Control of Pear and Apple Diseases in Israel with Sterol-Inhibiting Fungicides

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ABSTRACT

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Results obtained from fungicide evaluations in apple and pear orchards in Israel during 1978–1980 indicate the efficacy of sterol-inhibiting fungicides for control of scab and powdery mildew. These fungicides differed in their effective dosage rates and range of disease control. CGA 64251 and fenapanil were effective for the control of apple powdery mildew and apple and pear scab. Bitertanol was effective for the control of apple and pear scab and gave some control of apple powdery mildew. Triadimefon was excellent for the control of apple powdery mildew, being more effective than diclobutrazol or fenarimol. Prochloraz was an effective fungicide against scab but less active against powdery mildew. A captan-triforine combination was effective in pear scab control.

Additional key words: benomyl, benzimidazole fungicide resistance, carbendazim, *Podosphaera leucotricha, Venturia inaequalis, Venturia pirina*

Pear scab, incited by *Venturia pirina* Aderh., and apple scab, incited by *V. inaequalis* (Cke.) Wint., are widespread in Israel. They cause crop losses in pear orchards, in most apple cultivars in some orchards of the high-altitude regions of Golan and Galilee, and in orchards of the Ana apple cultivar throughout the country. Weather conditions prevailing during March, after budbreak of Gentile and Spadona pear cultivars, favor scab development (4). Because of its low chilling requirements, Ana breaks dormancy very early (in late January or early February). It is subjected to heavier disease pressure than other apple cultivars grown in Israel. In early February, rains are abundant; many leaves, infected with scab from the previous season and still hanging on the Ana trees, serve as the source of conidial inoculum causing primary scab infection of emerging buds.

Although the perithecial stage of *V. inaequalis* may be found later in the spring, the importance of ascospores as primary inoculum in orchards of the Ana cultivar is limited. Other apple cultivars, which break dormancy at the end of March, have suffered substantial crop losses in some orchards of the Golan and Galilee regions. In these orchards, the disease is prevalent on Grand, Red Delicious, and Golden Delicious. Primary infections from ascospores are initiated in these regions during rain after budbreak.

Powdery mildew, incited by *Podosphaera leucotricha* (Ell. & Everh.) Salm., is widespread in apple orchards throughout Israel. The most susceptible cultivars are Jonathan, Grand, and Ana. In some orchards, Golden Delicious may also be heavily infected. Powdery mildew is rare on pears, and the perfect stage has not been found on any host in Israel. After budbreak and during the main season of leaf development during April, May, and June, the climatic conditions are favorable for apple powdery mildew (1). Moreover, in the autumn after harvest there is a long period when new infections occur on new leaves. Thus, in addition to the infections in spring to early summer, autumn infection of buds may provide primary powdery mildew inoculum the following spring (E. Shabi, *unpublished*).

Although sulfur compounds are applied on apple for powdery mildew control, their use is limited. According to our observations, sulfur is less effective on the Ana cultivar, with its extensive leaf development during the cool, early spring months, than it is on cultivars that develop later. In most apple orchards (except Ana), sulfur is applied from budbreak through April. Severe injury to young leaves and fruit may be caused by sulfur starting in May (and even during April on Ana) because of hot and dry weather. Thus, for control of powdery mildew, the fungicides bupirimate, ditalimfos, and triadimefon are preferable to sulfur on Ana and are used on the other apple cultivars during the late spring (May and June) (3,6).

Since 1975, when *V. pirina* was found

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Table 1. Fungicide evaluation on apple cultivar Ana for the control of scab and powdery mildew in 1980[x]

Fungicide	Rate (μg a.i./ml)	Infection (%)[y] Scab Leaf	Scab Fruit	Powdery mildew Leaf
Benomyl	150	0.0 a	0.7 a	1.7 ab
Benomyl or captan + bupirimate[z]	150 or 1,250 + 100	0.7 ab	0.0 a	0.2 a
Benomyl + captan	100 + 1,000	0.0 a	0.7 a	0.0 a
Bitertanol	250	0.2 a	0.0 a	0.6 a
Captan + bupirimate	1,250 + 100	0.6 a	0.0 a	0.5 a
CGA 64251	25	0.2 a	0.3 a	0.2 a
Folpet + bupirimate	1,000 + 100	0.2 a	0.7 a	0.2 a
Fenapanil (EC)	360	2.8 ab	0.7 a	1.1 a
Fenapanil (LC)	360	0.4 a	0.0 a	0.4 a
Prochloraz	300	0.0 a	0.0 a	2.6 b
Bupirimate	100	63.3 b	11.3 b	0.4 a

[x]Eight spray applications in Dagan orchard, Meishar (coastal plain), Israel, 13 February through 16 April 1980.
[y]On 15 May 1980. Means followed by the same letter do not differ significantly at $P = 0.05$.
[z]Benomyl in the second, fourth, sixth, and eighth sprays; captan + bupirimate in the first, third, fifth, and seventh.

Table 2. Fungicide evaluation on apple for the control of *Podosphaera leucotricha* in 1980[y]

Fungicide	Rate (μg a.i./ml)	Leaf powdery mildew, secondary infection (%)[z] Jonathan A	Jonathan B	Golden Delicious A	Golden Delicious B
Bupirimate	100	4.7 a	3.4 a	11.7 ab	7.3 a
CGA 64251	25	1.8 a	0.9 a	2.4 a	0.7 a
Diclobutrazol	100	17.1 a	11.4 b	10.0 ab	7.8 a
Prochloraz	375	42.7 b	18.3 b	21.5 b	16.7 a
Unsprayed check	···	63.5 c	66.1 c	91.1 c	86.0 b

[y]Six spray applications in Daliya orchard, Mount Carmel, Israel, 2 April through 28 May 1980.
[z]Incidence of secondary powdery mildew was assessed (A) after four sprays, on 18 May 1980; (B) after six sprays, on 10 June 1980. Means followed by the same letter do not differ significantly at $P = 0.05$.

Table 3. Fungicide evaluation on pear for the control of *Venturia pirina* resistant to benzimidazole fungicides in 1980[y]

Fungicide	Rate (μg a.i./ml)	Fruit-scab infection (%)[z] Gentile Primary	Gentile Secondary	Spadona Primary	Spadona Secondary
Bitertanol	250	2.9 a	2.2 a	2.4 a	2.2 a
Captan	1,250	0.8 a	0.2 a	1.7 a	1.8 a
CGA 64251	25	1.1 a	2.6 a	1.7 a	3.0 a
Fenapanil (EC)	360	1.3 a	1.3 a	1.7 a	3.0 a
Fenapanil (LC)	360	2.0 a	2.4 a	3.1 a	6.9 a
Prochloraz	300	0.9 a	0.3 a	0.7 a	1.8 a
Unsprayed	···	12.5 b	13.4 b	10.7 b	24.2 b

[y]Six spray applications in Daliya orchard, Mount Carmel, Israel, 24 March through 28 May 1980.
[z]At harvest: Gentile cultivar on 17 June 1980, Spadona cultivar on 17 July 1980. Means followed by the same letter do not differ significantly at $P = 0.05$.

Table 4. Fungicide evaluation on pear cultivar Spadona for the control of *Venturia pirina* in 1978[x]

Fungicide	Rate (μg a.i./ml)	Scab infection (%)[y] Primary	Scab infection (%)[y] Secondary	Fruit finish[z]
Bitertanol	250	0.0 a	0.8 a	2
Captan	1,250	2.0 a	5.0 a	3
Captan + benomyl	750 + 100	0.4 a	1.3 a	2
Captan + triforine	750 + 100	0.1 a	0.1 a	8
Fenapanil	400	2.0 a	3.7 a	12
Unsprayed check	···	41.5 b	38.8 b	12

[x]Eleven spray applications in 'En haShofet orchard, Mount Carmel, Israel, 7 March through 12 June 1978.
[y]At harvest on 10 July 1978. Means followed by the same letter do not differ significantly at $P = 0.05$.
[z]Fruit finish rated from 0 = excellent to 100 = totally russeted.

to be resistant to benzimidazole fungicides (5), there arose the need for effective replacements for benomyl and thiophanate methyl for the control of pear scab. This prompted the evaluation of some sterol-inhibiting fungicides in pear and apple orchards in Israel.

MATERIALS AND METHODS

The sterol-inhibiting fungicides evaluated were bitertanol (Baycor 50W, Bay KWG 0599); CGA 64251 (10W; 1-[[2-(2,4-dichlorophenyl)-4-ethyl-1,3-dioxolan-2-yl]-methyl]-1*H*-1,2,4-triazole); diclobutrazol (Vigil 3F, PP296); fenarimol (Rubigan 12EC, EL-222); fenapanil (Sisthane 24EC or 24LC, RH 2161); prochloraz (BFN 8206 50W, BTS 40514); triadimefon (Bayleton 25W); and triforine (Saprol 20EC, Funginex). Benomyl (Benlate 50W) and captan (Merpan 50W) were used as standards in tests on pear and apple scab control. Folpet (Folpan 50W) and mancozeb (Manzidan 80W) were also included in apple scab tests. Bupirimate (Nimrod 25EC) was used as the standard fungicide in tests on apple powdery mildew.

Spadona and Gentile cultivars were used to determine the efficacy of fungicides for the control of pear scab. The Ana cultivar was used to determine the efficacy of fungicides for the control of both apple scab and apple powdery mildew. Jonathan, Grand, and Golden Delicious were used to evaluate fungicides for the control of apple powdery mildew.

Pear scab incidence was assessed on fruit at harvest. Fruits infected with primary scab (March and early April) or secondary scab (late April, May, and June) were counted separately. Apple scab assessment on Ana was done on fruit at harvest and on spur leaves at the middle of May (for scab and powdery mildew). Leaves from terminal shoots of Jonathan, Grand, and Golden Delicious apple cultivars were used for secondary powdery mildew evaluation. Terminal shoots and spurs that emerged from buds infected with powdery mildew the previous season were used in the evaluation of fungicides for the control of primary powdery mildew.

Three- to six-tree plots were sprayed to runoff by handgun at 20.7 bars (300 lb/in.^{2}).

Spores sensitive and resistant to benzimidazole fungicides were distinguished by the shape of their germ tubes after incubation 1–2 days at 20 C on potato-dextrose agar supplemented with 5 μM of carbendazim (5,9).

RESULTS AND DISCUSSION

Sterol-inhibiting fungicides were found to vary in their activity in controlling apple powdery mildew and apple scab (Tables 1 and 2). From a test on the mildew-susceptible Jonathan, it can be concluded that fenapanil and

triadimefon, as well as bupirimate (the standard fungicide for apple powdery mildew control), are excellent for control of primary mildew (6). Triadimefon was more effective against secondary powdery mildew, as compared with bupirimate, bitertanol, fenarimol, and fenapanil, which are also effective (6). CGA 64251 and fenapanil effectively controlled powdery mildew and scab (Tables 1 and 2), but CGA 64251 was much more effective on a dosage basis (25 μg/ml) than fenapanil (360 μg/ml).

Bitertanol gave excellent control of scab but was less effective than triadimefon, CGA 64251, and fenapanil in the control of powdery mildew on the very susceptible Jonathan and Grand cultivars (6,7). Bitertanol controlled powdery mildew as well as did CGA 64251 and fenapanil on the less susceptible apple cultivar Ana (Table 1). Prochloraz, at 300 μg/ml, was an effective fungicide for scab; however, its performance against powdery mildew was inferior despite the higher rate of 375 μg/ml (Tables 1,2 and 3). Dichlobutrazol was less effective than bupirimate and CGA 64251 for powdery mildew (Table 2). Benomyl or benomyl mixed with or alternated with captan was active in controlling apple scab (Table 1). Resistance to carbendazim was not found when the *V. inaequalis* population was monitored.

Three sterol-inhibiting fungicides—bitertanol, fenapanil, and triforine (mixed with captan)—gave good control of pear scab (Table 4). Although the disease incidence in the plots sprayed with mixtures of benomyl and captan was low, most of the *V. pirina* sampled from scab lesions found in this treatment was carbendazim-resistant. The scab pathogen in the plots sprayed with other fungicides remained mostly carbendazim-sensitive, as had been found in this orchard the previous year (9). Tests conducted in 1978–1980 in a pear orchard at Daliya, where *V. pirina* was found to be carbendazim-resistant (8–10), revealed that sterol inhibitors are efficient fungicides for pear scab control (Table 3).

These results indicate that sterol inhibitors may replace the benzimidazole fungicides in pear orchards infected with *V. pirina* resistant to benzimidazole fungicides. Moreover, the pear cultivars Spadona and Gentile cannot be treated with dithiocarbamate fungicides because of severe phytotoxicity, and dodine is sprayed only in the prebloom period because later applications increase russeting on pear fruit (2). For these reasons, the use of sterol-inhibiting fungicides may be more important in pear than in apple orchards in Israel.

Although the sterol inhibitors differed in their effective dosage rates and ability to control scab or powdery mildew, these fungicides were generally active in the control of diseases of both pear and apple.

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