodically reduced light from fallen leaves and fruit on top of the mesh (13).

If the potential ascospore dose is close to the critical threshold for a given management program, sanitation practices such as leaf shredding or application of urea can be used to further reduce the ascospore dose (14). Several management practices with mediocre individual efficiency have, collectively, the potential to greatly reduce *V. inaequalis* populations (14). This may be the usual situation in the Hood River Valley, where apple and pear scab are often not major problems in commercial or-

chards. The 17-year average number of primary infection periods is 3.3 per year, and usually a maximum of five fungicide applications for apple and three for pear are necessary, even in a protective program (R. A. Spotts, unpublished data). Under these conditions of low inoculum and relatively few infection periods, the further reduction in ascospore dose resulting from lime application may contribute to an overall management of apple and pear scab. Currently, lime application is viewed by apple and pear growers in the Hood River Valley as a supplement to fungicides

Table 2. Effect of dolomitic lime on *Venturia inaequalis* in apple leaves

Pseudothecial measure	Year	Dolomitic lime (metric tons/ha)	
		0	5.08
Leaves with pseudothecia (%) ^z	1994	95.2 a	46.9 b
	1995	58.2 a	45.5 b
Pseudothecia per leaf ^z	1994	3.7 a	0.5 b
	1995	2.5 a	1.6 b
Asci per pseudothecium	1994	139.3	69.0
	1995	121.4	86.5

^z Numbers within rows followed by different letters indicate a significant difference at $P = 0.01$ according to paired t test. Values are the means of a total of 42 to 61 leaves sampled biweekly (seven observations in 1994, eight in 1995).

Table 1. Effect of dolomitic lime on *Venturia pirina* in pear leaves

Pseudothecial measure	Year	Dolomitic lime (metric tons/ha)				Slope ^x	Intercept ^x	r^y
		0	1.27	2.54	5.08			
Leaves with pseudothecia (%) ^z	1994	57.9	47.2	41.7	20.4	-18.18	43.04	0.864
	1995	63.8	53.4	49.1	45.0	-10.70	53.55	0.993
Pseudothecia per leaf ^z	1994	2.0	1.3	1.0	0.4	-0.86	1.22	0.963
	1995	2.7	1.8	1.7	1.6	-0.65	2.01	0.981
Asci per pseudothecium	1994	134.2	108.9	69.9	69.5	-39.26	98.30	0.931
	1995	121.9	98.9	93.9	92.5	-18.05	103.03	0.990

^x Regression of Y on $\log(X + 0.1)$ where X is metric tons of dolomitic lime per ha.

^y All coefficients are significant at $P = 0.05$ except leaves with pseudothecia and asci/pseudothecium in 1994.

^z Values are the means of a total of 53 to 60 leaves sampled biweekly (eight times) each year. Means of the biweekly values were used in regression analysis.

Table 3. Effect of dolomitic lime on ascospore dose of *Venturia inaequalis* and *V. pirina* and on leaf area

Dolomitic lime (metric tons/ha)	Reduction of ascospores (%) ^y				Leaf area (cm ²) ^z	
	Apple		Pear		Apple	Pear
	1994	1995	1994	1995		
0.00	...	...	...	...	107 a	101
1.27	...	...	46	46	...	90
2.54	...	...	70	51	...	72
5.08	92	55	88	54	88 b	67

^y Values calculated from percent leaves with pseudothecia, pseudothecial density, and number of asci per pseudothecium.

^z Mean leaf area of three (apple) and four (pear) evaluations measured in 1995. Reduction of apple leaf area was significant at $P = 0.02$ according to paired t test. Regression of pear leaf area (Y) on $\log(X + 0.1)$ where X = metric tons dolomitic lime/ha = $-26.4X + 76.7$, $r = 0.95$ and is significant at $P = 0.05$.

in problem orchards rather than as a means to reduce the number of fungicide applications. However, lime is applied only when soil pH requires adjusting, about once every 4 to 5 years. Growers are cautious about omitting a fungicide application because of the high value of fresh market fruit, which makes up 74% of the Hood River pear crop and 67% of the apple crop (1). In addition, there is no economic advantage to replacing a fungicide application with a lime application intended solely for scab ascospore population reduction. Lime application costs about \$145 per hectare (2.54 metric tons), compared with \$112 per hectare for a fungicide (combination of mancozeb and triflumizole) (F. J. A. Niederholzer, *unpublished data*). Further commercial trials are necessary to validate the utility of lime for scab management.

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