Dissipation of Captan Residues from Cherry and Peach Fruits

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Mature sweet cherry, sour cherry, and peach trees were sprayed one to eight times with captan at 2.4–4.5 kg ha^{-1}. Captan residues on fruits were measured for 14 days after the last application and were negatively correlated with rainfall in seven of nine studies. A 50% reduction of captan was associated with 8.3–51.4 mm of rain. Residues after the last application exceeded 5 mg kg^{-1} in eight of nine studies, and the longest periods for residues to decline below this level were 11 days for sweet cherry and 14 days for sour cherry and peach. Captan did not degrade on sweet cherries stored at 4 and 20 °C, but it was easily removed with a 60-s tumbling wash in water. A captan tolerance of 10 mg kg^{-1} of cherry and peach fruits appears necessary for their adequate protection against brown rot (*Monilinia fructicola*).

INTRODUCTION

Captan, *N*-[(trichloromethyl)thio]cyclohex-4-ene-1,2-dicarboximide, was introduced in the early 1950s and is still widely used for the protection of many fruit crops against a broad range of fungal pathogens (Dunnett, 1982). It is especially useful for the protection of stone fruits against *Monilinia fructicola* (Wint.) Honey, the causal fungus of the brown rot disease. Captan is used alone and either alternated with or combined with fungicides prone to the selection of fungicide-resistant populations of pathogens. However, in 1983 the residue tolerance for captan on stone fruits in Canada was reduced from 25 to 5 mg kg^{-1} (Health and Welfare Canada, 1983), which might necessitate a change in the use of captan close to harvest on some stone fruits.

The present study was undertaken in 1981–1983 as part of a comprehensive examination of the persistence of captan on six fruit crops grown in Ontario, Canada. The results for apple, pear, and grape were reported by Frank et al. (1985), and this paper reports the results for sweet cherry, sour cherry, and peach. Related aspects that were examined include the variation of fruit residues between different regions of trees, the persistence of captan residues on cherries stored at 4 and 20 °C, the ease of removal of residues by washing, and the susceptibility of washed and unwashed sweet cherries to infection by *M. fructicola*.

MATERIALS AND METHODS

Orchard Application Procedures. Captan was applied to groups of mature fruiting trees in orchards of sweet cherry (*Prunus avium* L. cv. Bing), sour cherry (*Prunus cerasus* L. cv. Montmorency), and peach (*Prunus persica* (L.) Batsch cv. Redhaven and Garnet Beauty). The orchards were situated on well-drained Vineland sandy loam at Jordan Station and Vineland Station, Ontario, Canada. The application dates and rates of application of captan (active ingredient) are given in Table I and followed registered uses and commercial recommendations (Ontario Ministry Agriculture and Food, 1983). Dilute applications of captan were made to peach (1981) and sour cherry (1982) using a Bean four-nozzle broom spray gun operated at 3150 kPa using captan at 100 g 100 L^{-1}, at 3000 L ha^{-1}. Blocks of 20 trees were sprayed with a Swanson 530 airblast machine as described by Frank et al. (1985). A wettable powder formulation containing 50% captan (Stauffer Chemical of Canada Ltd.) was used in all experiments.

Fruit Sampling Procedures. Samples of mature fruits were collected immediately prior (i.e., prespray) to the final application of captan and again 2 h after the final application (i.e., postspray, 0 day) and thereafter generally at intervals of 1, 2, 3, 5, 7, 10, and 14 days. Fruits were collected in equal proportions from the inside and outside regions of trees, 1.5–2.0 m above ground. Cherries were picked by the stems to avoid touching the fruit surface. Peaches were picked in the normal commercial manner. Four replicate 350-g samples of cherries were collected and placed in polyethylene bags, frozen, and stored at −10 °C. With peaches, each of the replicate samples collected in 1981 and 1982 consisted of eight fruits that were frozen whole in polyethylene bags and subsampled just prior to residue extraction. In 1983, half of each of the eight peaches for each of the four replicates was cut into four slices, avoiding the pit, and the 32 slices were placed at random in a polyethylene bag and frozen at −10 °C.

Residues in Regions of Trees. To determine the variability of captan residues within trees, samples of 350 g of cherries or eight peaches were collected in four experiments as soon as the final spray had dried (0 day), from each of the lower outside and inside regions 1.5–2.0 m above ground and the upper outside and inside regions of trees 2.5–3.0 m above ground.

Captan on Stored Sweet Cherries. Sweet cherries with stems were picked and mixed to ensure greater uniformity of residue. Samples of 250 g of fruits were placed in polyethylene bags, sealed, and stored at either 4 or 20 °C. Four replicate bags were removed after storage for 0, 1, 2, 3, 5, 7, 11, and 14 days and frozen at −10 °C for later residue analysis.

Removal of Captan by Washing. Sweet cherries with stems were weighed into lots of 1 kg. Individual lots were dropped into 3 L of distilled water within a 4-L container and tumbled manually every 2.5 s to resemble domestic washing, for 15, 30, 60 or 120 s. In 1983, additional treatments included washes for 120 s in (1) 0.1% Tween 20 solution in distilled water followed by a rinse with 1 L of distilled water; (2) 4.2 g of $NaHCO_3$ L^{-1} (0.05 M) in distilled water, with or without a final rinse; and (3) tap water at 20 °C followed by a tap water rinse. Fruit lots were drained and dried on absorbent paper, without rubbing, for 1–2 h at 20 °C, subdivided into four replicate samples each of 250 g, and frozen in polyethylene bags at −10 °C for later residue analysis.

Peach fruits were individually hand rubbed in running tap water at 20 °C for 5 or 10 s or were vigorously brushed in running tap water with a stiff-bristle brush for 10 s.

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Table I. Details of the Application of Captan to Stone Fruits

fruit crop	year	appl method	appl dates	rate of captan used in final appl, kg ha^{-1}
sweet cherry	1982	airblast	5/6, 5/14, 5/21, 6/4, 6/17, 7/5, 7/19	2.4
	1983	airblast	6/1, 6/15, 6/24, 7/7, 7/21	4.5
sour cherry	1982	dilute[a]	7/26	3.0
	1982	airblast	5/6, 5/14, 5/21, 6/4, 6/17, 7/5, 7/19, 7/26	3.4
	1983	airblast	6/15, 6/24, 7/7, 7/21	3.4
peach	1981	dilute[a]	7/15, 7/29, 8/11	3.0
	1981	airblast	6/2, 7/8, 7/23	3.4
	1982	airblast	7/19, 8/3, 8/23	3.4
	1983	airblast	7/21, 8/3, 8/16, 8/24	3.4

[a] Dilute concentration of captan (100 g 100 L^{-1}) applied at approximately 3000 L ha^{-1}. Equivalent to 3.0 kg of captan ha^{-1}.

Each treatment was applied to 32 peaches that were grouped into four replicates of eight peaches. Fruits were dried on absorbent paper, without rubbing, for 1–2 h. Half of each peach was cut into four slices, randomized with other slices from the same replicate, and frozen at −10 °C for later analysis.

Inoculation of Sweet Cherry Fruit with *M. fructicola*. Sweet cherries (cv. Bing) were picked and randomized as described previously. Half remained unwashed and half were tumble washed in distilled water for 120 s at 28 °C and air-dried at 20 °C for 2 h. Stems were trimmed and replicate lots of 50 fruits were arranged on 12 × 12 mm wire screen in aluminum trays. Four replicates were used per treatment. Wound-free fruits were each inoculated with a 30-μL drop of conidial suspension of *M. fructicola* containing 10^3, 10^4, 10^5, or 10^6 viable conidia mL^{-1} suspended in a stimulant solution (SS) containing 2 g L^{-1} of sucrose and 0.01 g L^{-1} each of sodium citrate and potassium citrate in distilled water (Miller, 1944). Inoculated fruits were incubated for 24 h, dried briefly to terminate infection, incubated at 20 °C for 6 days, and evaluated for lesion development.

Analysis of Captan Residues. Captan residues were extracted and measured by using the procedures described in the Pesticide Analytical Manual (1973) and as described by Frank et al. (1985).

Climatological Measurements. Rainfall was measured with a recording rain gauge. The cumulative rainfall (mm) that fell after the final application of captan and prior to a particular sample collection and the average daily temperature for each study were calculated and appear in each appropriate table.

Statistical Analyses of Data. The replicated residue data were examined for significant differences at various sampling intervals by using analysis of variance procedures and Duncan's multiple-range test. The relation between captan residue (y, mg kg^{-1}) and cumulative rainfall (x, mm) for each experiment was examined by using replicated residue data in regression analyses. First-order linear regression equations fitted the data well and had the generalized form

$$\log y = a + b(x + 1) \quad (1)$$

The correlation coefficient (r) was tested for statistical significance (P), and the amount of rainfall equivalent to a reduction of captan residue by 50% (0.5y) was calculated from the regression equation.

RESULTS

Captan Residues on Sweet Cherry Fruits. In 1982, the application of a reduced rate of captan, 2.4 kg ha^{-1}, deposited 3.9 mg kg^{-1} of captan, elevating the initial residue to 6.7 mg kg^{-1}, which declined below the residue tolerance of 5 mg kg^{-1} after 2 days in the absence of rain (Table II). A rainfall of 26 mm reduced the residue by day 10 to 1.9 mg kg^{-1}, which was significantly ($P = 0.05$) below the initial residue. The decline of captan residue (y, mg kg^{-1}) in relation to rainfall (x, mm) was expressed by

Table II. Decline of Captan Residues on Sweet Cherry Fruits Remaining on Trees, in Relation to Cumulative Rainfall, in 1982 and 1983

	1982[a]		1983[a]	
time interval	residue, mg kg^{-1}	rainfall, mm	residue, mg g^{-1}	rainfall, mm
prespray	2.8 ab[b]		4.1 ab	
postspray				
0 day	6.7 c	0	26.5 e	0
1 day	5.2 bc	0	9.5 bcd	3
2 days	2.8 ab	0	7.9 bcd	3
3 days	4.6 bc	0	11.9 cd	3
5 days	5.0 bc	0	9.8 bcd	3
7 days	4.4 bc	0	13.4 d	3
10 days	1.9 ab	26		
11 days			4.5 abc	42
14 days	1.8 ab	26	4.3 ab	55
unsprayed	0.01 a		0.04 a	
mean temp, °C	21.1		23.6	

[a] Rates of airblast application of captan in 1982 and 1983 were 2.4 and 4.5 kg ha^{-1}, respectively. [b] Means in the same column followed by different letters differ significantly ($P = 0.05$), and those followed by the same letter(s) are not significantly different ($P = 0.05$), by Duncan's multiple-range test.

$$\log y = 0.602 - 0.013(x + 1) \quad (2)$$

The correlation coefficient, $r = -0.45$, was highly significant ($P < 0.01$), and the rainfall equivalent to a 50% reduction in residue was 23.0 mm.

In 1983, the recommended rate of captan, 4.5 kg ha^{-1}, increased the residue by 22.4 mg kg^{-1} to 26.5 mg kg^{-1} (Table II). The residue declined abruptly after 1 day and 3 mm of rain, but it remained at about 10.5 mg kg^{-1} until a further rainfall of 39 mm reduced it to 4.5 mg kg^{-1} on day 11. There was a very highly significant correlation between residue and rainfall ($r = -0.63$, $P < 0.001$), and the linear equation was

$$\log y = 1.091 - 0.013(x + 1) \quad (3)$$

A 50% decline in captan was equivalent to 23.4 mm of rain.

Captan Residue on Sour Cherry Fruits. A single dilute application of captan gave an initial captan residue of 16.8 mg kg^{-1}, which declined significantly to 7.6 mg kg^{-1} after 3 days and 26 mm of rain (Table III). The residue fell below 5 mg kg^{-1} 5 days after the application. The regression equation was

$$\log y = 1.216 - 0.018(x + 1) \quad (4)$$

where $r = -0.84$ and $P < 0.001$, and the rainfall equivalent to a residue reduction of 50% was 17.0 mm.

In 1982 and 1983, the airblast applicatons of captan, 3.4 kg ha^{-1}, raised the initial residues by 3.0 and 26.0 mg kg^{-1}

Table III. Decline of Captan Residues on Sour Cherry Fruits Remaining on Trees, in Relation to Cumulative Rainfall in 1982 and 1983

postspray interval	1982 dilute[a] residue, mg kg^{-1}	1982 airblast[a] residue, mg kg^{-1}	1982 rainfall, mm	1983 airblast[a] residue, mg kg^{-1}	1983 rainfall, mm
prespray	0.18 a	10.4 cd		3.5 ab	
postspray					
0 day	16.8 c	13.4 d	0	29.5 e	0
1 day	15.3 c	8.1 bc	0	31.5 e	3
2 days		6.2 bc	26	18.5 d	3
3 days	7.6 b	7.0 bc	26	10.6 c	3
5 days	4.9 ab	9.7 bcd	26	12.5 c	3
7 days		8.6 bcd	26	8.3 bc	3
8 days	4.8 ab		30		
10 days	4.3 ab	5.5 bc	40		
11 days				3.0 a	42
14 days	2.3 a	4.8 b	45	2.1 a	55
unsprayed	0.18 a	0.02 a		0.01 a	
mean temp, °C	20.8	20.8		23.6	

[a] Rates of captan used in dilute and airblast applications were 3.0 and 3.4 kg ha^{-1}, respectively. [b] Means in the same column followed by different letters differ significantly ($P = 0.05$) by Duncan's multiple-range test.

to 13.4 and 29.5 mg kg^{-1}, respectively (Table III). Residues declined significantly and fell below 5 mg kg^{-1} after 14 days and 45 mm of rain in 1982 and after 11 days and 42 mm of rain in 1983. For the 1982 data, the regression equation was

$$\log y = 0.991 - 0.006(x + 1) \quad (5)$$

where $r = -0.43$ and $P < 0.05$, and the rainfall equivalent to a 50% residue decline was 51.4 mm. In 1983, the regression equation was

$$\log y = 1.261 - 0.018(x + 1) \quad (6)$$

where $r = -0.86$ and $P < 0.001$, and the rainfall equivalent to a 50% reduction in residue was 17.0 mm.

Captan Residues on Peach Fruits. In 1981, the dilute application of captan, 3.0 kg ha^{-1}, deposited 9.1 mg kg^{-1} on peach fruits, elevating the postspray residue to 12.1 mg kg^{-1}, which declined to 4.8 mg kg^{-1} after 10 days and 7.0 mm of rain (Table IV). The regression equation was

$$\log y = 1.009 - 0.036(x + 1) \quad (7)$$

where $r = -0.52$ and $P < 0.01$, and the rainfall equivalent to a 50% reduction in residue was 8.3 mm.

The airblast applications of captan, 3.4 kg ha^{-1}, in 1981, 1982, and 1983 deposited 8.2, 1.6, and 1.5 mg kg^{-1}, increasing the initial preharvest captan residue to 9.9, 3.4, and 11.1 mg kg^{-1}, respectively (Table IV). The respective linear regression equations, correlation coefficients, and calculated rainfall equivalent to a 50% reduction of the captan residues (0.5y) were

$$\text{1981:} \quad \log y = 0.704 - 0.009(x + 1) \quad (8)$$

$r = -0.55$ (not significant), $0.5y = 34.4$ mm

$$\text{1982:} \quad \log y = 0.456 - 0.003(x + 1) \quad (9)$$

$r = -0.19$ (not significant), $0.5y = 109.1$ mm

$$\text{1983:} \quad \log y = 1.109 - 0.018(x + 1) \quad (10)$$

$r = -0.60$ ($P < 0.001$), $0.5y = 16.8$ mm

In the airblast experiments, the initial residues declined to less than 5 mg kg^{-1} after 4 days and 1 mm of rain in 1981 and after 14 days and 24 mm of rain in 1983 (Table IV). However, in 1982, the initial residue of 3.4 mg kg^{-1} did not exceed the 5 mg kg^{-1} tolerance, and it did not decline significantly despite 36 mm of rain during the 14 day postapplication period.

Residues in Various Regions of the Tree. In general, the highest residues were found on fruit in the lower outside regions of trees (Table V). On sweet cherry (1983 data), residues in the inside regions were lower than those on the outside regions. Limited replication coupled with considerable variation between replicate samples of peach fruits precluded a demonstration of a significant difference in residues within trees. Nevertheless, the mean residues on fruits from the upper regions of sour cherry and peach trees were about half of those from the lower region. The mean residue for the "whole tree" ranged from 72% to 91% of the mean value for the more commonly sampled lower region.

Residue Decline in Storage. There was no significant reduction of captan residues on sweet cherry fruits during storage for 14 days at either 4 or 20 °C (Table VI). Appreciable brown rot (*M. fructicola*) had developed on fruits after 14 days storage at 20 °C but not at 4 °C.

Residue Removal by Washing. Tumble washing for as little as 15 s significantly reduced captan residues on sweet cherry by 70–74%, but there was no further reduction below 0.3 mg kg^{-1} after 60 s (Table VII). The use of solutions of Tween 20 and baking soda ($NaHCO_3$) in 2-min tumble washing did not reduce residues below those

Table IV. Decline of Captan Residues on Peach Fruits Remaining on Trees in Relation to Cumulative Rainfall in 1981, 1982, and 1983

time interval	1981 dilute redhaven residue, mg kg^{-1}	1981 dilute redhaven rainfall, mm	1981 airblast garnet beauty residue, mg kg^{-1}	1981 airblast garnet beauty rainfall, mm	airblast redhaven 1982 residue, mg kg^{-1}	airblast redhaven 1982 rainfall, mm	airblast redhaven 1983 residue, mg kg^{-1}	airblast redhaven 1983 rainfall, mm
prespray	3.0 b[a]		1.7 a		1.8 ab		9.6 c	
postspray								
0 day	12.1 d	0	9.9 b	0	3.4 b	0	11.1 c	0
1 day	6.5 c	3	7.3 ab	0	2.6 b	0	10.2 c	0
2 days					2.2 b	32	11.7 c	0
3 days	5.8 bc	4			3.0 b	32	15.5 c	0
4 days			2.7 ab	1				
5 days	6.6 c	7			2.6 b	33	13.1 c	8
7 days	6.1 c	7	2.2 a	42	1.9 ab	33	11.1 c	14
10 days	4.8 bc	7			2.9 b	35	8.9 bc	14
12 days			2.9 ab	42				
14 days			1.7 a	42	3.2 b	36	2.9 ab	24
unsprayed	0.06 a				0.02 a		0.24 a	
mean temp, °C	19.1		20.7		16.7		23.1	

[a] Means in the same column followed by different letters differ significantly ($P = 0.05$) by Duncan's multiple-range test.

Table V. Variation of Captan Residues (mg kg^{-1}) on Fruits from Different Regions of Stone Fruit Trees Treated by Airblast Sprayer

region of tree	sweet cherry 1982	sweet cherry 1983	sour cherry, 1983	peach, 1983	mean
upper inside	1.7 a[a]	3.5 a	4.8 a	6.2 a	4.1 a
upper outside	2.6 ab	8.8 b	9.5 a	6.7 a	6.9 a
lower inside	1.7 a	2.7 a	9.6 a	15.5 a	7.4 ab
lower outside	4.8 b	12.0 b	18.8 b	14.0 a	12.4 b
mean values					
upper region	2.2	6.2	7.2	6.5	5.5
lower region	3.3	7.4	14.2	14.8	9.9
whole tree[b]	2.7 (82%)	6.8 (91%)	10.7 (75%)	10.7 (72%)	7.7 (78%)

[a] Means in the same column followed by different letters differ significantly (P = 0.05) by Duncan's multiple-range test. [b] Whole-tree residue is the mean of residues in upper and lower regions and is expressed in parentheses as the percentage of the lower region residue.

obtained with tap water or distilled water. A 5- or 10-s hand wash and a 10-s wet brushing of Redhaven peach fruits reduced a residue of 11.1 mg kg^{-1} to 3.3–4.9 mg kg^{-1}, just below the tolerance of 5 mg kg^{-1}.

Infection of Sweet Cherry Fruits. Unwashed fruits with a mean whole fruit residue of 2.7 mg kg^{-1} were adequately protected against inoculum of 10^4 and 10^5 conidia mL^{-1}, but 43% was infected at the highest inoculum level of 10^6 conidia mL^{-1} (Table VIII). In contrast, the washed fruits with a residue of 0.2 mg kg^{-1} were infected to a significantly (P = 0.05) greater degree by inoculum of 10^4, 10^5, and 10^6 conidia mL^{-1}. The washing treatment did not increase infection in the checks, indicating that there were no incipient infections that were arrested in the unwashed fruits because of captan deposits.

DISCUSSION

In these nine studies, a significant (P = 0.05) decline of captan residue was associated in seven instances with a rainfall ranging from 3 to 42 mm (mean 21.3 mm). In contrast, there were only two instances where there was a significant residue decline in the absence of rain, and these occurred on airblast-sprayed sour cherry fruits (Table III) within 3 days after application. Also there were four instances where residues did not decline significantly (P = 0.05) despite 14–32 mm (mean 22.8 mm) of rain. The association between cumulative rainfall and declining captan residues was confirmed by a significant (P < 0.05) negative correlation in seven of the nine studies. The two exceptions were the 1981 and 1982 studies of airblast applications of captan on peach (Table IV).

In the six experiments with highly (P < 0.01) and very highly (P < 0.001) significant negative correlations between cumulative rainfall and captan residues, the rainfall equivalent to a 50% reduction of residue ranged only from 8.3 to 23.4 mm, with a mean of 17.6 mm. This compared well with the 16.5 mm of rain equivalent ot a 50% reduction of captan on apple foliage under orchard conditions (Smith and McHardy, 1984) and with comparable losses of phosmet from peach foliage (Pree et al., 1984). These six experiments on cherry and peach fruits were conducted in July and August, and the mean daily temperature during these studies ranged from 19.1 to 23.6 °C with a mean of 21.9 °C. This contrasted with the five experiments conducted on grapes, pears, and apples (Frank et al., 1985) in September 1981–1983, in which there was a significant negative correlation between rainfall and captan residue. In these cases the rainfall equivalent to a 50% reduction of captan showed a higher range of 21–67 mm (mean of 49 mm) and also a lower mean daily temperature of 13.0–16.7 °C (mean of 14.6 °C) than for the experiments on cherry and peach fruits. Therefore, the hypothesis is advanced tentatively that the rate of erosion of captan from fruit surfaces by rain is positively correlated with temperature.

The surface deposits of captan and the equivalent whole-fruit residue, necessary for the protection of stone fruits against brown rot, were determined in laboratory experiments involving the precision spraying of harvested mature fruits. Surface deposits of captan of 0.8–0.9 and 1.2 μg cm^{-2} were required to provide 90% protection (ED_{90})

Table VI. Persistence Captan Residues (mg kg^{-1}) on Bing Sweet Cherry Fruits Stored at 4 and 20 °C

storage interval, days	storage temp, °C 4	storage temp, °C 20
0	6.8 abc[a]	6.8 ab
1	8.9 c	5.8 a
2	8.5 bc	6.4 a
3	9.1 c	7.5 ab
5	7.2 abc	9.3 ab
7	6.4 ab	10.7 b
11	5.4 a	9.5 ab
14	6.3 ab	11.1 b

[a] Means in the same column followed by the same letter do not differ significantly (P = 0.05) by Duncan's multiple-range test.

Table VII. Effect of Washing upon the Removal of Captan Residues (mg kg^{-1}) from Sweet Cherry and Peach Fruits in 1982 and 1983

wash treatment	1982	1983
Bing sweet cherry		
initial residue	2.7 d[a]	6.8 c
distilled water		
15 s	0.8 c	1.8 b
30 s	0.6 b	1.9 b
60 s	0.3 a	0.3 a
120 s	0.2 a	0.2 a
0.1% Tween 20, 120 s, rinse		0.2 a
4.2 g of $NaHCO_3$ L^{-1}, 120 s, no rinse		0.2 a
4.2 g of $NaHCO_3$ L^{-1}, 120 s, rinse		0.3 a
tap water, 120 s, rinse		0.6 a
Redhaven peach		
initial residue		11.1 b
hand wash, 5 s		4.9 a
hand wash, 10 s		4.6 a
brush wash, 10 s		3.3 a

[a] Means in the same column for the same fruit followed by different letters differ significantly (P = 0.05) by Duncan's multiple-range test.

Table VIII. Susceptibility of Washed and Unwashed Captan-Sprayed Bing Sweet Cherry Fruits to Infection by Differing Conidial Concentrations of *Monilinia fructicola*

conidial concn in stimulant soln, conidia mL^{-1}	fruits infected, % washed[a]	fruits infected, % unwashed[a]
no treatment	1 a[b]	2 a
0	1 a	2 a
10^3	4 a	4 a
10^4	23 b	3 a
10^5	90 d	3 a
10^6	99 e	43 c

[a] Captan residues on washed and unwashed fruits were 0.2 and 2.7 mg kg^{-1}, respectively. [b] Means followed by different letters differ significantly (P = 0.05) by Duncan's multiple-range test.

of cherry and peach fruits, respectively, against drop inoculations with 10^6 conidia mL^{-1} of *M. fructicola* (Northover, 1982). These surface deposits were equivalent to whole-fruit residues of cherries and peaches, with fruit radii of 1 and 3 cm, respectively, of 2.7 and 1.2 mg kg^{-1}, respectively. In the present study, field-sprayed sweet cherries with a residue of 2.7 mg kg^{-1} were only 57% protected (43% infected), attributable to some fruits having less than the average residue and being insufficiently protected against infection.

The nonuniformity of residues between different regions of fruit trees confirmed earlier findings (Chiba, 1974; Gaynor and Layne, 1979; Lewis and Hickey, 1972). It is probable that a whole-fruit residue of at least twice the theoretical amount is necessary for adequate fruit protection under orchard conditions (Chiba, 1974). For cherries the theoretical whole fruit residue for 90% fruit protection was 2.7 mg kg^{-1} (Northover, 1982), but the residue needed in practice would be at least 5.4 mg kg^{-1}. Therefore, for sweet and sour cherries the current residue tolerance of 5 mg kg^{-1} is equal to or below the minimum residue necessary for adequate protection. A captan tolerance of 10 mg kg^{-1} would allow the continued use of captan on cherries with a 3–4 day preharvest interval.

For peach, a "whole"-fruit captan residue of 1.2 mg kg^{-1} was found to be sufficient for the protection of ideally sprayed fruits (Northover, 1982). Allowing for a two- or fourfold safety factor to provide protection of fruit in regions of trees that are difficult to spray, a maximum residue tolerance for captan of 5 mg kg^{-1} is adequate for the protection of peach fruits against infection by *M. fructicola*. However, in the present studies, captan residues were very persistent on the hairy surface of peach fruits, necessitating a preharvest interval of 14 days to allow the residue to decline below 5 mg kg^{-1}. Therefore, a tolerance of 10 mg kg^{-1} with a preharvest interval of 4 days appears necessary to allow captan to be used effectively in the immediate preharvest period.

The accumulation of captan on peach fruits was observed in 1983, when the prespray residue, prior to the final application, was already at an excessive level of 9.6 mg kg^{-1}, resulting from the accumulation of residues from the three applications made during the previous 34 days. The monitoring of residues would help to avoid the use of unnecessary applications and might allow a reduction in the preharvest interval. The accumulation of captan residues was not observed on apple foliage (Smith and MacHardy, 1984).

The persistence of captan on sweet cherry fruits stored at 4 and 20 °C under humid conditions in sealed polyethylene bags was unexpected even though captan is acknowledged to be more stable at low temperatures and at low pH (Frank et al., 1983; Wolfe et al., 1976). Koivistoinen et al. (1965) showed that captan dissipated slowly at 4 °C and at 20 °C on stored beans and fruits and was reduced 27–33% on plums after 1 week and 54–61% on tomatoes after 4 weeks.

The high degree of chemical stability of captan on fruit surfaces contrasted with the significant correlation in most of these studies between rainfall and residue decline and the ease of removal of captan residues from sweet cherry fruits by tumble washing. These results support the hypothesis that the principal means of captan dissipation is by mechanical erosion by rain droplets or by the rubbing together of fruits or foliage.

Captan is an essential fungicide (Dunnett, 1982) for the protection of stone fruits. The widespread distribution of benzimidazole-resistant *M. fructicola* in cherry and peach orchards in Ontario, and the possible future development of fungal populations resistant to dicarboximide fungicides (Ritchie, 1983) and ergosterol biosynthesis-inhibiting fungicides, dictates that every effort be made to retain captan for use in the immediate preharvest period. However, a maximum residue tolerance of 5 mg kg^{-1} is too close to the residue necessary for the adequate protection of cherry fruits, and it is difficult to maintain peach residues within this tolerance because of the uncertain persistence of captan. Instead, a tolerance of 10 mg kg^{-1} on cherry and peach fruits with a preharvest interval of 4 days appears necessary if captan is to continue to be recommended at the rate of 3.4–4.5 kg ha^{-1} immediately prior to harvest. The washing or brushing of harvested stone fruits by the grower or by the consumer, or the peeling of peaches prior to consumption, would greatly reduce the ingestion of captan and other pesticide residues by consumers.

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