Recent Experience in Timing Sprays for Control of Apple Scab: Equipment and Test Results

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ABSTRACT

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Two weather monitoring instruments, developed for use in commercial orchards, were used to detect infection periods of apple scab in Maine and New Hampshire. Eradicant treatments using nonregistered fungicides were as effective in controlling leaf and fruit scab as registered and nonregistered protectant treatments. Three sprays were saved using the eradicant spray program. An experimental spore trap, developed for use by growers in detecting *Venturia inaequalis* ascospores, was tested in a wind tunnel against a recording volumetric spore trap and in three commercial orchards with low inoculum levels. The experimental unit trapped ascospores at about 65% of the efficiency of the recording volumetric spore trap. Ascospores were detected during only one wetness period in each commercial orchard.

Additional key words: integrated pest management, spore trap

Control of apple scab disease, caused by *Venturia inaequalis* (Cke.) Wint., accounts for about half of the total cost of pest management in Maine and New Hampshire apple orchards. Because of the normally low incidence of other fungal diseases in this region, the timing of fungicide applications and the selection of spray materials can be based largely upon optimum apple scab control strategies.

Considerable information exists (4,7–9) on the weather conditions needed for the initiation of primary apple scab infection, and several methods have been developed (3,6,13) to detect primary infection periods. The perithecial stage of the pathogen has been studied (2,11), and spore traps have been used extensively (4,10) to study the ascospore discharge patterns in both experimental and commercial orchards with high inoculum levels. However, little progress has been made in providing growers with useful information concerning spore numbers actually present in commercial orchards during primary infection periods. Integrated pest management programs for apple currently being developed in Maine and New Hampshire emphasize the importance of on-site monitoring of weather and inoculum conditions by growers, using inexpensive instruments developed and adapted to local needs.

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A key factor in the development of apple scab management programs is the need for fungicides with adequate postinfection activity. Preliminary studies show that the sterol-inhibiting fungicides possess significantly longer postinfection activity than materials currently registered for use against apple scab (1,5,12). This paper presents the results of tests using eradicant and protectant treatments of the following nonregistered, sterol-inhibiting fungicides against apple scab: bitertanol, triforine, prochloraz, and CGA 64251 (1-[[2-(2,4-dichlorophenyl)-4-ethyl-1,3-dioxolan-2-yl]methyl]-1*H*-1,2,4-triazole). Also included is a description of equipment being used by Maine and New Hampshire orchardists to monitor apple scab infection conditions.

MATERIALS AND METHODS

Maine fungicide trials: 1980. Fungicides were applied, using an air-blast sprayer nozzled at ×5 (500 L/ha), to 24-yr-old McIntosh apple trees grafted on seedling rootstock. A randomized complete block design was used with single-tree plots and four replications. Protectant treatments were applied on 28 April, 6 May, 13 May, 19 May, 4 June, 11 June, 23 June, 7 July, 21 July, and 4 August; eradicant treatments were applied following Mills' infection periods (7), but not more frequently than once every 7 days during the primary infection season.

The dates of eradicant spray applications, followed in parentheses by the number of hours after the start of each infection period when they were applied, were 30 April (20), 9 May (57), 21 May (64), 9 June (64), 23 June (63), and 10 July (41). Cover applications of the same materials used as eradicants were made on 21 July and 4 August. Mills' infection periods occurred on 29 April, 6 May, 18 May, 3 June, 20 June, 2 July, and 8 July. Benomyl-tolerant strains of the pathogen were present in the orchard in which this trial was conducted.

New Hampshire fungicide trials: 1980. Fungicides were applied to 15-yr-old McIntosh and Cortland trees grafted to MM109 rootstocks. Treatments were applied using a Solo 423 backpack mist blower (Solo Inc., Box 5030, Newport News, VA 23605) at a rate equivalent to 360 L/ha. Single-tree plots were used in a completely randomized block design with four replications of McIntosh and three replications of Cortland. Protectant treatments were applied on 30 April, 7 May, 14 May, 21 May, 28 May, 4 June, 18 June, 3 July, 16 July, and 30 July.

Eradicant treatments were applied following Mills' infection periods, but not more frequently than once every 7 days. The dates of eradicant treatment applications, followed in parentheses by the number of hours after the start of each infection period when they were applied, were 30 April (112), 8 May (37), 19 May (19), 3 June (24), 21 June (20), 9 July (20), and 31 July (43). Beginning dates of Mills' infection periods were 14 April, 25 April, 7 May, 18 May, 2 June, 5 June, and 7 June.

Weather monitoring. In Maine, hygrothermographs (Belfort Instrument Co., 1600 S. Clinton St., Baltimore, MD 21224) were converted to temperature/leaf-wetness recorders by removing the relative humidity sensor and replacing it with a hemp-string wetness sensor (Fig. 1D). Mills' infection periods were detected using a plastic transparency placed over the recorder chart as described by Weltzien and Studt (13).

In New Hampshire, hygrothermographs (Bendix Corp., Environmental and Process Instruments Div., Baltimore, MD 21204) were modified (Fig. 1A and B) by adding sensing modes for leaf wetness and rainfall. Leaf wetness was detected by using a cotton-string sensor, located remotely from the recorder, which activated a relay connected to a solenoid-operated, auxiliary pen that tracked along the bottom of the temperature chart. An electronic circuit "fired" at 7-min intervals, showing

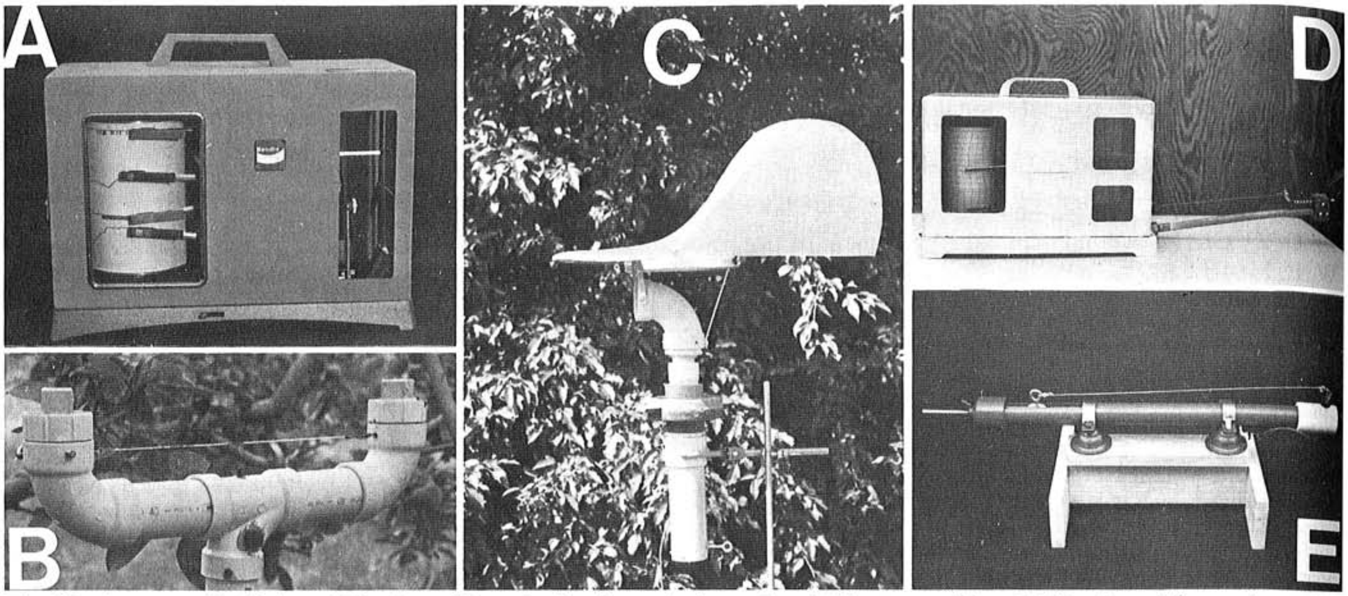

Fig. 1. Equipment used by Maine and New Hampshire orchardists in monitoring apple scab infection conditions. (**A**) New Hampshire recorder used to monitor temperature, leaf wetness, rainfall, and relative humidity. (**B**) Leaf-wetness sensor, using cotton string, which is located remotely from A and activates a solenoid-operated, auxiliary pen on recorder chart. (**C**) Experimental volumetric spore trap designed for use by apple growers. (**D**) Temperature/leaf-wetness recorder. (**E**) Moisture-activated switch used to operate C during wetness periods.

Table 1. Comparison of eradicant and protectant spray programs against apple scab using nonregistered and registered fungicides in a McIntosh orchard in Maine, 1980

Treatment (g/378.5 L)	Spray program[w]	Sprays applied (no.)	Leaf scab (%)[x]		Fruit scab (%)[y]
			Cluster	Terminal	
Bitertanol 50 WP (170)	E	8	6.7 a[z]	5.4 a	5.5 a
CGA 64251 10 W (71)	E	8	11.4 a	8.2 a	5.0 a
Prochloraz 50 WP (99)	P	11	2.3 a	2.0 a	3.0 a
Prochloraz 50 WP (57)	P	11	4.9 a	3.8 a	4.0 a
Bitertanol 50 WP (43) + Benomyl 50 WP (57)	P	11	3.9 a	4.2 a	1.0 a
Captan 50 W (907)	P	11	2.7 a	3.7 a	0.8 a
Untreated			41.0 b	28.2 b	74.5 b

[w] E = eradicant, P = protectant.
[x] Leaf scab rated on 3 July 1980. Leaves from 10 clusters and 10 terminals per replicate were examined for presence or absence of scab lesions.
[y] Fruit scab rated on 13 August 1980. One hundred fruits per replicate were rated for presence or absence of scab lesions.
[z] Letters denote Duncan's multiple range groupings within columns ($P = 0.05$).

periods of leaf wetness as a series of short marks on the recorder chart. Rainfall was detected by a tipping-bucket gauge that measured rain in 0.25-mm increments. This device operated a second auxiliary pen tracking along the top of the temperature chart, showing rainfall as a series of short marks.

Inoculum assessment. An inexpensive, volumetric spore trap is under development at the University of Maine for use by growers in assessing inoculum levels in each orchard (Fig. 1C). Spores are trapped by impaction directly on a microscope slide that is coated with one to two drops of a 1:25 (w/w) mixture of silicone grease and hexane. Spores are deposited in an area measuring approximately 20 × 2 mm. The spore trap is semiautomatic in operation, using a hemp string as the basis for a moisture-activated switch that can be coupled to an electronic timer circuit to allow variable sampling periods. Power is supplied to the 12 V AC/DC vacuum blower from a car or motorcycle battery. Sampling volume is 15 L/min.

The spore trap shown in Figure 1 was tested in a wind tunnel at two wind velocities for efficiency in collecting ascospores of *V. inaequalis* as compared with a recording volumetric spore trap operating at 10 L/min (Burkard Manufacturing Co., Ltd., Rickmansworth, Herts, U.K.). Leaf litter was moistened in plastic trays and placed in front of the wind tunnel fan with the spore traps positioned 1.5 m downwind. Relative positions of the two traps were alternated, and a total of 10 sample runs was performed at each wind velocity.

An earlier prototype of the spore trap shown in Figure 1C was tested in three commercial orchards in which scab control had been excellent the previous year. Spore traps were operated by growers during critical wetness periods. Spores were counted under the microscope by making three complete scans along the long axis of the spore deposit at ×430.

In New Hampshire, the beginning, peaks, and end of the ascospore discharge season were monitored using a Burkard recording volumetric spore trap operating in an experimental orchard. Ascospore maturity was estimated by making regular observations of the perithecial stage of the pathogen.

RESULTS

The results of the 1980 apple scab fungicide trials conducted in experimental orchards in Maine and New Hampshire are presented in Tables 1 and 2. No significant differences in leaf and fruit scab control were observed ($P = 0.05$) in either trial between eradicant and protectant spray treatments. Three fewer sprays were applied in the eradicant spray program than in the protectant spray program in both the Maine and New Hampshire trials.

Seven Mills' infection periods were detected in central Maine between 28 April and 8 July using the temperature/leaf-wetness recorder; 12 Mills' periods were detected in southern New Hampshire during the same period.

In wind tunnel comparisons of the experimental and Burkard spore traps, the efficiency of the experimental spore trap, based on sampling volume, averaged about 65% that of the Burkard trap for the two wind velocities tested. Spore counts were based on one complete scan at ×430 along the long axis of each spore deposit. At a wind velocity of 10 m/min, the experimental and Burkard traps recorded 1.1 and 1.0 spores, respectively, per millimeter of scan; at 20 m/min, they recorded 0.17 and 0.20 spores, respectively.

Field testing of the prototype experimental spore trap produced the data shown in Figure 2. Small differences were observed among the commercial orchards with respect to the dates of wetness periods during which spores were trapped and the number of *V. inaequalis* ascospores trapped.

DISCUSSION

The effectiveness of eradicant treatments of bitertanol, CGA 64251, triforine, and prochloraz in controlling apple scab under field conditions represents a significant asset in the development of workable apple disease management programs. The comparatively short postinfection activities of currently registered fungicides have significantly hindered growers in their attempts to control scab with an eradicant or integrated pest management spray program. Some growers are thus reluctant to depart from a strictly protectant spray program. Further field testing of these new fungicides should focus on determining the limits of their after-infection activity under varied temperature, leaf wetness, and inoculum conditions.

The generally higher level of leaf and fruit scab among all treatments in the Maine fungicide trials, as compared with the New Hampshire tests, can probably be attributed to extremely high inoculum levels present in the Maine orchard, which adjoins a 5-ha block of unsprayed McIntosh trees.

The weather monitoring devices described in this paper offer Maine and New Hampshire growers inexpensive, reliable, and understandable instrumentation for detecting Mills' apple scab infection periods. By using the recorder to monitor temperature, leaf wetness, rainfall, and relative humidity, it is also possible to detect the better-defined infection periods of Preece and Smith (9). By detaching the leaf-wetness sensor from the recorder, the sensor can be placed at any height in the orchard canopy while the recorder is protected in a standard weather shelter. The rainfall data gathered by this recorder are useful in estimating fungicide residue and redistribution and in differentiating between heavy dew and actual precipitation when both occur the same night.

The operation of our experimental spore trap is simple enough to permit routine use of the trap by growers to monitor ascosporic inoculum levels. The relatively simple construction of the trap, using plastic pipe and fittings, lends itself to small-scale commercialization at a modest cost. The low sampling volume makes the trap useful in pest management applications, where it is desirable to sample for periods of 8–24 hr without excessive buildup of spores and dust on the collecting surface.

The relatively low numbers of spores caught by the two spore traps during wind tunnel testing reflect the maximum spore density that was attainable under the test conditions. It is possible that the efficiency of the experimental spore trap would vary in relation to that of the Burkard trap under different inoculum and wind conditions. We are currently continuing development of the experimental spore trap with the aim of improving efficiency and ease of operation and of reducing the cost of construction.

A meaningful threshold of inoculum density must be established to permit growers to use spore trapping devices with confidence in making spray decisions. These decisions must be based not only on weather conditions but also on inoculum level. The low number of spores trapped in Maine orchards during 1980 using the spore trap described here reflects the high level of scab control that is routinely achieved by growers. It also raises the question of how rapidly the

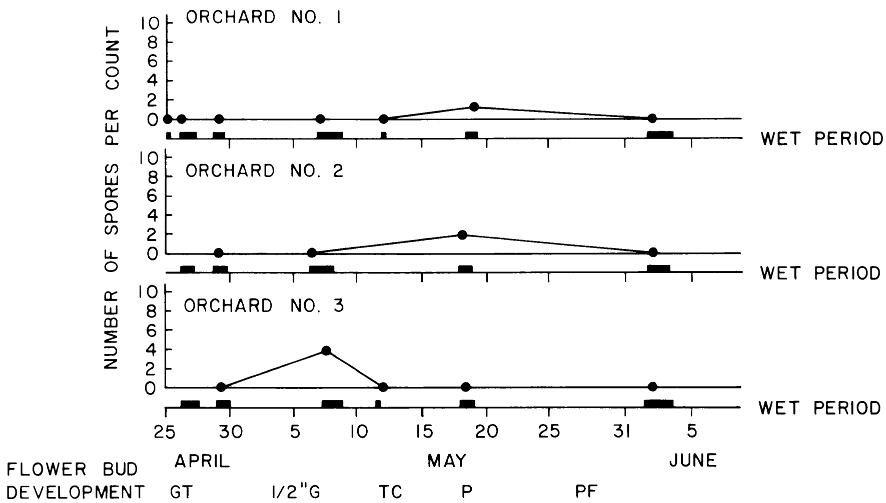

Fig. 2. Levels of *Venturia inaequalis* ascospores trapped using an experimental spore trap at three commercial apple orchards in Maine, 1980. One trap was operated for 8–16 hr at the start of wetness periods at each location. Heavy horizontal bars indicate duration of wetness periods at each orchard. Spore numbers are based on three complete scans of the spore deposit at ×430. GT = green tip, 1/2" G = half-inch green, TC = tight cluster, P = pink, and PF = petal fall.

Table 2. Comparison of eradicant and protectant spray programs against apple scab using nonregistered and registered fungicides in a Cortland and McIntosh orchard in New Hampshire, 1980

Treatment (g/378.5 L)	Spray program[v]	Sprays applied (no.)	Leaf scab (%)[w] Cluster Cort.	Leaf scab (%)[w] Cluster McInt.	Leaf scab (%)[w] Terminal Cort.	Leaf scab (%)[w] Terminal McInt.	Fruit scab (%)[x] Cort.	Fruit scab (%)[x] McInt.
Bitertanol 50 WP (227)	E	7	...[y]	0.0 a	...	0.0 a	...	0.3 a
Bitertanol 50 WP (113)	E	7	0.0 a[z]	1.0 a	0.0 a	0.1 a	0.7 a	1.5 a
CGA 64251 10 W (71)	E	7	0.0 a	0.0 a	0.0 a	0.1 a	0.0 a	0.3 a
Prochloraz 50 WP (284)	E	7	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.3 a
Prochloraz 50 WP (141)	E	7	0.0 a	0.0 a	0.0 a	0.8 a	4.7 a	0.5 a
Triforine 18.2 EC (284)	E	7	0.0 a	1.0 a	0.0 a	0.2 a	1.6 a	2.2 a
Captan 50 W (907)	P	10	0.0 a	0.0 a	0.3 a	0.8 a	1.0 a	0.7 a
Untreated			37.3 b	38.0 b	12.2 b	10.8 b	67.7 b	54.8 b

[v] E = eradicant, P = protectant.

[w] Leaf scab rated on 26 June 1980. Leaves from 20 clusters and 20 terminals per replicate were examined and rated for presence or absence of scab lesions.

[x] Fruit scab ratings performed 13 August 1980. One hundred fruits per replicate were examined and rated for presence or absence of scab lesions.

[y] ... = not tested.

[z] Letters denote Duncan's multiple range groupings within columns ($P = 0.05$).

pathogen is capable of reestablishing itself at economically important levels in well-protected plantings. Indirect methods of estimating inoculum levels, such as modeling ascospore maturity or examining perithecia collected from high-inoculum orchards, are useful in determining onset, duration, and peaks of the ascospore discharge season; however, they fail to account for inherent differences in inoculum levels among commercial orchards.

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