

Control of primary and secondary apple scab infections with sterol-inhibiting fungicides

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Field and laboratory studies were conducted to determine the effectiveness and postsymptom activity of several sterol-inhibiting fungicides for controlling primary and secondary apple scab infections. Under low inoculum pressure the sterol-inhibiting fungicides were no more effective than conventional materials. However, under extreme inoculum pressure, some sterol-inhibiting fungicides were very effective. Apple scab lesions collected from the fungicide treated trees were examined in the laboratory for quantity and germinability of conidia, and germ tube growth. Most of the sterol-inhibiting materials reduced the numbers of viable conidia relative to captan. This reduction in viable conidia was generally comparable to that achieved with dodine. The fungicides were ranked according to their field performance and inhibitory effects on conidia to provide a quantitative guideline for their use.

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On a réalisé des études au champ et en laboratoire pour déterminer l'efficacité de plusieurs fongicides inhibiteurs des stérols à l'égard des infections primaires et secondaires de tavelure de la pomme. En faible densité d'inoculum, les fongicides anti-stérols n'étaient pas plus efficaces que les produits d'usage courant. En revanche, dans le cas des infections graves, certains d'entre eux se sont révélés très efficaces. Les lésions de tavelure prélevées sur les arbres traités aux fongicides ont été examinées au laboratoire, relativement à l'abondance et à la faculté germinative des conidies ainsi qu'à la croissance du tube germinatif. La plupart des substances anti-stérols ont réduit le nombre de conidies viables par comparaison avec le captan. Cette réduction était d'une façon générale comparable à celle obtenue avec la dodine. Les fongicides ont été classés selon leur performance en culture et leurs effets inhibiteurs sur les conidies, ce qui pourra servir de guide quantitatif pour leur emploi.

Apple scab caused by *Venturia inaequalis* (Cke.) Wint. is the most economically important disease affecting apples (*Malus domestica* Borkh.) in Ontario. The disease is usually controlled with a seasonal spray program using protectant fungicides.

Much interest has developed in the use of sterol-inhibiting (SI) fungicides for apple scab control (10,12). Some SI fungicides have exhibited improved postinfection activity (3,4,5,7,12) and presymptom activity (5,12) when compared to currently registered materials. Sterol-inhibiting fungicides are effective against *V. inaequalis* at rates lower than the presently recommended standard fungicides (3,5,12,13) and provide alternative materials which could be used in rotation or as mixtures with other fungicides to prevent or delay the development of fungicide resistance.

Contradictory results on the postsymptom activity of SI fungicides have been reported (3,5,12,13). However, none of the SI fungicides is currently registered for apple scab control in Canada.

This paper reports the results of field and laboratory studies which assessed the effectiveness and postsymptom activity of several SI fungicides for the control of primary and secondary apple scab.

Materials and methods

Fungicides. The materials used in the field and laboratory studies were bitertanol (Baycor 50 WP, Chemagro Ltd., Mississauga, ON), captan (Captan 50 WP, Stauffer Chemical Co. of Canada, Ltd., Toronto, ON), diniconazole (Spotless 25 WP, Chevron Chemical Canada Ltd., Burlington, ON), dodine (Cyprex 65 WP, Cyanamid Canada Inc., Willowdale, ON), flusilazole (Nustar 400 EC, 20 F, Dupont Canada, Inc., Mississauga, ON), myclobutanil (Sythane 40 WP, Rohm and Haas Canada, Inc., West Hill, ON), and triflumizole (Procure 50 WP, Uniroyal Chemical Co., Elmira, ON). Concentrations of fungicides and spray dates are given in the appropriate tables.

Field trials. *Jordan Station* — Experiments were conducted in an orchard of semi-dwarf McIntosh trees on M 26 rootstock planted in 1976 and spaced at 2.4 × 4.9 m. Five-tree plots were arranged in four blocks using a randomized complete block design. Guard trees were positioned between treated trees and between blocks (rows) to reduce spray drift. Fungicides were sprayed at approximately 14-day intervals until runoff with a handgun attached to a John Bean plot sprayer operating at 2760 kPa.

In 1984, apple scab lesions were first observed on 23 May. Disease incidence was estimated on 13 June by examining 10 cluster and 10 terminal shoots for foliar infections from the three central

trees in each five-tree plot. Disease incidence for clusters was calculated using the percentage of clusters exhibiting lesions on any of the cluster leaves. Disease incidence for terminals was calculated by determining the percentage of terminals with lesions on any of the terminal leaves. Disease incidence was assessed again on 20 July by examining the leaves on 10 terminals per tree from the three central trees in each five tree plot. No insecticides were applied during the test period.

In 1985, lesions were first observed on 3 June. Disease incidence was assessed on 25 June on 10 cluster and 10 terminal shoots. Additional disease incidence data were collected on 1 August from leaves on 10 terminals and 30 fruits per tree. Insecticide applications were as required to control plum curculio (*Conotrachelus nenuphar* W.) and codling moth (*Cydia pomonella* (L.)) (Guthion, 4 June; Imidan, 17 July; and Lannate, 22 August).

In 1986, trees were sprayed with the same fungicides and at the same rates as in 1985 except that captan was excluded from the bitertanol + captan treatment, thus providing two rates of bitertanol alone. A different formulation of flusilazole (2OF) was utilized in 1986. No insecticides were applied during this period. Apple scab lesions were first observed on 12 May. Data on disease incidence for cluster and terminal shoot foliage were collected on 3 June and for fruit and terminal shoot foliage on 4 and 28 July as described previously.

In all years, data on temperature and leaf wetness duration were recorded using a hygrothermograph (Enercorp Instruments, Ltd., Toronto, ON) and a DeWitt leaf wetness metre (Hengelo, The Netherlands). Infection periods were determined using Mills' criteria (6). The severity of each infection period was rated as light (L), moderate (M), or severe (S) using Mills' chart (6). Infection periods prior to the observation of visible lesions were considered as primary; whereas, all infection periods subsequent to this were considered secondary, even though both ascospores and conidia might have been present.

Smithfield — Experiments were conducted in a semi-dwarf McIntosh orchard planted in 1971 on MM 106 rootstock with trees spaced at 3.0 × 5.0 m. Treatments were replicated four times in a randomized complete block design using three tree plots. Guard trees were left between plots to minimize spray drift. Fungicides were sprayed until runoff with a hydraulic handgun attached to a Rittenhouse plot sprayer operated at 2700 kPa.

In 1985, fungicide applications were started on 21 May (petal fall) 24 hours after the first secondary infection period. Apple scab lesions, first visible on

17 May, were present on many of the older cluster leaves and first five terminal leaves prior to the first spray. Applications continued at approximately 7-day intervals until mid July at the lower rate.

On 19 June apple scab was assessed on all leaves and fruit of 20 clusters and all leaves on 10 terminals per plot. The leaf position of scab lesions on terminals was recorded. On 5 September, preharvest assessments were made on all leaves of 20 terminals per plot. Percent fruit infection was determined from 100 fruit per plot on 16 September.

This experiment was repeated in 1986; however, dodine was substituted for captan and the lower rate of diniconazole was used in all sprays. The first fungicide application was on 3 June, after fruit set, and 12 days after the first apple scab lesions appeared. Primary scab infections were present on the cluster leaves and the first 11 terminal leaves before the first spray was applied. Subsequent sprays were applied at weekly intervals until 1 August. Percentage of cluster and terminal leaves and fruit with scab was assessed during the first week of July and the third week of August as described for 1985. Infection periods were determined using Mills' criteria (6). Environmental data were obtained using the instrumentation described for the Jordan Station site.

Influence of fungicides on conidial quantity and viability. In the Smithfield experiment, in 1985 and 1986, leaves with active scab lesions prior to the first fungicide application were used to examine the effect of subsequent fungicide sprays on conidial quantity and viability. Six leaves with primary apple scab lesions were selected from each plot after 24 or 48 hours and again at 7 days after the first spray. A second spray was applied and leaves with lesions that had received two sprays were collected 48 hours and 7 days after the second spray.

In 1985, three lesions with 1 to 2 mm of surrounding plant tissue per leaf from three leaves per plot were excised with a 7 mm diameter cork borer, placed in 5 mL of distilled water, and vortexed for 30 sec. The combined spores from each leaf were counted using a hemocytometer and the number of spores per lesion was calculated from the mean of three observations. A 1-mL sample of the spore suspension from each leaf was placed on 2% water agar (Difco brand) in 9 cm diameter petri dishes and incubated for 18 hours at room temperature. The percentage of germinated spores was assessed in six 250× microscope fields (12 leaves per treatment). A spore was considered as germinated if the germ tube was longer than the width of the spore. Germ tube lengths from 10 germinated conidia were measured from each petri

Table 1. Influence of sterol-inhibiting fungicides on the incidence of foliar apple scab in 1984 at Jordan Station

Treatment and rate (g a.i./100 L)	Disease incidence (%) ^y		
	13 June		20 July
	Clusters	Terminals	Terminals
Nonsprayed	1.6a	0.8a	85.0a
Captan (225)	2.6a	1.2a	9.2bc
Bitertanol (25.0)	2.3a	0.4a	10.0bc
Bitertanol + captan (12.5, 225)	5.0a	1.6a	5.0cd
Flusilazole (5.4)	1.6a	1.2a	1.7d

^yDisease incidence assessed as the percentage of 10 terminals or clusters per tree exhibiting foliage with apple scab lesions. Different letters in columns denote significant differences using Duncan's multiple range test ($P = 0.05$). Data were transformed to the arcsin $\sqrt{\text{percentage}}$ for analysis using a randomized complete block design. Fungicides were applied on 7, 17, and 31 May; 15 June; and 9 July. Infection periods occurred on 8, 23, and 29 May, and 13-14 June.

dish. For each fungicide treatment, measurements were taken from three replicate leaves in a randomized complete block design with four blocks (12 leaves per treatment). This experiment was repeated in 1986. A 4 mm diameter cork borer was used to excise the lesions so that the number of spores per square millimeter of lesion surface could be calculated. In 1986, the final sample was collected 7 days after the third spray.

Data analysis. The data were subjected to analysis of variance and, when a significant F-test was obtained ($P \leq 0.05$), means were separated using Duncan's multiple range test ($P \leq 0.05$). All percentage data were transformed to the arcsin percentage prior to analyses (11). Data from the Smithfield experiments and the laboratory studies were converted to ranks for the different fungicides. The ranks were subjected to a nonparametric one-way analysis of variance (11) to determine the overall relative effectiveness of the different SI fungicides.

Results

Field trials. Jordan Station — In 1984, four infection periods occurred on 8 (M), 23 (M), and 29 May (M) and 13-14 June (M). Disease incidence was low on 13 June and none of the fungicide treatments were statistically different from the nonsprayed control (Table 1). On 20 July, all fungicide treatments had less apple scab infections on terminal leaves than the nonsprayed control. Flusilazole was the most effective treatment. Bitertanol and bitertanol + captan were similar to captan in effectiveness (Table 1).

In 1985, 10 infection periods were recorded on 20-21 (L) and 26-27 May (S), 11-12 (S), 15-16 (S), 17-18 (M), and 20-21 June (M), 6 (L), 8 (L), and 12 July (L), and 15 August (L). All fungicide treatments reduced apple scab infections on foliage and fruit relative to the nonsprayed control (Table 2). The SI fungicides offered control equivalent to captan when used in a 10- to 14-day spray program.

Table 2. Influence of sterol-inhibiting fungicides on the incidence of apple scab on foliage and fruit in 1985 at Jordan Station

Treatment and rate (g a.i./100 L)	Disease incidence (%) ^y			
	25 June		1 August	
	Clusters	Terminals	Terminals	Fruit
Nonsprayed	10.0a	1.7a	75.0a	23.7a
Captan (70)	2.5b	0.8a	0.8b	0b
Bitertanol (16.8)	1.7b	0a	5.0b	0.4b
Bitertanol + captan (8.4, 70)	1.7b	0a	0b	0b
Flusilazole (5.6)	0.8b	0a	0b	0b
Flusilazole (2.8)	1.7b	0a	3.3b	0.8b
Flusilazole (1.4)	0b	0a	1.7b	0b

^yDisease incidence assessed as the percentage of 10 terminals or clusters per tree exhibiting foliage with apple scab lesions. Disease on fruit assessed from 30 fruit per tree. Different letters in columns denote significant differences using Duncan's multiple range test ($P \leq 0.05$). Data were transformed to the arcsin $\sqrt{\text{percentage}}$ for analysis using a randomized complete block design. Fungicides were applied on 7 and 21 May; 3 and 19 June; 11 and 30 July. Infection periods occurred on 20-21 and 26-27 May; 11-12, 15-16, 17-18, and 20-21 June; 6, 8, and 12 July.

Table 3. Influence of sterol-inhibiting fungicides on the incidence of apple scab on foliage and fruit in 1986 at Jordan Station

Treatment and rate (g a.i./100 L)	Disease incidence (%) ^y					
	3 June		4 July		28 July	
	Clusters	Terminals	Terminals	Fruit	Terminals	Fruit
Nonsprayed	69.8a	82.8a	100.0a	100.0a	100.0a	100.0a
Captan (70)	4.6b	20.3b	98.6b	69.6b	100.0a	84.3b
Bitertanol (16.8)	0c	0c	13.5d	41.4c	14.1b	61.0c
Bitertanol (8.4)	0c	0.1c	42.8c	77.6b	18.0b	85.7b
Flusilazole (5.6)	0c	0c	0.4e	0.8e	0.1d	3.2f
Flusilazole (2.8)	0c	0.1c	2.2e	9.4d	2.9c	26.3e
Flusilazole (1.4)	0.38c	1.7c	10.7d	38.5c	17.3b	47.3d

^yDisease incidence assessed as the percentage of 10 terminals or clusters per tree exhibiting foliage with apple scab lesions. Disease on fruit assessed from 30 fruit per tree. Different letters in columns denote significant differences using Duncan's multiple range test ($P \leq 0.05$). Data were transformed to the arcsin $\sqrt{\text{percentage}}$ for analysis using a randomized complete block design. Fungicides were applied on 13 and 27 May; 11 and 25 June; 9 and 23 July. Infection periods occurred on 15-17 and 20-21 April; 18-20 and 22-23 May; 1, 5, 8, and 11-12 June; and 2, 12, 13, 14, 19, and 20 July.

Table 4. Influence of sterol-inhibiting fungicides on fruit and foliar apple scab in 1985 at Smithfield

Treatment and rate (g a.i./100 L) ^z	Leaves or fruit with scab (%) ^y					
	19 June					
	Cluster leaves	Terminal leaves		Fruit	Preharvest	
		Position 1-5	Position 6-tip		Terminal leaves	Fruit
Nonsprayed	91.6a	17.6a	24.3a	83.8a	100.0a	100.0a
Captan (100)	58.6b	14.6a	4.5b	11.8b	15.0b	20.0b
Bitertanol (15.0, 7.5)	49.6b	10.7a	1.5bcd	19.0b	3.0c	10.0c
Diniconazole (3.0, 1.5)	52.7b	10.2a	4.3bc	24.2b	14.2b	26.3b
Flusilazole (2.4, 1.8)	40.6b	13.3a	0.7d	4.4bc	4.1c	3.3d
Myclobutanil (8.0)	56.6b	12.0a	0d	0c	1.7c	0d
Triflumizole (16.6, 12.5)	48.2b	10.2a	0.8cd	7.3bc	10.9b	2.5d

^yMeans followed by different letters in columns are significantly different according to Duncan's multiple range test ($P \leq 0.05$). Data were transformed to the arcsin $\sqrt{\text{percentage}}$ for analysis using a randomized complete block design. Fungicides were applied on 21 and 29 May; 4, 11, 18, and 25 June; and 2 and 16 July. Primary infection periods occurred on 4-6, 20, 26-28, and 31 May-1 June and 11-12 June. Ten secondary infection periods occurred through the middle of July.

^zThe higher rate was used in the first spray only.

Table 5. Influence of sterol-inhibiting fungicides on fruit and foliar apple scab in 1986 at Smithfield

Treatment and rate (g a.i./100 L) ^z	Leaves or fruit with scab (%) ^y					
	4 July					
	Cluster leaves	Terminal leaves		Fruit	Preharvest	
		Position 1-11	Position 11-tip		Terminal leaves	Fruit
Nonsprayed	60.2a	75.0a	41.6a	83.4a	97.1a	96.6a
Captan (63.0, 43.0)	45.4b	60.0a	5.5b	53.6b	27.5bc	46.3c
Bitertanol (15, 7.5)	46.3b	59.8a	3.8bc	39.0bc	26.5bc	36.8c
Diniconazole (1.5)	41.1bc	62.5a	5.3b	51.1b	37.5b	67.5b
Flusilazole (2.4, 1.8)	30.0c	57.0a	0.6bc	19.5c	21.1c	12.5d
Myclobutanil (8.0)	37.3bc	57.5a	0c	20.9c	26.6bc	6.5d
Triflumizole (16.6, 12.5)	46.9b	59.1a	0.7bc	34.7bc	27.0bc	44.3c

^yMeans followed by different letters in columns are significantly different according to Duncan's multiple range test ($P \leq 0.05$). Data were transformed to the arcsin $\sqrt{\text{percentage}}$ for analysis using a randomized complete block design. Leaves at position 1-11 were present prior to the first spray on 3 June. Fungicides were applied on 3, 10, 17, and 25 June; 2, 9, 16, and 23 July; and 1 August. Infection periods occurred on 20-21 April; 16, 18-21, and 22-23 May. Fourteen primary and secondary infections occurred in June and July.

^zThe higher rate was used in the first spray only.

Table 6. Percent germination of apple scab conidia following fungicide treatment of symptomatic leaves at Smithfield in 1986

Fungicide ²	Sampling time ³					
	Before first spray	First spray + 48 h	First spray + 7 days	Second spray + 48 h	Second spray + 7 days	Third spray + 7 days
Nonsprayed	95.7a	87.4a	79.2a	85.1a	86.9a	75.2a
Dodine	94.9a	70.6ab	48.4b	35.5d	26.3d	63.2ab
Bitertanol	95.4a	52.9b	58.5b	69.0b	58.6c	55.8bc
Diniconazole	93.3a	87.3a	59.2b	69.4b	77.2b	70.8ab
Flusilazole	88.4a	71.6ab	55.1b	62.1bc	58.4c	60.6abc
Myclobutanil	91.0a	71.4ab	57.3b	54.3c	73.1b	46.6c
Triflumizole	93.5a	80.7a	53.5b	67.0b	68.0bc	55.5bc

¹Means followed by different letters in columns are significantly different using Duncan's multiple range test ($P \leq 0.05$). Each value represents the percentage of germinated conidia from 72 microscope fields (250 \times). Data were transformed to the arcsin $\sqrt{\text{percentage}}$ for analysis using a randomized complete block design.

²Amounts of fungicides are presented in Table 5.

Weather conditions in 1986 favoured an apple scab epiphytotic, with 14 infection periods occurring on 15-17 (L) (silver tip) and 20-21 April (L), 18-20 (S) and 22-23 May (M), and 1 (M), 5 (M), 8 (M), and 11-12 June (S) and 2 (M), 12 (M), 13 (M), 14 (L), 19 (M), and 20 July (S). Infections were controlled on cluster and terminal leaves by the SI fungicides applied on a 14-day schedule (Table 3). Control was enhanced over that provided by captan. Control plots and guard rows exhibited greater than 50% defoliation and 100% fruit and terminal shoot infection in July. All the SI fungicide treatments except the lower rate of bitertanol provided better control than captan alone. Flusilazole at 5.6 g a.i./100 L was the only material to provide acceptable disease control on both fruit and foliage under these extreme conditions. Flusilazole at the 2.8 g a.i./100 L gave excellent control of foliar disease and moderate control of fruit infections.

Smithfield — Results from two years of tests on control of apple scab infections are presented in Tables 4 and 5. In 1985, two infection periods occurred on 4-6 May (S) and 20 May (L), before the first spray was applied on 21 May. Twelve additional infection periods were recorded on 26-28 May (S), 31 May — 1 June (S), 11-12 (L), 16 (S), 17-18 (S), 20-21 (M), 22 (M), and 28-30 June (S), and 3 (L), 5-6 (S), 12-13 (M), and 15-16 July (S). By 19 June, all the fungicides had provided more effective apple scab control relative to the nonsprayed control (Table 4). Myclobutanil, flusilazole, and triflumizole provided better control of conidial infection on new terminal leaves at midseason than captan. At harvest all fungicides had provided better fruit and foliage scab control than the nonsprayed treatment; however, the standard protectant fungicide captan, and the SI fungicides diniconazole and triflumizole were less effective.

The leaves of trees treated with myclobutanil were darker green than those of other treatments and had a crinkled appearance. Myclobutanil, flusilazole, and triflumizole provided better control of fruit infections than captan, diniconazole, and bitertanol.

In 1986 environmental conditions favoured a severe apple scab epiphytotic. Five infection periods occurred on 20-21 April (L), 16 (M), 18-21 (S), 22-23 May (M) and 1 June (L), before the first spray was applied on 3 June. Thirteen infection periods followed on 7-8 (M), 10-11 (S), 12-13 (S), 19-20 (S), 22-23 (M), and 27-28 June (S), and 2 (L), 4 (L), 12-14 (S), 18-19 (S), 19-20 (S), 24-25 (M), and 29-30 July (M). By 4 July, all materials provided better scab control on the new terminal leaves and the fruit relative to the nonsprayed control (Table 5). Myclobutanil provided the best scab control on the new terminal leaves, and all other SI fungicides were comparable to dodine. On fruit, myclobutanil and flusilazole gave the best disease control at this time. By mid August, all fungicides were still providing better scab control on fruit and foliage than in the nonsprayed plots. Diniconazole did not control fruit scab as well as the other SI fungicides. Flusilazole and myclobutanil gave the best fruit scab control in 1986.

Influence of fungicides on conidial quantity and viability. Only the data gathered in 1986 are presented because the results from the 1985 and 1986 experiments were similar regarding the reduction in conidial viability. In 1986, conidial germination, when examined within 48 hours of the first fungicide application, was reduced by bitertanol relative to the nonsprayed control (Table 6). None of the other SI fungicides differed from dodine or the nonsprayed control at this time. Seven days after the first spray, all SI fungicides inhibited germination of conidia to an extent

Table 7. Number of apple scab conidia per mm² ($\times 10^2$) of lesion following fungicide treatment of symptomatic leaves at Smithfield in 1986

Fungicide ²	Sampling time ¹					
	Before first spray	First spray + 48 h	First spray + 7 days	Second spray + 48 h	Second spray + 7 days	Third spray + 7 days
Nonsprayed	8.16a	10.25a	12.13a	8.60a	5.35ab	6.50a
Dodine	11.05a	3.75e	4.48c	1.15d	0.36d	2.17b
Bitertanol	9.38a	5.56cde	11.33ab	3.10cd	2.67cd	1.52b
Diniconazole	12.93a	4.84de	12.35a	6.14ab	6.15a	5.29a
Flusilazole	11.63a	7.87abc	6.79bc	3.97bc	0.36d	1.59b
Myclobutanil	13.72a	6.65bcd	9.53ab	1.95cd	2.38cd	0.43b
Triflumizole	10.11a	9.03ab	8.38abc	5.85b	3.39bc	0.22b

¹Means followed by different letters in columns are significantly different using Duncan's multiple range test ($P \leq 0.05$). Each value represents the mean number of conidia from 12 lesions. Data were analyzed using a randomized complete block design.

²Amounts of fungicides are presented in Table 5.

greater than that for captan (1985, data not presented) and similar to that for dodine (Table 6). This inhibitory effect was observed at all sampling times subsequent to the second spray. Whereas SI fungicide-treated lesions produced conidia with reduced germination relative to captan and the nonsprayed control in 1985, none of the SI materials was consistently better than dodine in 1986. At day 7 after the third spray, lesions treated with dodine, flusilazole, and diniconazole showed conidial germination percentages similar to those from nonsprayed lesions.

Numbers of conidia per lesion area (mm²) were reduced by treatments with some SI fungicides (Table 7). Seven days after the first spray application, only flusilazole and dodine caused a reduction in conidial numbers. Following the second and third sprays all materials except diniconazole induced reductions in numbers of conidia relative to the nonsprayed control. None of the SI materials were superior to dodine although flusilazole appeared comparable to dodine at day 7 after all three spray applications.

Viable spores from fungicide-treated lesions showed reductions in germ tube lengths of approximately 25% within 48 h following the first spray (Table 8). This effect continued for the duration of the experiment with some exceptions. In general, in the nonsprayed treatment germ tube length shortened as the lesions aged and the comparisons with fungicide treatments became less pronounced. The 48-h post-spray samples displayed the most consistent results regarding germ tube length. No single treatment was recognized as superior using the germ tube length criterion.

Comparison of fungicides. The SI fungicides were ranked from 1 (most effective) to 5 (least effective) for field performance, and for reducing conidia number, percent spore germination, and germ tube length in the 1985 and 1986 experiments at Smithfield. Fungicide performance in field trials in 1985 and 1986 was correlated (Spearman's $r = 0.80$, $t = 2.35$, $P = 0.05$); however, laboratory results from 1985 and 1986 were not correlated. By summing the ranks for both years for the three

Table 8. Germ tube length (μm) of apple scab conidia from fungicide-treated leaves at Smithfield in 1986

Fungicide ²	Sampling time ¹					
	Before first spray	First spray + 48 h	First spray + 7 days	Second spray + 48 h	Second spray + 7 days	Third spray + 7 days
Nonsprayed	281.2cd	366.0a	289.3a	153.0a	127.5abc	163.0a
Dodine	269.2d	259.0d	258.7abc	114.0b	108.2d	125.4b
Bitertanol	291.8bcd	288.8c	206.3d	115.5b	118.5bcd	130.0ab
Diniconazole	303.3bc	283.0cd	246.7bc	122.5b	129.8abc	139.0ab
Flusilazole	318.2ab	277.0cd	279.0ab	117.5b	139.3a	119.1b
Myclobutanil	292.5bcd	323.8b	242.0c	110.5b	133.8ab	120.0b
Triflumizole	333.0a	197.0e	225.3cd	120.2b	116.3cd	143.0ab

¹Means followed by different letters in columns are significantly different using Duncan's multiple range test ($P \leq 0.05$). Each value represents the mean germ tube length from 120 measurements. Data were analyzed using a randomized complete block design.

²Amounts of fungicides are presented in Table 5.

biological effects examined and the field results, we combined the five materials into 3 groups in order of decreasing efficacy: 1) flusilazole and myclobutanil; 2) bitertanol and triflumizole, and 3) diniconazole (Kruskal Wallis $X^2 = 40.5$, $P = 0.01$, 4 d.f.).

Discussion

The experiments reported herein demonstrated that under low inoculum pressure the SI fungicides were similar in effectiveness to captan when used on a 10- to 14-day protective spray program. Under heavy inoculum pressure, as experienced in 1986, the SI materials were more effective than captan. This difference is probably due to the demonstrated postinfection, presymptom, and postsymptom activity of the SI fungicides (3,4,5,7,12). The SI fungicides also provided control of secondary inoculum in the present study although differences in the effectiveness of the fungicides were noticed. Flusilazole at 5.6 g a.i./100 L applied on a 14-day schedule provided acceptable disease control under severe conditions in 1986. Lower rates were acceptable when applied on a 7-day schedule. It may be useful to test higher rates of diniconazole.

Considerable reductions in the production of conidia have been achieved with postsymptom sprays of dodine and benomyl (1,3,4,7,13). In the present study, only flusilazole appeared to reduce conidial production comparable to dodine when examined 7 days after the first spray. Additional sprays with the other SI fungicides were necessary to reduce conidial production to that achieved with dodine. Our results are generally in agreement with those of Yoder and Hickey (13) regarding reduced conidial numbers overtime on nonsprayed lesions.

The germinability of conidia was reduced similarly by dodine and SI fungicides (approximately 70% of the control) when examined 7 days after the first spray. This reduction in germination by the SI materials may not be biologically significant by itself, although when considered together with the highly significant decrease in spore production by these fungicides, it seems clear that two applications of flusilazole could be useful in reducing the viable inoculum from established lesions. Three applications of bitertanol, myclobutanil, and triflumizole may have a similar effect.

Our results confirm those of Drandarevski and Schicke (2), who observed that postsymptom triforine application to established lesions caused reduced germination in conidia produced subsequently. O'Leary and Sutton (7) also demonstrated a similar effect with several SI fungicides. From these studies it can be concluded

that the germination of mature conidia produced from lesions subsequent to fungicide treatment, is reduced.

The present study confirms earlier reports on the mediocre postsymptom activity of most SI fungicides (5,7,8,9,12). Only flusilazole appeared comparable to dodine in reducing the numbers of viable conidia produced on established lesions after one or two sprays. In contrast, Gupta and Kumar (3) have shown that the SI fungicides bitertanol, etaconazole, and triforine were comparable to dodine in inhibiting conidial production in established lesions. These differences may be due to environment or the methods of applying the fungicides to the lesions. In the present study, fungicides were applied as high volume (dilute) sprays. Studies using air blast applications to simulate low volume commercial production methods may lead to different conclusions. The quantitative ranking of fungicides may prove to be beneficial in making pest control recommendations when and if these products become registered for commercial use in Canada.

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