Protection of Peach Shoots Against Species of Leucostoma with Benomyl and Captafol

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ABSTRACT

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Fungicides were applied to severely cankered Loring peach trees during leaf fall and in early spring to prevent infection of 1-year-old scaffold shoots by *Leucostoma cincta* and *L. persoonii*. Benomyl and captafol reduced the disease, but captan, dichlone, dichloran, ferbam, and sulfur were ineffective. Bordeaux mixture and dinitro-*o*-cresol were phytotoxic and increased the severity of the disease. Optimum timing of fungicide application was during and immediately after leaf fall. Late-summer use of benomyl gave slight control, but spring applications of captafol were ineffective. Fungicide programs were effective for only one season. Captafol was equally effective when applied by airblast sprayer in either 850 or 2,270 liter/hectare(ha) of spray, and comparable to dilute sprays of 5,110 liter/ha. *Leucostoma persoonii* was the minor pathogen and was almost as well controlled by benomyl and captafol as was *L. cincta*. Shoot infection can be controlled most economically as a secondary effect of the summer application of benomyl against *Monilinia fructicola*, and particularly from the application of captafol during or immediately after leaf fall for the control of *Taphrina deformans*.

Additional key words: canker, *Cytospora* spp., fungicide, *Valsa* spp.

Spring girdling and dieback of shoots on peach trees [*Prunus persica* (L.) Batsch] is an important phase of *Leucostoma (Cytospora, Valsa)* canker (12, 15). The primary pathogen is *Leucostoma cincta* (Pers. ex Fr.) Höhn. [= *Valsa cincta* (Pers. ex Fr.)]; *L. persoonii* (Nits.) Höhn. [= *Valsa leucostoma* (Pers. ex Fr.) Fr.] is of minor importance, even though it commonly is associated with other phases of peach canker (13, 14). Infections of large scaffold shoots render them unsuitable as replacement limbs and infections of short shoots often initiate cankers in the supporting branches. Most of the lesions are nodal and arise from infections of either newly exposed leaf scars (12, 15) or dead buds (2, 12), between leaf fall in late October and bud break in late April.

Despite the economic importance of shoot infections by *Leucostoma*, relatively little progress has been made in the development of simple, effective, and safe control measures. Many chemicals, including most of the fungicides used for peach protection, show moderate-to-high in vitro fungitoxicity towards species of *Leucostoma* (1, 3, 8, 9). However, only copper salts, with a low innate fungitoxicity (5, 9), have been found effective for shoot protection (10, 11). The effectiveness of organic fungicides against natural shoot infections has not been examined previously.

The efficacies of several fungicides for preventing *Leucostoma* lesions on peach shoots were determined in the present study. The effects of application timing and of water volume used to apply the fungicide were assessed in an attempt to integrate the *Leucostoma* control program with fungicide programs against brown rot [*Monilinia fructicola* (Wint.) Honey] and peach leaf curl [*Taphrina deformans* (Berk.) Tul.].

MATERIALS AND METHODS

Experiments were conducted on severely cankered Loring peach trees, 10-15 years old, growing in commercial orchards on the Niagara Peninsula, Ontario, Canada, and maintained according to cultural recommendations (7). Each spring ferbam was applied at bud-swelling time to prevent leaf curl, and captan was used for protection against blossom blight (caused by *M. fructicola*). Experimental fungicide treatments were applied to compact plots of 6-12 trees, spaced 6 m × 6 m, and replicated two or three times in randomized blocks.

The following nine fungicides were used: benomyl (Benlate, 50% WP, Du Pont); captafol (Difolatan 4.8F, 39%, Flowable, Chevron); captan (Orthocide, 50% WP, Chevron); dichlone (Phygon XL, 50% WP, Bartlett); dichloran (Botran, 75% WP, Howard); dinitro-*o*-cresol (DNOC) (Elgetol, 1.95 lb/Imp. gal., Niagara); ferbam (Ferbam W, 76% WP, Niagara); sulfur (Micro Niasul W, 92% WP, Niagara); Bordeaux mixture, prepared with equal weights of hydrated copper sulfate (25% copper, Canadian Copper Refiners) and hydrated spray lime (Domtar).

Fungicides were applied in four experiments as dilute sprays to initial runoff by using a hand-held, four-nozzle boom and a double-tank Bean sprayer. Each tree received approximately 14 liters (3 Imp. gal.) of spray, equivalent to 5,110 liter/ha (450 Imp. gal./acre) applied on a commercial basis with an airblast sprayer. In two large-scale experiments, fungicides were applied with a Swanson Model 530 airblast orchard sprayer nozzled to deliver 850 liter/ha (75 Imp. gal./acre) or 2,270 liter/ha (200 Imp. gal./acre) with a ground speed of 3.2 km/h (2 mph).

One-year-old unbranched shoots 30-100 cm long, were evaluated for *Leucostoma* lesions. Shoots in the centers of trees were tagged with adhesive paper tape during the winter, prior to lesion development, and were harvested in June. Detailed examinations were made in the laboratory and isolations from infected tissues were made

on potato-dextrose agar (PDA) for pathogen identification. The number of shoots sampled per replicate was uniform within each experiment, but it varied from 68 to 114 among the experiments. Disease incidence was expressed as the percentage of shoots with *Leucostoma* infection, and the data were subjected to an analysis of variance and Duncan's multiple range test of significance.

RESULTS

Efficacy of fungicides.—Nine fungicides were applied as dilute sprays and, with the exception of DNOC, three applications were made during leaf fall and a further three during the spring dormant period (Table 1). Dinitro-*o*-cresol (DNOC) was discontinued after the third autumn application because of desiccation of the nodal regions and tips of shoots following premature defoliation. Of these materials, only benomyl and captafol reduced shoot infection by *Leucostoma* spp. relative to the water check (Table 1). Captan, dichlone, dichloran, ferbam, and sulfur were ineffective. Bordeaux mixture and DNOC were phytotoxic and increased the severity of the disease. Injury from the Bordeaux mixture developed in the spring and consisted of severe purple mottling and blistering with occasional gumming of one-year-old shoots.

TABLE 1. Efficacy of fungicides applied as a six-spray, autumn-spring program for control of *Leucostoma* infection of peach shoots[w]

Fungicide	Concentration in water (kg/100 liter)	Relative incidence of shoot infection (check = 100)[x]
Benomyl	0.05	37 a[y]
Captafol	0.24	49 ab
Sulfur	1.10	73 abc
Dichlone	0.05	76 abc
Captan	0.20	85 abc
Nontreated check	. . .	100 abc
Dichloran	0.15	107 bcd
Water check	. . .	122 cd
Ferbam	0.30	188 d
Bordeaux mixture	1.0 + 1.0	278 e
Dinitro-*o*-cresol[z]	0.20	331 e

[w]Application dates: 8 and 23 October, and 6 November 1970; 18 and 31 March, and 15 April 1971.
[x]Incidence of shoot infection in nontreated check was 22.4%.
[y]Means followed by different letters differ significantly ($P = 0.05$).
[z]Spray program was discontinued after the third application.

Optimum timing of fungicide applications.—Two applications of benomyl and captafol during leaf fall were equally effective in reducing shoot infection, whereas two spring applications of captafol were ineffective (Table 2). The effectiveness of the autumn captafol program was not increased when combined with the spring program.

A second evaluation of the autumn and autumn-spring programs was made a year later to determine the extent of recurrence of the disease. Despite more shoot infection in the second year, none of the 1971-1972 fungicide programs reduced infection during the 1972-1973 dormant period.

Benomyl was tested in a subsequent field experiment to determine whether its summer use for fruit protection against brown rot would reduce *Leucostoma* shoot infection. Preharvest applications of 0.85 kg benomyl in 850 liters of spray/ha were made with an airblast sprayer on 17 and 28 August and 6 September 1972, to plots within captan-sprayed orchards. Other plots were dilute-sprayed during leaf fall on 25 October and 7 November 1972 (at 12% and 68% defoliation, respectively), using the concentration of 0.05 kg benomyl/100 liter (equivalent to 2.6 kg benomyl/ha/application) which previously was found to be effective (Tables 1 and 2).

The three preharvest applications of benomyl gave a slight (13%), but significant ($P = 0.05$), reduction of relative disease severity. The two-spray leaf fall program gave a 61% reduction; however, the two programs cannot be directly compared because twice as much benomyl per hectare was used in the autumn program as in the summer program.

A study was undertaken to determine the optimum stages of tree defoliation for single and multiple applications of captafol for prevention of shoot infection. Captafol was chosen because of its additional effectiveness against leaf curl, in contrast with the ineffectiveness of benomyl (6). Captafol was applied as a dilute spray at concentrations effective against leaf curl (Table 3).

The captafol programs reduced *Leucostoma* shoot

TABLE 2. Comparison of autumn applications of benomyl and captafol with spring applications of captafol for control of *Leucostoma* infection of peach shoots, and their effect on disease recurrence 1 year later

Fungicide[w]	Time of application[x]	Relative incidence of shoot infection (check = 100)[y]	
		1972	1973
Benomyl	Autumn	16 a[z]	81 c
Captafol	Autumn	23 a	80 c
Captafol	Autumn and Spring	10 a	104 c
Captafol	Spring	95 b	. . .
Water check	Autumn	105 b	. . .
Nontreated check	. . .	100 b	100 c

[w]Concentration of fungicide in spray: benomyl 0.05 kg/100 liter; captafol 0.24 kg/100 liter.
[x]Autumn applications were made 28 October and 8 November 1971 (respectively 10% and 70% defoliation), and spring applications 21 March and 14 April 1972.
[y]Shoot infection in nontreated check was 32% and 72% in 1972 and 1973, respectively.
[z]Means in the same column followed by different letters differ significantly ($P = 0.05$).

infection to between 51% and 73% of the nontreated check. A single post-leaf fall application reduced the disease to 55%, and was more effective than an application at 12% defoliation, whereas an application at 37% defoliation gave an intermediate reduction (Table 3). A single application of captafol at twice the concentration (0.48 kg/100 liter) at 12% defoliation, and programs of two and three applications of captafol at the lower concentration gave disease reductions comparable to that of the single post-leaf fall application.

Low-volume airblast application of captafol.—In a further attempt to integrate the control of *Leucostoma* shoot infection with that of leaf curl, captafol was applied at a rate effective against leaf curl (8.2 kg/ha) (6) and at half that rate. Application was made with an airblast orchard sprayer using 850 liter/ha or 2,270 liter/ha. This is in contrast with the earlier dilute applications of 5,110 liter/ha, equivalent to 12.3 kg captafol/ha. Two applications were made during leaf fall instead of the normal single post-leaf fall spray against leaf curl.

The captafol treatments gave only moderate reduction of shoot infection to 70-76% of the airblast check and there was no difference between the two spray volumes at either captafol rate (Table 4).

Effect of benomyl and captafol on the incidence of infections by Leucostoma cincta and Leucostoma persoonii.—To determine the identity of the pathogens and the respective ease of their control, isolations were made from lesions on 566 shoots in the nontreated and water-treated checks of the initial timing study (Table 2). Isolations also were made from 285 and 286 shoots sprayed twice in the autumn with benomyl and captafol, respectively. The incidences of *L. cincta* and *L. persoonii* in the checks were respectively 43 and four lesions/100 shoots, including 0.5 lesion/100 shoots from which both species were isolated. Benomyl reduced *L. cincta* and *L. persoonii* infections by 88% and 72% and captafol reduced them by 79% and 53%, respectively.

DISCUSSION

Benomyl and captafol are moderately to highly fungitoxic to species of *Leucostoma* in in vitro tests (1, 3, 9) and both materials gave moderate-to-good control of natural shoot infections in the present studies. In contrast, captan, dichlone, ferbam, and sulfur also are moderately to highly fungitoxic (3, 9) but none of them reduced shoot infection. This shows that the relative orchard effectiveness of fungicides against species of *Leucostoma* cannot be judged solely from their in vitro fungitoxicity.

The effectiveness of captafol against shoot infections by *Leucostoma* spp. has not been described previously. Benomyl recently was reported to protect artificially wounded peach branches inoculated with *L. persoonii* (4); however, its efficacy against natural *L. cincta* infections of shoots has not been reported.

Bordeaux mixture was phytotoxic and increased *Leucostoma* shoot infection on Loring peach trees in the present study. In contrast, Tekauz (11) reported that with Elberta and Veteran peach trees, Bordeaux mixture gave a moderate reduction of shoot infection without phytotoxicity. It appears, therefore, that Bordeaux mixture reduces shoot infection only on copper-tolerant peach cultivars, whereas on copper-sensitive cultivars such as Loring, it can predispose shoots to infection.

Autumn fungicide applications gave moderate to good control of shoot infection, whereas late-summer applications were only slightly effective and spring applications were ineffective. These results contrast with the effectiveness of late-summer Bordeaux applications reported by Rolfs (10). However, they extend Tekauz' findings (11) of the effectiveness of an autumn-spring Bordeaux program and the ineffectiveness of a spring program.

Shoot infection can occur through both leaf scars and dead buds (2, 12, 15). The substantial reduction of shoot infections with fungicide applications during or

TABLE 4. Effect of water volume and rate of captafol applied by airblast sprayer on control of infection of peach shoots by *Leucostoma* spp.[x]

Volume of water (liter/ha)	Rate of captafol (kg/ha)	Relative incidence of shoot infection (check = 100)[y]
2,270	4.1	74 a[z]
2,270	8.2	70 a
850	4.1	76 a
850	8.2	73 a
Airblast only	. . .	100 b

[x]Two applications made respectively on 25 October and 6 November 1972 at 16% and 64% defoliation of scaffold shoots.
[y]Shoot infection in airblast check was 72%.
[z]Means followed by different letters differ significantly ($P = 0.05$).

TABLE 3. Effect of stage of defoliation upon the efficacy of captafol against infection of peach shoots by *Leucostoma* spp.[x]

Captafol concentration (kg/100 liter)	Application dates (A)			Relative incidence of shoot infection (check = 100)[y]
	25 Oct.	7 Nov.	17 Nov.	
0.48	A	. . .	. . .	64 abc[z]
0.24	A	. . .	. . .	73 c
0.24	. . .	A	. . .	70 bc
0.24	. . .	. . .	A	55 ab
0.24	A	A	. . .	62 abc
0.24	A	A	A	51 a
Nontreated	. . .	. . .	. . .	100 d

[x]Defoliation of shoots on 25 October, 7 and 17 November 1972, was 12%, 37%, and 100%, respectively.
[y]Shoot infection in nontreated check was 62%.
[z]Means followed by different letters differ significantly ($P = 0.05$).

immediately after leaf fall is attributed therefore to the prevention of leaf scar infection. The failure to obtain a high degree of control each year was believed to result from a variable amount of spring infection of winter-killed buds. Furthermore, some of the dead bud infections may have occurred prior to the start of the spring fungicide programs, resulting in only moderate disease control even with intensive autumn-spring six-spray programs.

The efficacy of captafol was unchanged when applied by commercial airblast sprayer as either 850 or 2,270 liters of spray per hectare. Furthermore, the control obtained with two applications of 8.2 kg captafol in 850 liters per hectare was similar to that obtained with correspondingly timed dilute applications of 12.3 kg captafol/5,110 liter/ha in the preceding experiment. These results indicate that captafol was still moderately effective, even when applied at the lower rate and in smaller volumes of water consistent with its commercial use for the control of leaf curl.

The reduction of *Leucostoma* shoot infection resulted primarily from the control of *L. cincta,* the principal pathogen. However, a low incidence of *L. persoonii* also was suppressed by benomyl and captafol, thereby substantiating the reported effectiveness of benomyl against *L. persoonii* (4).

Of the fungicides currently used for peach protection, only benomyl and captafol were effective in reducing *Leucostoma* shoot infection. However, neither fungicide gave sufficient control with enough consistency to justify its application for this purpose alone. Nevertheless, partial control can be obtained as a benefit of the summer use of benomyl against brown rot and the application of captafol during or immediately after leaf fall for the control of leaf curl.

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