Bacterial Canker Control of Stone Fruit Trees

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Agiculture et Agroalimentaire Canada

Canada

OUTLINE

- **Bacterial canker of stone fruits**

  Etiology

  Epidemiology

- **Control of bacterial canker**

  Chemical control

  Biological control

  Cultural practices

- **Summary**

- **Bacterial canker significance**

  - Occurs wherever cherries are planted

(Úrbez-Torres. AAFC - Summerland RDC)

(Úrbez-Torres. AAFC - Summerland RDC)

  - One of the most destructive diseases of cherries

  - Pathogen capable to kill both young and mature trees

  - Number one killer of young cherry trees

  - ‘Gummosis’, ‘blossom blast’, ‘twig and spur blight’

  - A problem also on peach, plum, apricot, and almond

- **Bacterial canker significance**

Can be a limiting factor for cherry orchard establishment in the Pacific Northwest

75% cherry tree losses in young orchards under favorable conditions

<u>Cool and wet weather and high risk of frost in spring</u>

10-20% losses under normal conditions

(Spotts *et al.* 2010)

Over 60% affected cherry trees and 35-45% apricots reported in the Rhine Valley area

(Krauthausen *et al.* 2013)

Up to 30% plum mortality/year in Southwest Germany

(Hinrichs-Berger 2004)

Up to 50% mortality of young trees in Switzerland

(Bosshard *et al.* 2007)

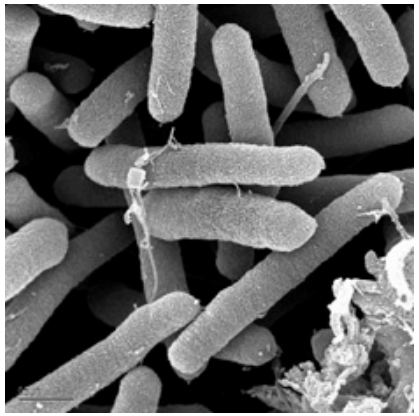
- **Bacterial canker causal agent9s)**

  - ***Pseudomonas syringae* pv. *syringae***

    Plurivorous phytopatogenic bacteria

    Gram (-), aerobic, rod shape, motile

    Able to grow as an epiphyte



G. Vrdoljak (University of California Berkeley)

Pseudomonas syringae pathovars causing bacterial canker in stone fruits

Organism	Cherry	Sour Cherry	Plum	Peach	Apricot
P. syringae pv. *syringae*	√	√	√	√	√
P. syringae pv. *avii*	√	√			
P. amygdali pv. *morsprunorum* (formerly *P. syringae pv. morsprunorum* race 1)	√		√		√
P. avellanae pv. *morsprunorum* (formerly *P. syringae pv. morsprunorum* race 2)	√				
P. syringae pv. *persicae**			√	√	

*Quarantine bacterium (A2 list) by the European Plant Protection Organization (EPPO)

- **Bacterial canker causal agent(s)**

  - ***Pseudomonas syringae* pv. *syringae***

    Full genome sequencing assists to better understand the different *Pseudomonas* spp. causing bacterial canker

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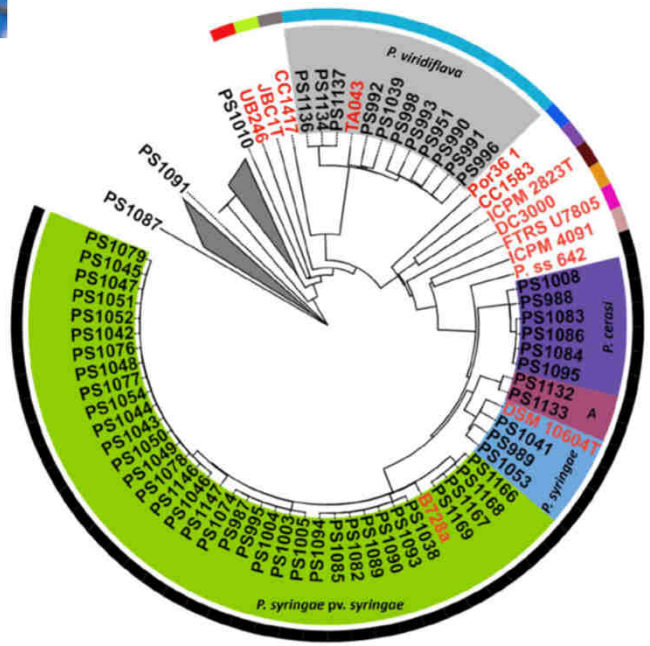

	Symptoms		
***Pseudomonas* spp. identified**	**Canker**	**Leaf spots**	**Fruit lesions**
P. syringae pv. *syringae*	√	√	√
P. syringae	√	-	-
P. cerasi	√	-	-
P.s viridiflava	√	-	-
genomospecies *A*	-	-	-

(Maguvu et al. 2024. *Microbiology Spectrum* 12 (10). 1128)

- **Bacterial canker causal agent(s)**

  - ***Pseudomonas syringae* pv. *syringae***

    Full genome sequencing assists to better understand the different *Pseudomonas* spp. causing bacterial canker

First Report of Bacterial Canker Caused by *Pseudomonas syringae* pv. *morsprunorum* Race 1 on Sweet Cherry in Chile

Héctor M. García, Elisa M. Miranda, Miguel A. López, Samuel J. Parra, Carlos F. Rubilar, Evelyn Del C. Silva-Moreno, Julia M. Rubio, and Cecilia B. Ramos

Affiliations

Published Online: 22 Oct 2021 | https://doi.org/10.1094/PDIS-11-20-2524-PDN

Eur J Plant Pathol (2024) 168:297–314
https://doi.org/10.1007/s10658-023-02755-3

Review of *Pseudomonas* species causing bacterial canker of *Prunus* species with emphasis on sweet cherry (*Prunus avium*) in New Zealand

M. Virginia Marroni · Seona Casonato · Andrew R. Pitman · Sandra B. Visnovsky · Robert M. Beresford · E. Eirian Jones

First Report of *Pseudomonas amygdali* pv. *morsprunorum* Causing Bacterial Canker in Sweet Cherry Orchards in Washington State

Sheersa Manna, Ricardo Delgado Santander, and Youfu Zhao

Affiliations

Published Online: 1 Aug 2024 | https://doi.org/10.1094/PDIS-04-24-0718-PDN

Characterization and genetic diversity of causal agent of stone fruit bacterial canker *Pseudomonas cerasi*, a new pathogen of cherry

Authors: M. Kałużna, A. Willems, J.F. Pothier, M. Ruinelli, P. Sobiczewski, J. Pulawska
Keywords: *Pseudomonas* sp., bacterial canker, diagnosis, diversity, DNA-DNA hybridization, MLSA, MALDI TOF MS
DOI: 10.17660/ActaHortic.2016.1149.2

Abstract:
Based on phenotypic tests, 49 out of 168 isolates of *Pseudomonas syringae* obtained from various organs of diseased tissue originating from various regions in Poland, were identified as *P. syringae* pv. *morsprunorum* race 1 (*Psm*1), 10 as race 2 of this pathovar (*Psm*2), 53 as pathovar *syringae* (*Pss*) and 56 as an atypical taxon. The pathogenicity test on immature sweet cherry fruits divided the tested strains into two groups: one with isolates causing black brown necrosis and the second containing isolates inducing water soaked superficial lesions. Phenotypic and genetic studies on toxins production by bacteria showed that all *Pss* produced syringomycin. However, only some *Psm*1 isolates have the gene for coronatine production. All strains belonging to *Psm*2 possessed genes encoding yersiniabactin. Results of genetic analyses (rep-PCRs, PCR MP) confirmed the homogeneity of isolates within pathovar *morsprunorum* and the atypical taxon and revealed diversity within pathovar *syringae*. A detailed polyphasic approach including phenotypic and genetic characterization applied for eight strains from the atypical taxon showed that the strains represent a novel species of the genus *Pseudomonas* for which *Pseudomonas cerasi* sp. nov. (non Griffin, 1911) is proposed.

Plant Protect. Sci., 2021, 57(3):196-205 | **DOI: 10.17221/140/2020-PPS**

Epidemiology studies of *Pseudomonas syringae* pathovars associated with bacterial canker on the sweet cherry in Serbia

Original Paper

Renata Iličić [*,1], **Jelica Balaž** [1], **Vladislav Ognjanov** [1], **Tatjana Popović** [2]

[1] Department for Environmental and Plant Protection, Faculty of Agriculture, University of Novi Sad, Sad, Serbia

[2] Institute for Plant Protection and Environment, Belgrade, Serbia

- **Bacterial canker causal agent(s)**

- *Pseudomonas syringae* pv. *syringae*

Full genome sequencing assists to better understand the different *Pseudomonas* spp. causing bacterial canker

Organism	Sweet cherry	Sour cherry	Plum	Peach	Apricot	Almond	Chinese plum	Cherry plum	Japanese cherry	Symptoms	Distribution
P. amygdali pv. *morsprunorum*	√	√	√	√	√	√				BB, C, LS, FL	E, NA, CA, SAf, AAs
P. avellanae pv. *morsprunorum*	√	√	√		√					BB, C, LS, FL	E, SAs
P. syringae pv. *syringae*	√	√	√	√	√	√				BB, C, LS, FL	E, NA, CA, SA, CAs, AAs
P. syringae pv. *avii*	√									C	E
P. cerasi	√	√								BB, C, LS, FL	E
P. amygdali						√				C	E, CAs
P. syringae pv. *persicae*			√	√			√	√		C, LS, FL	E, AAs
P. syringae pv. *cerasicola*	√				√				√	Galls	EAs
P. viridiflava	√	√	√	√	√					C, apoplexy	E, Af, NA

Symptoms. BB: Blossom blast, **C**: Canker, **LS:** Leaf spots, **FL**: Fruit lesions

(Adapted from Hullin et al. 2020. *Plant Pathology* 69:962-978)

Distribution. E: Europe, **NA:** North America, **CA:** Central America, **SA:** South America, **Af:** Africa, **SAf:** South Africa, **AAs:** Australasia, **CAs:** Central Asia, **EAs:** East Asia

- **Bacterial canker causal agent(s)**

- *Pseudomonas* species identified in Rheinland-Plafz

Organism	Cherry	Sour Cherry	Plum	Peach	Apricot
P. syringae pv. *syringae*	√	√			√
P. syringae pv. *morsprunorum*		√			

(Krauthausen, H.-J., Dahlbender, W., Hensel, G. DPG-AK-Phytobakteriologie. Sept. 2013)

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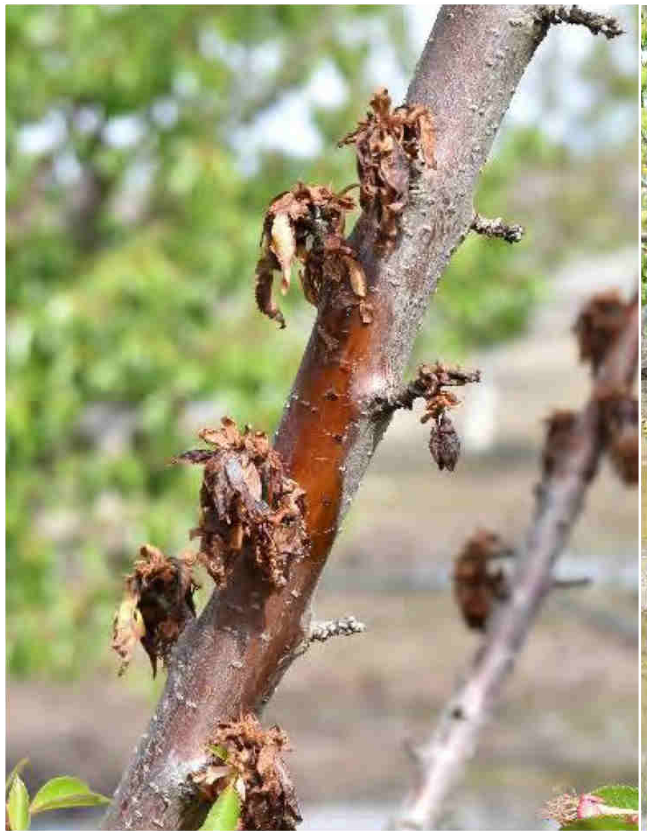
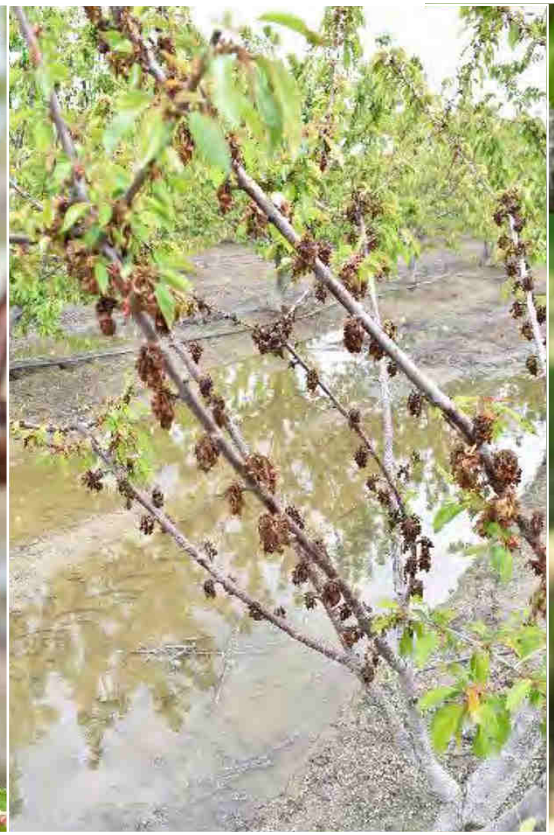
- **Bacterial canker symptoms**

  - Blossom blast



(F. Trouillas, University of California Davis)



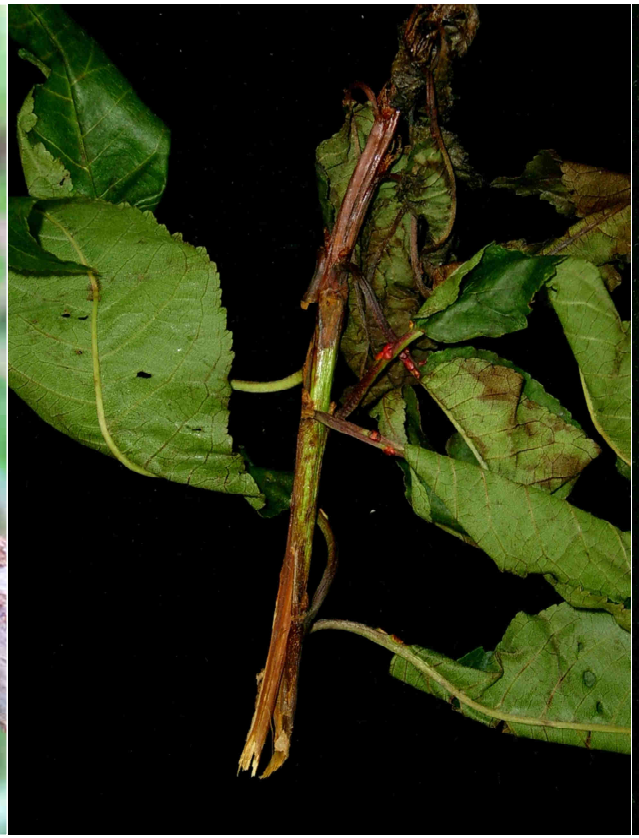
(F. Trouillas, University of California Davis)

(Úrbez-Torres. AAFC - Summerland RDC)

- **Bacterial canker symptoms**

  - Spur and shoot dieback

(Úrbez-Torres. AAFC - Summerland RDC)



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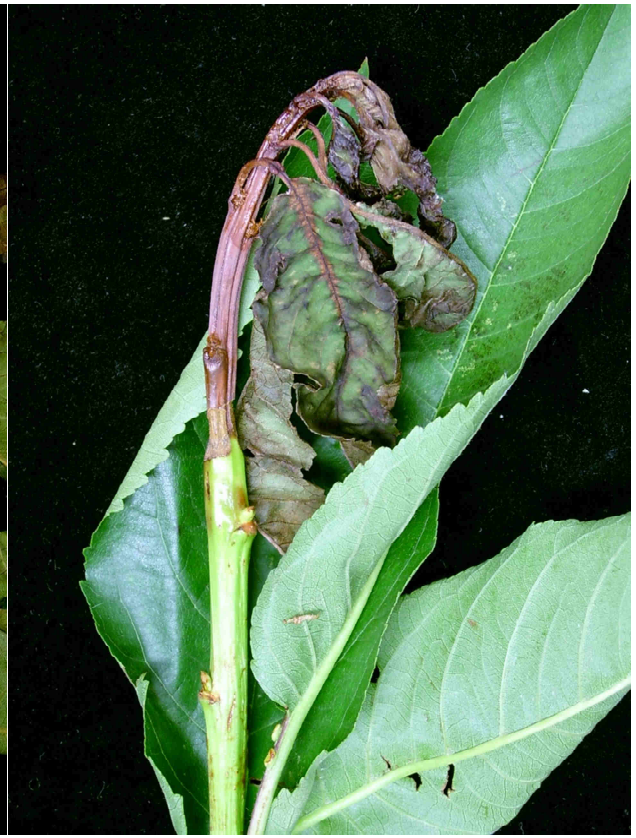
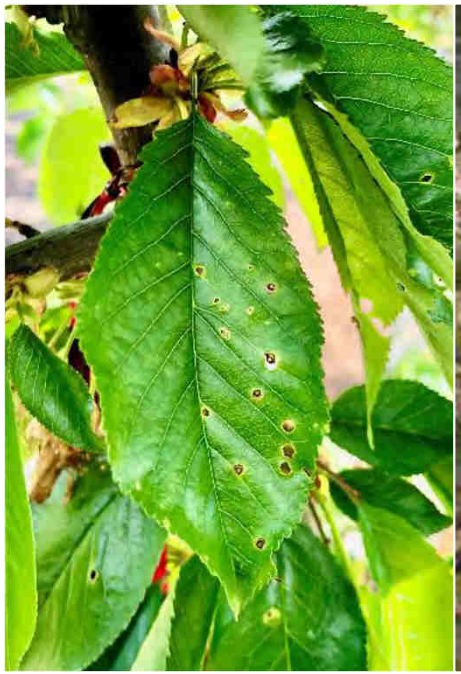


(Úrbez-Torres. AAFC - Summerland RDC)

- **Bacterial canker symptoms**

  - Leaf spots and fruit lesions



(F. Trouillas, University of California Davis)

(Kenelly et al. 2007. Plant Disease 91:4-17)

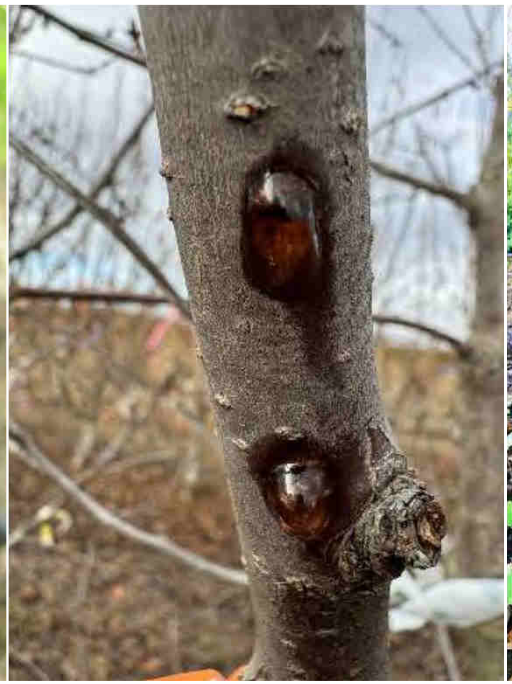
(McFadden-Smith, Ontario Ministry of Agriculture)

- **Bacterial canker symptoms**

  - Cankers and Gummosis

(Úrbez-Torres. AAFC - Summerland RDC)

(Úrbez-Torres. AAFC - Summerland RDC)



(F. Trouillas, University of California Davis)

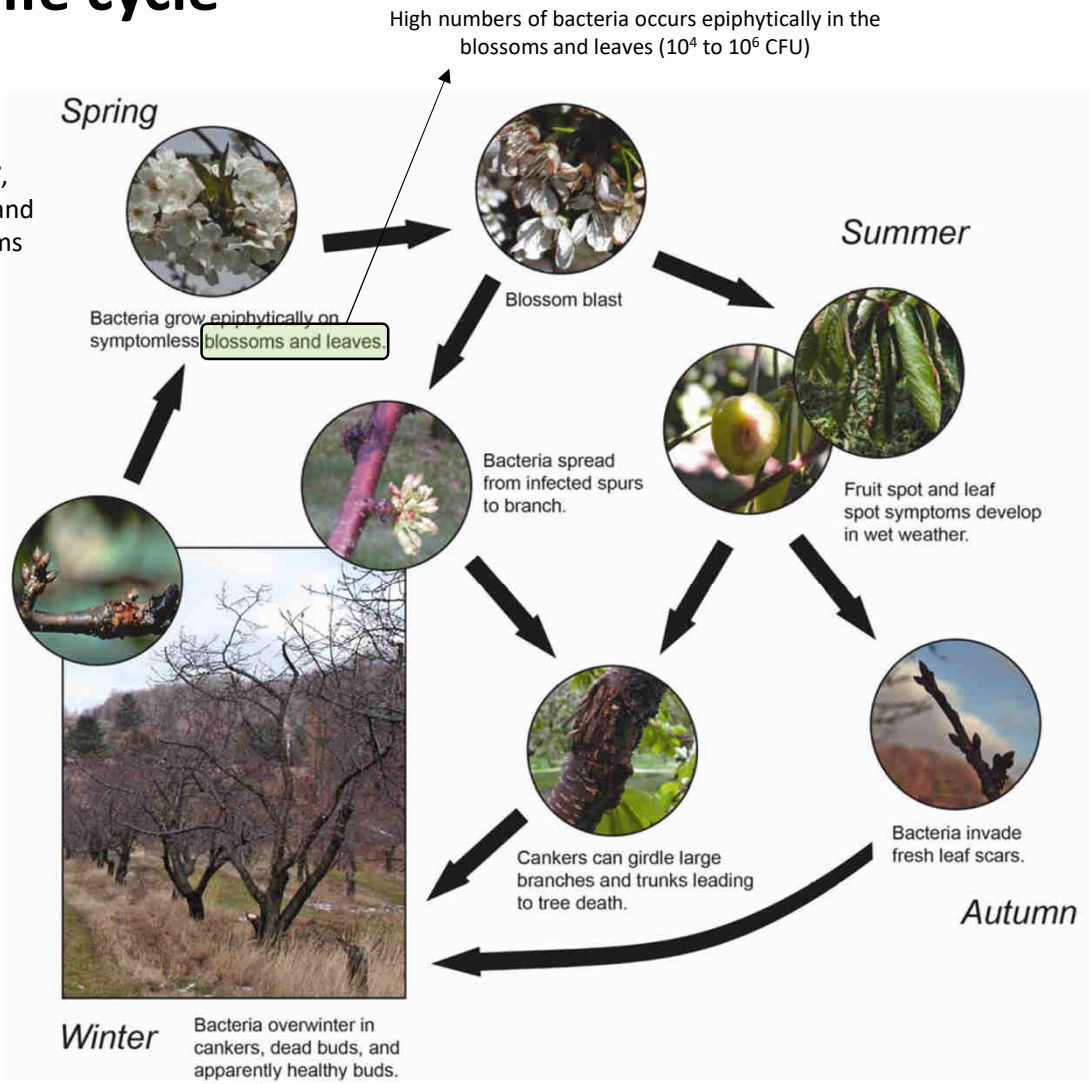
(F. Trouillas, University of California Davis)

Cankers spread infecting branches and trunk with a characteristic gumming.

When girdle by a canker, the branch or trunk can die within weeks

• Bacterial canker life cycle

Extended period of **rain**, **high RH** and **cool T**, and frost events promote bacterial growth and colonization causing **blossom blast** symptoms



(Kenelly et al. 2007. *Plant Disease* 91:4-17)

- **Bacterial canker life cycle**

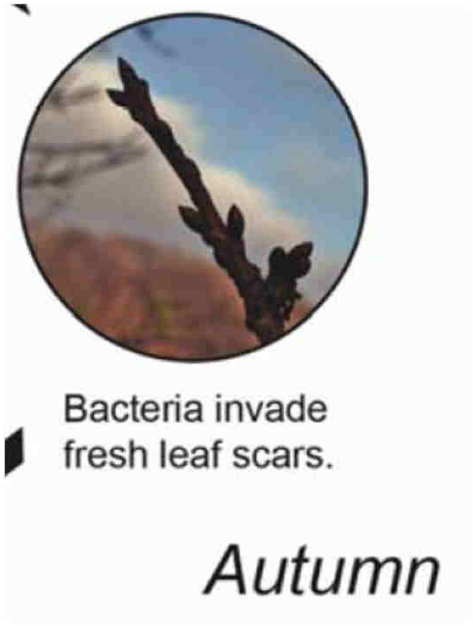


Table II.
Effect of leaf scar age on the average disease incidence of leaf scar infection in cherry, peach and prune (21 stems tested for each leaf scar age).

Leaf scar age	Arcsine mean[1]	Disease incidence[2] (%)
0 h	0.985 a	69.1 ± 4.8
2 h	0.920 a	65.4 ± 6.0
4 h	0.682 b	46.5 ± 6.5
12 h	0.488 c	26.6 ± 5.5
1 day	0.451 c	22.7 ± 4.2
2 days	0.200 d	3.0 ± 1.8
5 days	0.147 d	0

[1] Arcsine-transformed value = $(1/2) \times [\arcsin[(X / (n + 1))^{0.5}] + \arcsin[((X + 1) / (n + 1))^{0.5}]]$, where X = number of infected leaf scars per stem, n = total number of inoculated leaf scars per stem.
Means followed by the same letter are not different at $P < 0.05$ according to Duncan's multiple range test.
[2] Mean of disease incidence ± standard error.

Table III.
Disease incidence resulting from leaf scar infection in cherry, peach and prune (49 stems treated for each species).

Species	Arcsine mean[1]	Disease incidence[2] (%)
Cherry	0.679 a	42.8 ± 4.6
Peach	0.507 b	30.1 ± 5.2
Prune	0.473 b	27.0 ± 4.3

[1] Arcsine-transformed value = $(1/2) \times [\arcsin[(X / (n + 1))^{0.5}] + \arcsin[((X + 1) / (n + 1))^{0.5}]]$, where X = number of infected leaf scars per stem, n = total number of inoculated leaf scars per stem.
Means followed by the same letter are not different at $P < 0.05$ according to Duncan's multiple range test.
[2] Mean of disease incidence ± standard error.

(Cao et al. 2013. *Fruits* 68:245-254)

- **Bacterial canker epidemiology**

  - Lenticels

Table VII.
Effect of freezing-thawing on lenticel infection in 'French' prune.

Treatment	Inoculation	% of lenticel infection[1] (%)	Number of infected lenticels	Total lenticels inoculated	Lesion length[2] (mm)
Freezing/thawing	Bacteria	1.3 a	28	2101	31.1 ± 2.9 a
Nonfrozen	Bacteria	0.8 b	29	3752	16.8 ± 1.2 b
Control	sdH_2O	0.0 c	0	1241	0

[1] Data followed by the same letter are not significantly different at $P < 0.05$ based on the χ^2 test.
[2] Means (± standard error) followed by the same letter are not significantly different at $P < 0.05$ based on the t test.

(Cao et al. 2013. *Fruits* 68:245-254)

Lenticels infection by *P. syringae* pv. *syringae* is possible under field conditions

OUTLINE

- Bacterial canker of stone fruits

  Etiology

  Epidemiology

- **Control of bacterial canker**

  Chemical control

  Biological control

  Cultural practices

- **Bacterial canker chemical control**

  - Control is extremely difficult due to the high populations of bacteria in different tissues

  - Copper has been the standard to control bacterial canker and long been used

  Contact material: Does not target dormant buds, knots and internal populations of bacteria in canker

  Copper sprays need to be timed: Host is susceptible

  Pathogen is accessible

  Conditions favorable to disease

Table II.
Effect of leaf scar age on the average disease incidence of leaf scar infection in cherry, peach and prune (21 stems tested for each leaf scar age).

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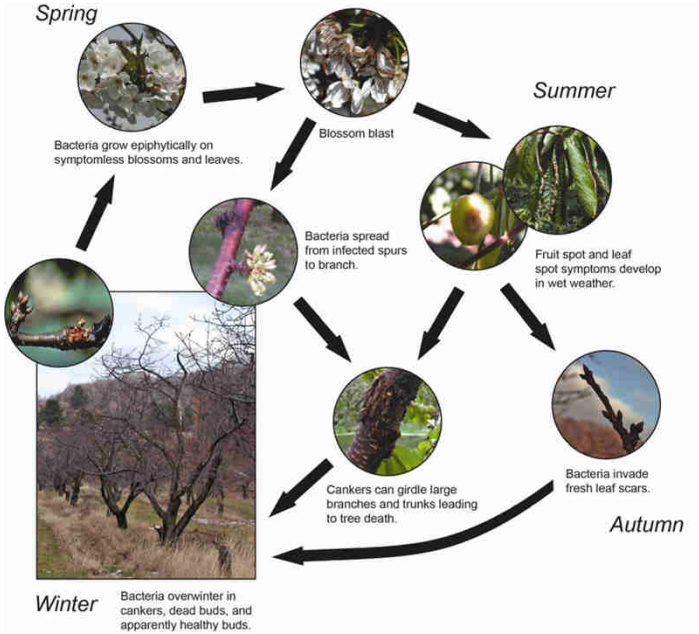
[1] Arcsine-transformed value = $(1/2) \times [\arcsin(\sqrt{X / (n+1)}) + \arcsin(\sqrt{(X+1) / (n+1)})]$, where X = number of infected leaf scars per stem, n = total number of inoculated leaf scars per stem.
Means followed by the same letter are not different at $P < 0.05$ according to Duncan's multiple range test.
[2] Mean of disease incidence ± standard error.

Extended period of **rain**, **high RH** and **cool T**, and frost events promote bacterial growth and colonization causing **blossom blast** symptoms



- **Bacterial canker chemical control**

  - Control is extremely difficult due to the high populations of bacteria in different tissues

  - Copper has been the standard to control bacterial canker and long been used

  Copper can be highly phytotoxic to cherries

  <u>Different copper formulations</u>

  Bordeaux mixture: copper sulfate + calcium hydroxide

  Fixed copper sulfate (Cuprofix, Phyton,…)

  Copper ammonium carbonate (Copper-Count-N)

  Copper hydroxide (Champion, Kocide,…)

  Copper oxide (Nordox)

  Copper octanoate (Cueva)

  Copper oxychloride (Badge, C-O-C-S)

  Produce low doses of copper to reduce toxicity to plants

- **Bacterial canker chemical control**

- Copper has been the standard to control bacterial canker and long been used

Field trials completed in New York in sweet cherry variety Hedelfingen

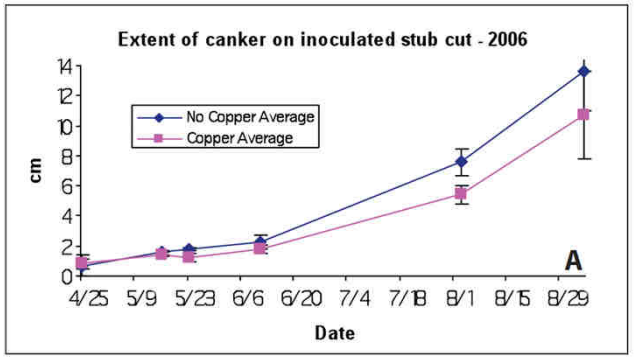


Figure 5. A. 2006. B. 2008. Progression of canker on pruning stubs, cut in April and inoculated with *Pseudomonas syringae* pv. *Syringae*. Trees were sprayed before and after pruning (Copper) or shielded from spray (No Copper).

Effect of pruning date

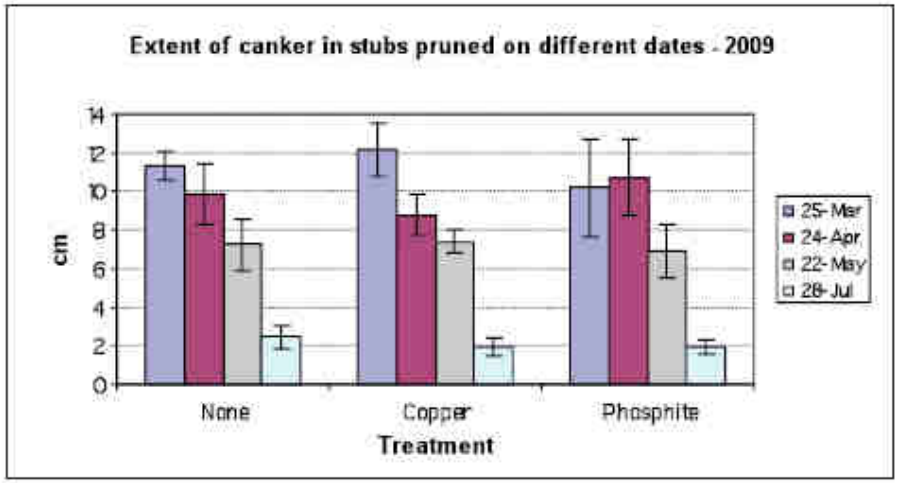


Figure 6. Progression of canker measured October 8 on pruning stubs cut on March 25, April 24, May 22, or July 28 and inoculated with *Pseudomonas syringae* pv. *Syringae* in Geneva, NY. Trees in three replicate blocks were not sprayed or sprayed with copper (COCS or Cuprofix Ultra at 4 lb/100 gal), or phosphite (Agri-Fos at 2.5 qt/100gal) on March 26, April 24 and April 25.

(Caroll *et al.* 2010. NY Fruit Quarterly Vol. 18)

- **Bacterial canker chemical control**

  - **Copper has been the standard to control bacterial canker and long been used**

    Field trials completed in New York in sweet cherry green fruit (Kocide 2000 - copper hydroxide 53.8%)

FlameOut(TM) 17 WP Fungicide/Bactericide
Material Safety Data Sheet
Cerexagri-Nisso LLC

1 PRODUCT AND COMPANY IDENTIFICATION

Pre-Harvest Experimental
Cerexagri-Nisso, LLC

EMERGENCY PHONE NUMBERS:
Chemtrec: (800) 424-9300 (24hrs) or (703) 527-3887
Medical: Rocky Mountain Poison Control Center (866) 767-5089 (24Hrs)

Information Telephone Numbers	Phone Number	Available Hrs
R&D Technical Service	610-878-6100	8:00 am - 5:00 pm EST

Product Name: FlameOut(TM) 17 WP Fungicide/Bactericide
Product Synonym(s):
Chemical Family:
Chemical Formula: C22H24N2O9HCL
Chemical Name: Oxytetracycline hydrochloride
EPA Reg Num: 60990-1-82695
Product Use: Control of bacterial diseases in agricultural crops

2 COMPOSITION / INFORMATION ON INGREDIENTS

Ingredient Name	CAS RegistryNumber	Typical Wt. %	OSHA
Quartz	14808-60-7	<46.4	Y
Mica	12001-26-2	<19.3	Y
Oxytetracycline hydrochloride	2058-46-0	17	Y
Kaolin	1332-58-7	<3.9	Y

The substance(s) marked with a "Y" in the OSHA column, are identified as hazardous chemicals according to the criteria of the OSHA Hazard Communication Standard (29 CFR 1910.1200)

Tables 8 and 9. Eradicant tests in a green cherry fruit assay using treatment products applied after wound-inoculation with PSS. The diameter (mm) of the resulting lesion was measured after 48 hours. Means followed by the same letter do not significantly differ (P=.05, Tukey's HSD).

Eradicant Treatment	Amount per 100 gal	Diam 48 hr	% control
Uninoculated		1.1 c	-
Inoculated		3.1 a	-
Flameout	0.75 lb	1.4 bc	54.5
Kasumin + Captan	64 fl oz + 2.5 lb	2.3 abc	26.3
Kasumin	64 fl oz	2.3 abc	25.3
Prophyt	32 fl oz	2.6 ab	15.2
Kocide 2000	12 lb	3.0 a	2.0
Pentra Bark	32 fl oz	3.1 a	0.0
Oxidate	128 fl oz	3.1 a	0.0
Regalia	1 %	3.2 a	0.0
Prophyt + Pentra Bark	32 fl oz + 32 fl oz	3.2 a	0.0
BCYP	as directed	3.3 a	0.0
Serenade	3 lb	3.3 a	0.0

Eradicant Treatment	Amount per 100 gal	Diam 48 hr	% control
Uninoculated		1.0 d	-
Inoculated		3.9 a	-
Flameout + Pentra Bark	0.75 lb + 32 fl oz	1.9 cd	51.3
Flameout	0.75 lb	2.2 bcd	44.4
Kocide 2000	12 lb	2.7 abc	31.7
Kasumin + Pentra Bark	64 fl oz + 32 fl oz	2.8 abc	29.4
Kasumin + Captan	64 fl oz + 2.5 lb	2.9 abc	27.0
BCYP	as directed	3.2 abc	19.8
Serenade	3 lb	3.4 ab	13.5
Prophyt + Pentra Bark	32 fl oz + 32 fl oz	3.4 ab	13.5
Kasumin	64 fl oz	3.4 ab	13.5
Regalia	1 %	3.5 ab	10.3
Oxidate	128 fl oz	3.6 ab	7.9
Prophyt	32 fl oz	3.8 a	4.8
Pentra Bark	32 fl oz	3.8 a	3.2
Urea	28 lb	4.0 a	0.0

Tables 10 and 11. Protectant tests in a green cherry fruit assay using treatment products applied before wound-inoculation with PSS. The diameter (mm) of the resulting lesion was measured after 48 hours. Means followed by the same letter do not significantly differ (P=.05, Tukey's HSD).

Protectant Treatment	Amount per 100 gal	Diam 48 hr	% control
Uninoculated		1.1 c	-
Inoculated		3.1 ab	-
Flameout	0.75 lb	2.6 b	17.2
BCYP	as directed	2.7 b	14.1
Oxidate	128 fl oz	2.8 ab	10.1
Kasumin + Captan	64 fl oz + 2.5 lb	2.8 ab	9.1
Kocide 2000	12 lb	2.8 ab	9.1
Regalia	1 %	2.9 ab	7.1
Pentra Bark	32 fl oz	3.0 ab	4.0
Kasumin	64 fl oz	3.1 ab	1.0
Prophyt	32 fl oz	3.1 ab	0.0
Serenade	3 lb	3.3 ab	0.0
Prophyt + Pentra Bark	32 fl oz + 32 fl oz	3.7 a	0.0

Protectant Treatment	Amount per 100 gal	Diam 48 hr	% control
Uninoculated		1.1 d	-
Inoculated		3.9 abc	-
Flameout + Pentra Bark	0.75 lb + 32 fl oz	2.3 cd	40.7
Flameout	0.75 lb	2.7 bcd	32.5
Kocide 2000	12 lb	2.8 bcd	30.2
Kasumin + Pentra Bark	64 fl oz + 32 fl oz	3.3 abc	17.5
BCYP	as directed	3.6 abc	7.9
Kasumin	64 fl oz	3.7 abc	7.1
Prophyt + Pentra Bark	32 fl oz + 32 fl oz	3.9 abc	0.8
Prophyt	32 fl oz	4.0 abc	0.0
Kasumin + Captan	64 fl oz + 2.5 lb	4.0 ab	0.0
Serenade	3 lb	4.0 ab	0.0
Urea	28 lb	4.0 ab	0.0
Pentra Bark	32 fl oz	4.1 ab	0.0
Oxidate	128 fl oz	4.2 ab	0.0
Regalia	1 %	4.5 a	0.0

(Caroll *et al.* 2010. NY Fruit Quarterly Vol. 18)

- **Bacterial canker chemical control**

  - Copper has been the standard to control bacterial canker and long been used

  - Copper used in Autum sprays Target epiphytic bacteria populations

  Shown to protect leaf scars

  Reduction in bacterial canker inoculum

Trials in sweet cherry using high dispersion copper sulphate formulation (Copper HD)

Applied doses 18 to 25 times smaller than conventional sprays (Bordelaise mixture or Kocide 101 WP)

HD made by depositing it on a bioactive support, including ions: Mg^{2+}, PO_4^{3+}, Ca^{2+}, NH_4^{+} (food source for the tree)

Variant	Degree of attack (%)	Degree of attack as to control (%)	Differences as to control (%)	Significance of difference
Pseudomonas syringae van Hall				
Control	18.67	100.00	-	
Bordelaise mixture	5.67	30.36	13.00	**
Kocide 101WP	3.67	19.65	15.00	**
Cooper HD	3.33	17.83	15.34	**
DL 5% = 8.04		DL 1% = 12.73	DL 0.1% = 20.45	

(Mittre et al. 2011. Bulletin UASVM Horticulture 68:1)

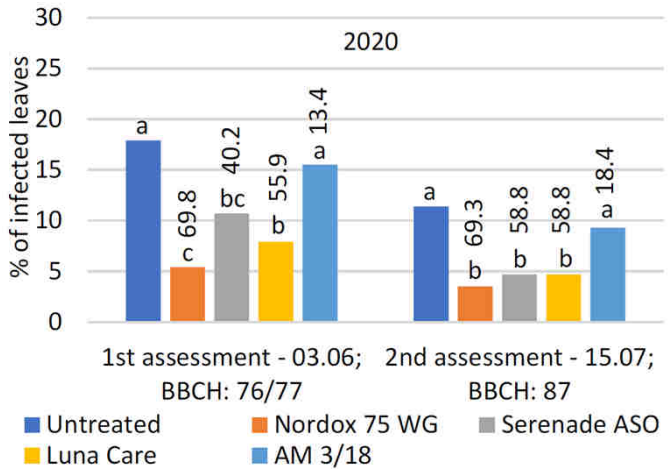
- **Bacterial canker chemical control**

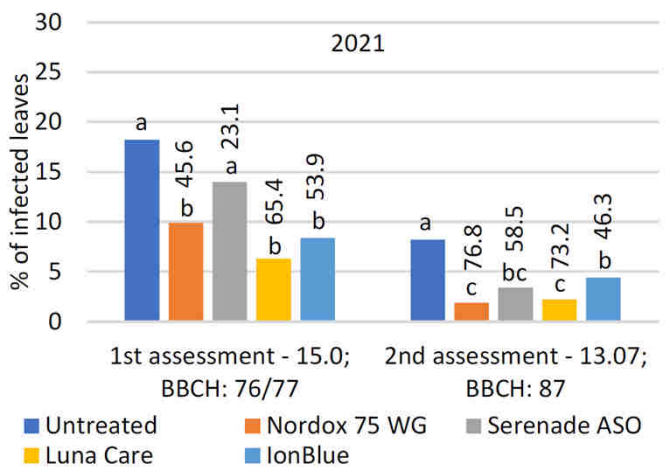
- Copper has been the standard to control bacterial canker and long been used

Field trials completed in Poland in sweet cherry. Three treatments

Before flowering, (BBCH 54/59), during flowering (BBCH 60/67) and after flowering (BBCH 69/73)

Nordox 75 WG	1.0 kg	copper oxide—750 g/kg
Serenade ASO	8.0 L	bacteria *Bacillus amyloliquifaciens* strain QST 713—13.96 g/L (minimum concentration 1042 × 10^{12} CFU/L)
Luna Care 71.6 WG	3.0 L	fluopyram—50 g/kg and fosetyl-Al—666 g/kg
IonBlue	1.5 L	copper—5.1% and sulfur—4.97% in the form of nanoparticles
AM3/18	73.5 g/1 L of water	prototype formulation containing bacteria *Pantoea agglomerans*—107 CUF/mL





(Broniarek-Niemiec et al. 2023. *Agronomy* 13:1166)

- **Bacterial canker chemical control**
  - **Copper bactericides are failing in many regions to control bacterial canker**
  - **Copper hydroxide has been shown to make the disease worse than unsprayed treatments**
  - ***Pseudomonas syringae* resistance to copper first reported in 1991**

Development of resistance is widespread in the Pacific NW

Copper resistance in *Pseudomonas syringae* mediated by periplasmic and outer membrane proteins

(copper-binding proteins/blue copper proteins)

JAE-SOON CHA AND DONALD A. COOKSEY*

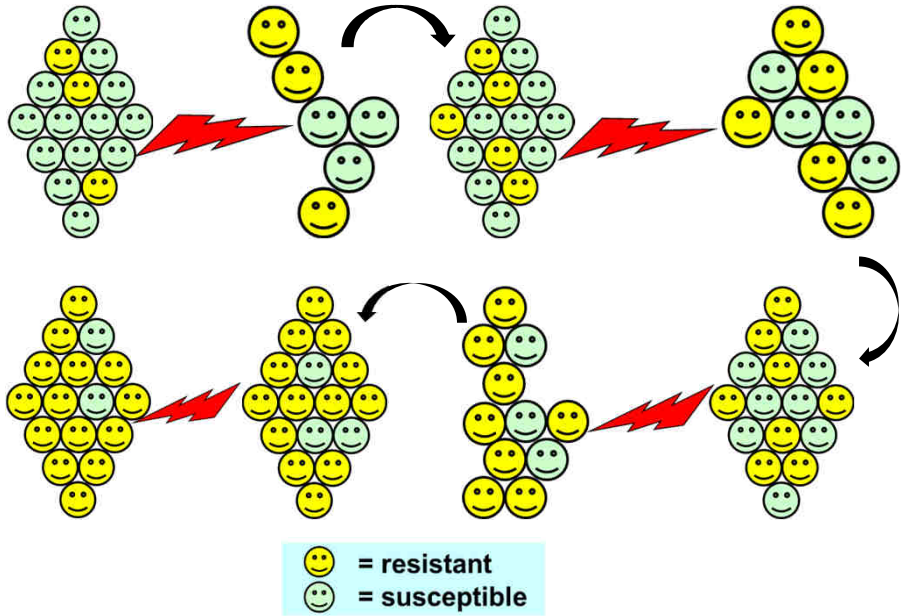
Department of Plant Pathology, University of California, Riverside, CA 92521-0122

Communicated by George A. Zentmyer, June 24, 1991

ABSTRACT **Copper-resistant strains of *Pseudomonas syringae* pathovar *tomato* accumulate copper and develop blue colonies on copper-containing media. Three of the protein products of the copper-resistance operon (*cop*) were characterized to provide an understanding of the copper-resistance mechanism and its relationship to copper accumulation. The Cop proteins, CopA (72 kDa), CopB (39 kDa), and CopC (12 kDa), were produced only under copper induction. CopA and CopC were periplasmic proteins and CopB was an outer membrane protein. Leader peptide sequences of CopA, CopB, and CopC were confirmed by amino-terminal peptide sequencing. CopA, CopB, and CopC were purified from strain PT23.2, and their copper contents were determined. One molecule of CopA bound 10.9 ± 1.2 atoms of copper and one molecule of CopC bound 0.6 ± 0.1 atom of copper. The Cop proteins apparently mediate sequestration of copper outside of the cytoplasm as a copper-resistance mechanism.**

copper resistance mechanisms is available in general (9). Bitton and Freihofer (10) reported that *Klebsiella aerogenes* strains producing a polysaccharide capsule were more tolerant to copper than noncapsulated strains, and the isolated capsular polysaccharides bound copper efficiently. A copper-resistant strain of *Escherichia coli*, isolated from pig effluent, where the pigs were fed a copper-supplemented diet, contained a copper-resistance determinant on a conjugative plasmid, and the copper resistance was induced by copper. Induced resistant cells accumulated less copper than uninduced cells, which suggested that an efflux mechanism is involved in the copper resistance (11, 12). Erardi *et al.* (13) reported that the copper-tolerant *Mycobacterium scrofulaceum*, which has a 173-kb plasmid carrying copper resistance, accumulated copper from the medium as a black intracellular precipitate of copper sulfide.

Cellular copper sequestration has been suggested as the copper-resistance mechanism in copper-resistant *P. syringae*



- **Bacterial canker chemical control**

  - **Copper bactericides are failing in many regions to control bacterial canker**

CHILEANJAR

RESEARCH

Bacterial community associated with canker disease from sweet cherry orchards of central valley of Chile presents high resistance to copper

M. Francisca Beltrán[1], Valeria Osorio[1], Gamalier Lemus[1], Paz Millas[2], Andrés France[2], Francisco Correa[1], and Boris Sagredo[1*]

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Received: 2 February 2021; Accepted: 3 May 2021; doi:10.4067/S0718-58392021000300378

Table 3. Minimum inhibitory concentration (MIC) of bacterial isolates from cherry trees to copper sulfate on MGY medium.

	MIC (mM) interval for copper sulfate				
	Sensitive		Resistant		
Site of isolation	< 0.8 mM	0.8-1.6 mM	2.0-2.8 mM	3.2-3.6 mM	Total
Codegua	-	1	-	-	1
Coltauco	-	-	2	1	3
Graneros	-	1	-	-	1
Las Cabras	-	1	-	3	4
Malloa	-	-	3	3	6
Olivar	-	2	-	-	2
Quinta de Tilcoco	-	1	-	-	1
Rengo	-	3	3	4	10
Requinoa	1	-	-	-	1
San Fernando	1	4	4	13	22
San Vicente	3	6	9	10	28
Los Lagos Region	-	-	-	1	1
Total	5	19	21	35	80

(Francisca-Beltran et al. 2021. Chilean Journal of Agriculture 81:378-389)

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Pathogenicity, phylogenomic, and comparative genomic study of *Pseudomonas syringae* sensu lato affecting sweet cherry in California

Tawanda E. Maguvu,[1,2] Rosa J. Frias,[1] Alejandro I. Hernandez-Rosas,[1] Erin Shipley,[2] Greta Dardani,[2,3] Mohamed T. Nouri,[4] Mohammad A. Yaghmour,[5] Florent P. Trouillas[1,2]

TABLE 1 Correlations of kasugamycin and copper resistance genotypes with their phenotypes

Genomospecies	Annotated copper resistance genotype (*ctpV*)	Copper resistance phenotype		
		200 µg/mL MCE	300 µg/mL MCE	400 µg/mL MCE
P. syringae pv. *syringae*	16/35 isolates (47.5%)	100%	47.50%	47.50%
P. syringae	0/3 isolates (0%)	100%	0%	0%
A	0/2 isolates (0%)	100%	0%	0%
P. cerasi	0/6 isolates (0%)	100%	0%	0%
P. viridiflava	5/11 isolates (45.5%)	100%	45.50%	45.50%

MCE: Metallic Copper Equivalent

(Maguvu et al. 2024. *Microbiology Spectrum* 12 (10). 1128)

- **Bacterial canker biological control**

  - **Most of biological control products show low efficacy controlling bacterial canker**

Field trials completed in New York in sweet cherry green fruit (Chemicals, antibiotic, biologicals)

Prophyt: Potassium phosphite
Oxidate: Hydrogen peroxide
Regalia: Giant Knotweed (*Reynoutria sachalinensis*)
BCYP: Yeast
Serenade: *Bacillus subtillis*

Tables 8 and 9. Eradicant tests in a green cherry fruit assay using treatment products applied after wound-inoculation with PSS. The diameter (mm) of the resulting lesion was measured after 48 hours. Means followed by the same letter do not significantly differ (P=.05, Tukey's HSD).

Eradicant Treatment	Amount per 100 gal	Diam 48 hr	% control
Uninoculated		1.1 c	-
Inoculated		3.1 a	-
Flameout	0.75 lb	1.4 bc	54.5
Kasumin + Captan	64 fl oz + 2.5 lb	2.3 abc	26.3
Kasumin	64 fl oz	2.3 abc	25.3
Prophyt	32 fl oz	2.6 ab	15.2
Kocide 2000	12 lb	3.0 a	2.0
Pentra Bark	32 fl oz	3.1 a	0.0
Oxidate	128 fl oz	3.1 a	0.0
Regalia	1 %	3.2 a	0.0
Prophyt + Pentra Bark	32 fl oz + 32 fl oz	3.2 a	0.0
BCYP	as directed	3.3 a	0.0
Serenade	3 lb	3.3 a	0.0

Eradicant Treatment	Amount per 100 gal	Diam 48 hr	% control
Uninoculated		1.0 d	-
Inoculated		3.9 a	-
Flameout + Pentra Bark	0.75 lb + 32 fl oz	1.9 cd	51.3
Flameout	0.75 lb	2.2 bcd	44.4
Kocide 2000	12 lb	2.7 abc	31.7
Kasumin + Pentra Bark	64 fl oz + 32 fl oz	2.8 abc	29.4
Kasumin + Captan	64 fl oz + 2.5 lb	2.9 abc	27.0
BCYP	as directed	3.2 abc	19.8
Serenade	3 lb	3.4 ab	13.5
Prophyt + Pentra Bark	32 fl oz + 32 fl oz	3.4 ab	13.5
Kasumin	64 fl oz	3.4 ab	13.5
Regalia	1 %	3.5 ab	10.3
Oxidate	128 fl oz	3.6 ab	7.9
Prophyt	32 fl oz	3.8 a	4.8
Pentra Bark	32 fl oz	3.8 a	3.2
Urea	28 lb	4.0 a	0.0

Tables 10 and 11. Protectant tests in a green cherry fruit assay using treatment products applied before wound-inoculation with PSS. The diameter (mm) of the resulting lesion was measured after 48 hours. Means followed by the same letter do not significantly differ (P=.05, Tukey's HSD).

Protectant Treatment	Amount per 100 gal	Diam 48 hr	% control
Uninoculated		1.1 c	-
Inoculated		3.1 ab	-
Flameout	0.75 lb	2.6 b	17.2
BCYP	as directed	2.7 b	14.1
Oxidate	128 fl oz	2.8 ab	10.1
Kasumin + Captan	64 fl oz + 2.5 lb	2.8 ab	9.1
Kocide 2000	12 lb	2.8 ab	9.1
Regalia	1 %	2.9 ab	7.1
Pentra Bark	32 fl oz	3.0 ab	4.0
Kasumin	64 fl oz	3.1 ab	1.0
Prophyt	32 fl oz	3.1 ab	0.0
Serenade	3 lb	3.3 ab	0.0
Prophyt + Pentra Bark	32 fl oz + 32 fl oz	3.7 a	0.0

Protectant Treatment	Amount per 100 gal	Diam 48 hr	% control
Uninoculated	1.1 d	-	
Inoculated	3.9 abc	-	
Flameout + Pentra Bark	0.75 lb + 32 fl oz	2.3 cd	40.7
Flameout	0.75 lb	2.7 bcd	32.5
Kocide 2000	12 lb	2.8 bcd	30.2
Kasumin + Pentra Bark	64 fl oz + 32 fl oz	3.3 abc	17.5
BCYP	as directed	3.6 abc	7.9
Kasumin	64 fl oz	3.7 abc	7.1
Prophyt + Pentra Bark	32 fl oz + 32 fl oz	3.9 abc	0.8
Prophyt	32 fl oz	4.0 abc	0.0
Kasumin + Captan	64 fl oz + 2.5 lb	4.0 ab	0.0
Serenade	3 lb	4.0 ab	0.0
Urea	28 lb	4.0 ab	0.0
Pentra Bark	32 fl oz	4.1 ab	0.0
Oxidate	128 fl oz	4.2 ab	0.0
Regalia	1 %	4.5 a	0.0

(Caroll *et al.* 2010. NY Fruit Quarterly Vol. 18)

- **Bacterial canker biological control**

  - Most of biological control products show low efficacy controlling bacterial canker

Field trials completed in Poland in sweet cherry. Three treatments

Before flowering, (BBCH 54/59), during flowering (BBCH 60/67) and after flowering (BBCH 69/73)

Nordox 75 WG	1.0 kg	copper oxide—750 g/kg
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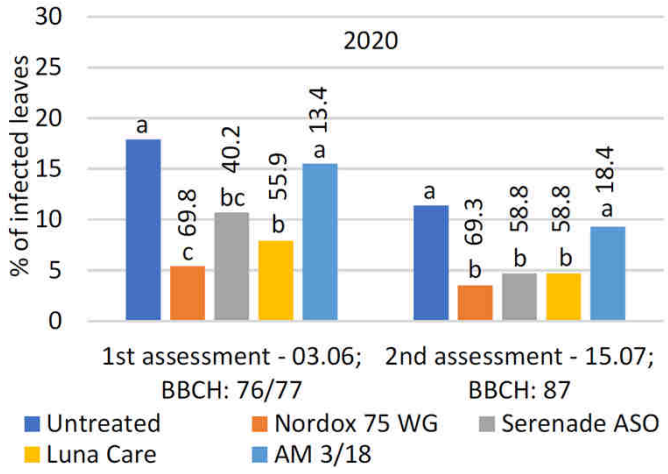
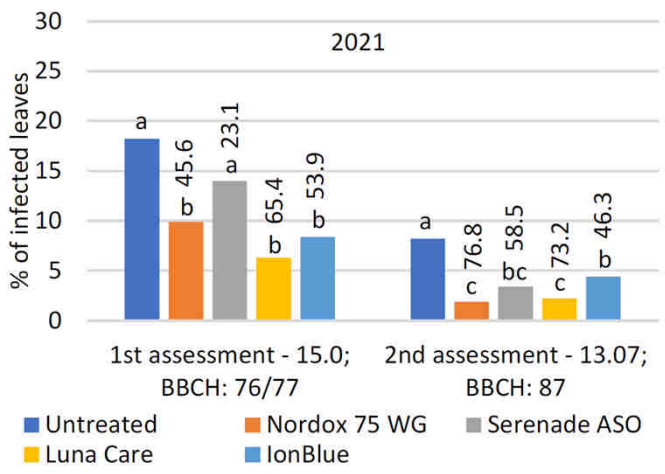




(Broniarek-Niemiec et al. 2023. *Agronomy* 13:1166)

- **Bacterial canker biological control**

  - Most of biological control products show low efficacy controlling bacterial canker

Resistance inducers:
Phostrol [Phosphorous Acid] [Nufarm, Chicago Heights, Illinois]
Actigard [acibenzolar-S-methyl] (Syngenta, Minnetonka, Minnesota)

Microbial biocontrols
Blossom Protect [*Aureobasidium pullulans*]
Botector [*Aureobasidium pullulans*] (bio-ferm, Tulln, Austria)
Optiva [*Bacillus subtilis*] (Agraquest Inc., Davis, California)
Bloomtime [*Pantoea agglomerans*] [Northwest Agricultural Products Inc., WA)

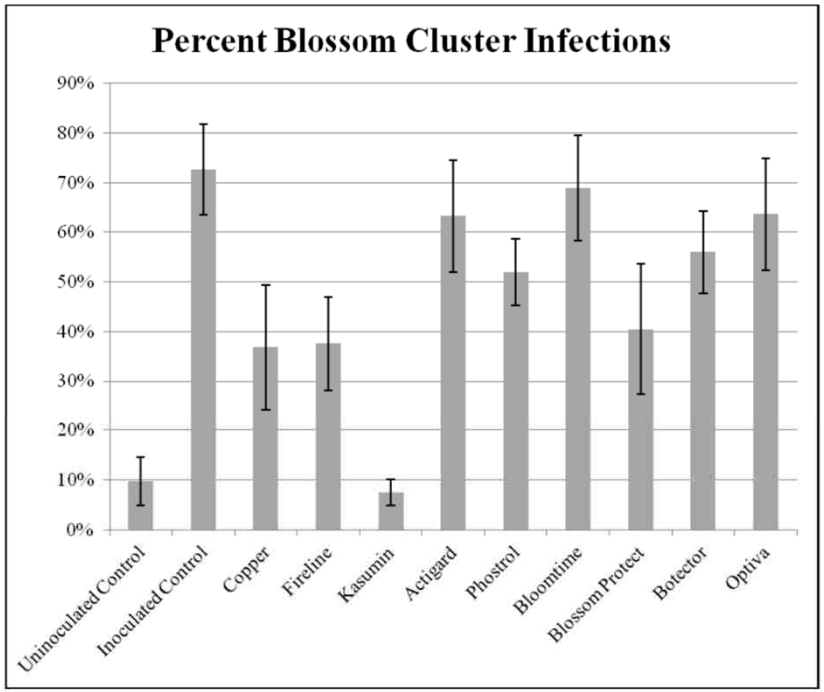


Figure 2. Percent infected sweet cherry blossom clusters after simulated wounding and inoculation with *Pseudomonas syringae* pv. *syringae*, following prophylactic treatment with antibiotics (copper, Fireline and Kasumin), plant resistance inducers (Actigard and Phostrol), or bio-controls (Bloomtime, Blossom Protect, Botector and Optiva). Bars represent standard errors.

(Lillrose et al. 2017. *Acta Horticulturae* 73:1161)

- **Bacterial canker biological control**

  - **Most of biological control products show low efficacy controlling bacterial canker**

Laboratory trials with plant essential oils

Table 1. Main compounds of selected essential oils tested for potential inhibitory effect against plant pathogenic and saprophytic bacteria.

Plants	Origin	Plant organ	Main compounds (relative area %)[a]
Melissa officinalis	Spain	Flowers/leaves	citronellal (12.9), citronellol (6.3), neral (24.5), geranial (31.3), β-caryophyllene (3.9)
Mentha arvensis	India	Aerial part	menthol (74.5), menthone (9.2), methyl acetate (3.1)
Nepeta cataria	Canada	Flowering tops	nepetalactone (81.1), β-caryophyllene (10.8)
Origanum compactum	Morocco	Aerial part	carvacrol (36.2), p-cymene (22.3), thymol (18.6), γ-terpinene (5.2)
Origanum vulgare	Greece	Aerial part	thymol (28.5), thymyl methyl ether (5.7), carvacrol (19.5), β-bisabolene (12.6)
Thymus vulgaris	Spain	Aerial part	p-cymene (16.3), γ-terpinene (5.6), geraniol (8.3), thymol (6.8), carvacrol (7.9)

[a] According to the data of the gas chromatography analysis of essential oils provided by the manufacturer.

Essential oil/Chemical	Growth reduction expressed as average of inhibition zone diameters (cm)		
	Pseudomonas syringae pv. *syringae*		
	CCM 4073	*LMG 1247*	Average
Mellisa officinalis	5.8 ± 0.75	7.7 ± 0.82	6.7 ± 1.22
Mentha arvensis	4.5 ± 0.55	5.5 ± 1.22	5 ± 1.04
Nepeta cataria	3.5 ± 0.55	4.2 ± 0.75	3.8 ± 0.72
Origanum compactum	15.5 ± 1.22	26.3 ± 3.83	20.9 ± 6.27 *
Origanum vulgare	14.5 ± 0.55	25.7 ± 1.37	20 ± 5.92 *
Thymus vulgaris	16.0 ± 0.89	24.0 ± 1.55	20 ± 4.35 *
Streptomycin 0.02 %	3.7 ± 0.52	3.7 ± 0.82	3.7 ± 0.65

(Kokoskova et al. 2011. *Journal of Plant Pathology* 93:133-139)

- **Bacterial canker biological control**

- Most of biological control products show low efficacy controlling bacterial canker

Laboratory trials with plant essential oils

Need to complete field trials under natural conditions

Table 1. Growth inhibitions zones (mm) of bacterial pathogens caused by fungicides and essential oils on KingB medium after 48 h of incubation

Treatment	Ps110
Control (water)	0.0 a
Copper oxychloride (Miedzian 50 WG)	2.0 c
Copper oxychloride (Miedzian 50 WG)**	2.7 d
Metalaxyl-M, mancozeb (Ridomil MZ Gold 68 WG)	1.7 c
Tolylfluanid (Euparen Multi 50 WG)	0.0 a
Captan (Captan 80 WG)	0.0 a
Mancozeb (Dithane Neotec 75 WG)	2.0 c
Essential oils:	
BioZell	1.0 b
Lavender	0.0 a
Lemon balm	0.0 a
Sage	3.0 d
Clove	1.0 b

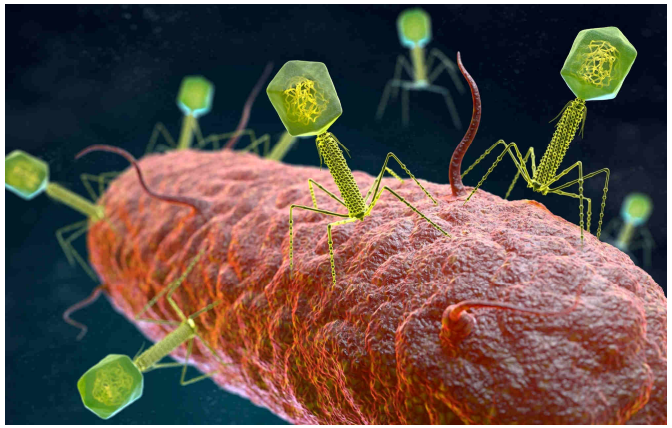
(Mikicinski et al. 2012. *Journal of Plant protection Research* 52: 467-471)

- **Bacterial canker biological control**

- Most of biological control products show low efficacy controlling bacterial canker

Evaluation of bacteriophages to control *Pseudomonas syringae pv. syringae*

Bacteriophages are viruses that infects bacteria cells and use the bacterial processes to replicate



https://www.news-medical.net/news/20230110/Researchers-review-bacteriophage-treatment.aspx

Table 6 Biocontrol (%) at bacteriophage treatments on *Pseudomonas syringae* pv. *syringae* disease's severity in micropropagated cherry plantlets within a growth chamber

Treatments	Treatment concentration (pfu/ml)	Average disease index (%)[a]	Efficacy (%)[b]
Φ1226	$2{,}2 \times 10^9$	9.7 ± 0.75 **a**[c]	79.8
Φ137	$1{,}5 \times 10^9$	13.9 ± 0.77 **ab**	71.2
Φ358	$4{,}1 \times 10^{10}$	15.3 ± 0.63 **ab**	68.3
Φ369	6×10^{10}	20.8 ± 1.10 **ab**	56.7
ΦCombination of phages	5×10^9	27.8 ± 0.54 **b**	42.3
Φ1215	4×10^9	38.9 ± 0.49 **c**	19.2
BY5L316 (control +)	**0**	**48.1 ± 0.51 c**	**0.0**

a. The results are an average of the two trials. Four plantlets were evaluated in each trial for each treatment
b. Percentage reduction in diseases severity compared to plants treated with pathogen alone
c. Means within columns sharing a letter in common are not significantly different ($P < 0.05$; Duncan's test). The standard error of each set is displayed

Need to complete field trials under natural conditions

(Akbaba and Ozaktan 2021. *Egyptian Journal of Biological Pest Control* 31:35 467-471)

- **Bacterial canker biological control**

- Most of biological control products show low efficacy controlling bacterial canker

Evaluation of lime sulphur (Calcium polysulphide) to manage bacterial canker

Applied in dormancy, is an eradicant primarily used for the control of fungal diseases

Field trials conducted in Chile in 2013 and 2014 using POLISUL-35 (Tessenderlo Kerley)

(Mauricio Sanchez - Tessenderlo Kerley International)

Treatments applied by the end of leaf fall

- **Bacterial canker biological control**

- Most of biological control products show low efficacy controlling bacterial canker

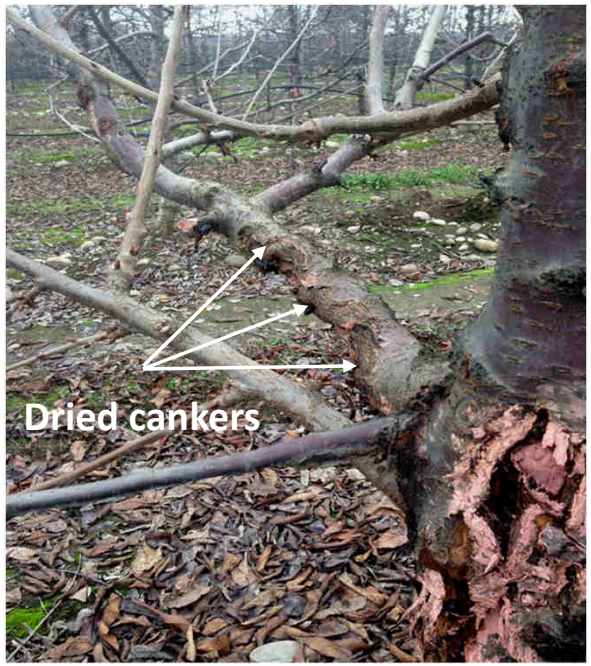
Evaluation of lime sulphur (Calcium polysulphide) to manage bacterial canker

Applied in dormancy, is an eradicant primarily used for the control of fungal diseases

Field trials conducted in Chile in 2013 and 2014 using POLISUL-35 (Tessenderlo Kerley)

Treatment	Rate (L/ha)	% cankers with gummosis
Control	-	37.5 a
Polisul 35	95	12.5 b
Polisul 35	60	15.6 b

Trial completed by AGROLAB Ltda. Chile



(Mauricio Sanchez - Tessenderlo Kerley International)

- **Bacterial canker management by cultural practices**

  - **Pruning:** Plays a critical role in disease severity

    Winter pruning is problematic due to freezing of the wood tissue infected by *Pss*

Effect of pruning date

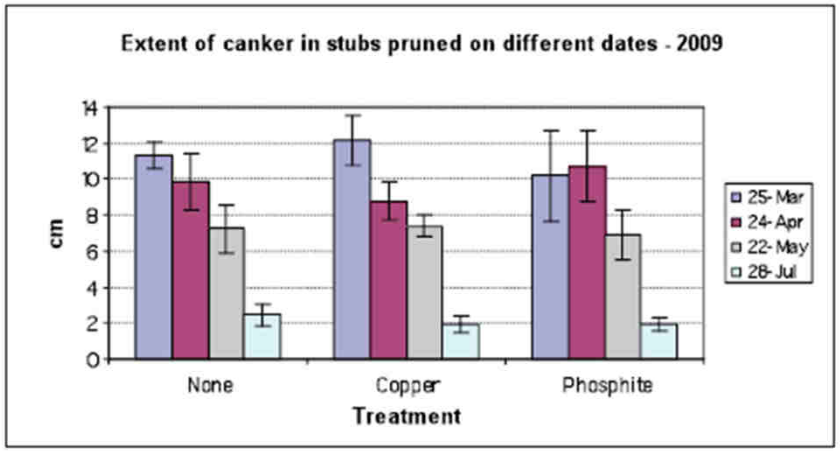


Figure 6. Progression of canker measured October 8 on pruning stubs cut on March 25, April 24, May 22, or July 28 and inoculated with *Pseudomonas syringae* pv. *Syringae* in Geneva, NY. Trees in three replicate blocks were not sprayed or sprayed with copper (COCS or Cuprofix Ultra at 4 lb/100 gal), or phosphite (Agri-Fos at 2.5 qt/100gal) on March 26, April 24 and April 25.

(Caroll *et al.* 2010. NY Fruit Quarterly Vol. 18)

Georgia (USA): **October-December** pruning
57 to 100% peach tree mortality
April pruning = no peach mortality

(Chandler & Daniel, 1976. HortScience 11:103-104)

California (USA): **December or March** = high infections
November pruning = low infections

(Otta and English, 1970. Plant Dis. Rep. 54: 332-336)

- **Bacterial canker management by cultural practices**

  - **Pruning:** Plays a critical role in disease severity

Susceptibility of pruning wounds

Table 6. Duration of susceptibility of heading cut wounds on sweet cherry cv. Sweetheart to infection by *Pseudomonas syringae* pv. *syringae*

	Mean canker length (mm) for each inoculation date		
Time (weeks)[z]	6 June 2007	9 August 2007	30 January 2008
0	25.0	11.5	9.7
1	7.3	6.0	7.3
2	6.0	4.0	5.7
3	5.3	5.0	1.7
Control	3.7	3.7	1.3
Regression *P*	0.046	0.038	0.010

[z] Time between wounding and inoculation. June and August inoculations were evaluated after one mo, January inoculation after 5 mo. Control cuts were not inoculated. Regression: $\log (Y + 1) = 1.14 - 0.133X$ for June, $\log (Y + 1) = 0.988 - 0.104X$ for August, and $\log (Y + 1) = 1.07 - 0.224X$ for January; where Y = canker length (mm) and X = time (weeks).

(Spotts et al. 2010. *Plant Disease* 94:345-350)

- **Bacterial canker management by cultural practices**

  - **Fertilization:** Nitrogen fertilization shown to decrease host susceptibility in peach

    N = reduces *syrB* gene expression (syringomicin)

    (Cao *et al.* 2005. Phytopathology 95:581-586)

    N + urea increases [N] in the bark in almonds resulting in smaller lesions than non-fertilized

Table VI.
Effect of nitrogen and calcium fertilization on lesion length and bark nitrogen and calcium concentrations in 'Nonpareil' almond (10 replicates per treatment).

Treatment	Power length[a]	Lesion length (mm)	Bark nitrogen concentration (%)	Bark calcium concentration (%)
			Mean ± standard error	
CAN-17 + urea spray	0.791 a	15.3 ± 2.6	1.66 ± 0.04 a	0.75 ± 0.05 a
Nutri-Cal spray (Ca)	0.739 b	35.3 ± 6.2	1.47 ± 0.05 b	0.69 ± 0.05 a
Control	0.731 b	40.9 ± 7.6	1.38 ± 0.04 b	0.72 ± 0.06 a

[a] Power length = (Lesion length)$^{-0.09}$.
Means within the column followed by the same letter are not significantly different at $P < 0.05$ based on Duncan's Multiple Range Test.

Mineral nutrients play a minor role in the susceptibility to bacterial canker

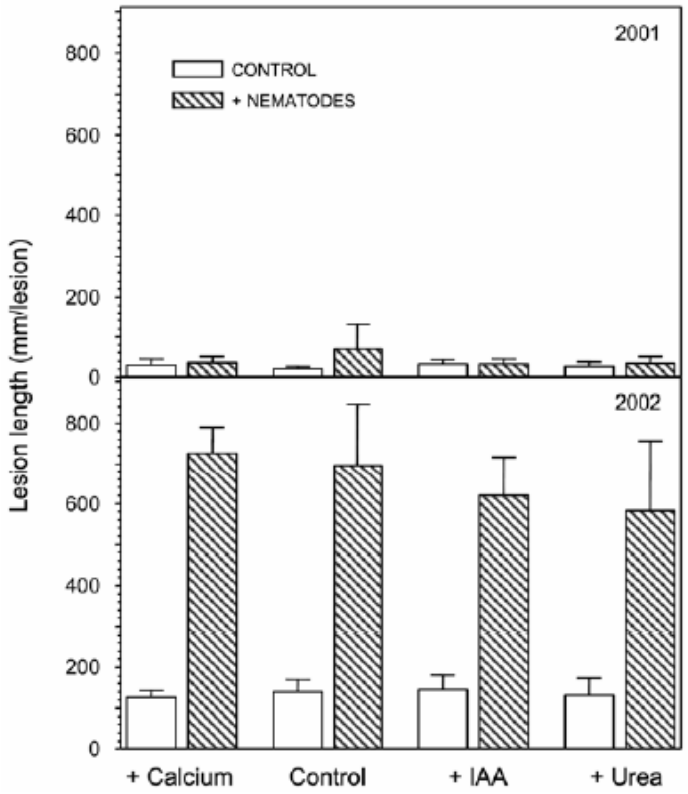
(Cao et al. 2013. *Fruits* 68:245-254)

- **Bacterial canker management by cultural practices**

  - **Biotic stress:** Nematodes are a predisposing factor increasing susceptibility in peach

    California: Ring nematode (*Mesocriconema xenoplax*)

Fig. 1. Mean ($n = 9$) canker lesion length (nontransformed) ± the ≈95% confidence interval for ring nematode infestation and post-planting treatments over 2 years in the Kearney Agricultural Center experiment. In 2001, there were no significant differences (based on log-transformed values) between trees with and without nematodes for any treatment combinations. In 2002, lesion lengths were significantly greater in trees stressed with ring nematodes than in trees free of nematodes. Canker lesions also were significantly longer in 2002 than in 2001for trees stressed with ring nematodes. IAA = indoleacetic acid.



Sandy soils predispose bacterial canker on peach and apricot

(Scortichini 2010. J. Plant Pathol. 92:73-78)

(Cao et al. 2016. *Phytopathology* 96:608-615)

- **Bacterial canker management by cultural practices**

  - **Host tolerance/resistance:** Not sufficient knowledge

Table 3. Bacterial canker severity on five sweet cherry cultivars at Hood River, OR[x]

	Canker length (mm) for each infection site/year[y]						
Cultivar	**Heading/2007**	**Scoring/2008**	**Scoring/2009**	**Leaf/2008**	**Shoot/2008**	**Shoot/2009**	**Dead (%)[z]**
Bing	18.0 b	13.6 bc	16.1 a	4.3 ab	5.2 a	2.6 a	70 b
Sweetheart	12.6 a	13.8 bc	12.5 a	5.0 b	6.6 a	4.3 a	43 a
Sylvia	12.1 a	8.2 a	10.8 a	2.7 ab	4.0 a	2.7 a	60 ab
Regina	11.3 a	10.6 ab	11.7 a	0.3 a	4.9 a	5.3 a	50 a
Rainier	9.5 a	15.7 c	11.0 a	0.5 a	4.4 a	3.5 a	47 a

[x] Heading cuts in 2007, scoring and shoot cuts in 2008 and 2008, leaf scars in 2008, and percentage of trees dead in 2009. Data from Gisela 6, Mazzard, and Maxma 14 rootstocks were combined for each cultivar.

[y] Numbers followed by the same letter within columns are not significantly different at $P = 0.05$ according to analysis of variance and least significant difference tests.

[z] Numbers followed by the same letter within columns are not significantly different at $P = 0.05$ according to χ^2 test.

Rainier and Regina more tolerant than Sweetheart and Bing

(Spotts et al. 2010. *Plant Disease* 94:345-350)

- **Bacterial canker management by cultural practices**

  - **Host tolerance/resistance:** Not sufficient knowledge

Table 2. Mean severity ratings of symptom development for detached leaves of various cherry cultivars inoculated by wound injection, 2002.

Cultivar	Mean severity[1] of symptom development on wound injected leaves[2]
Merchant	4.7 a[3]
Merpet	6.5 a
Sweetheart	9.8 b
Standard error	± 1.1

[1]Calculated as the mean value over all isolates tested using the sum of values for each inoculation point for leaves inoculated three times. Each injection point was rated using a 0–4 scale: 0 = no symptoms, 1 = distinct necrosis at point of injection, 2 = distinct necrosis at point of infiltration plus local tissue chlorosis, 3 = distinct necrosis at point of injection plus local tissue necrosis, 4 = widespread leaf necrosis.

[2]Mean of all pathogenic strains of *Pseudomonas syringae* pv. *syringae* tested, *Pseudomonas fluorescens* saprophyte and sterile distilled water control.

[3]Numbers within the column followed by the same letter were not significantly different at the p=.05 level.

Tolerance/resistance to bacterial canker need to be introduced in breeding programs

(Bedford et al. 2003. Acta Horticulturae 662:365-368)

- **Bacterial canker management by cultural practices**

  - **Host tolerance/resistance:** Rootstocks have a significant effect on variety susceptibility

Rootstock	Tree Mortality
Gisela 6	77%
Mazzard	30%
Bing/Gisela 6	90%
Bing/Colt	0%
Bing/Krymsk 5	43%
Bing/Mazzard	50%

(Spotts et al. 2010. *Plant Disease* 94:345-350)

- **Bacterial canker management by cultural practices**

  - Plastic vs. steel wire used in cherry trellis systems

(Úrbez-Torres. AAFC - Summerland RDC)

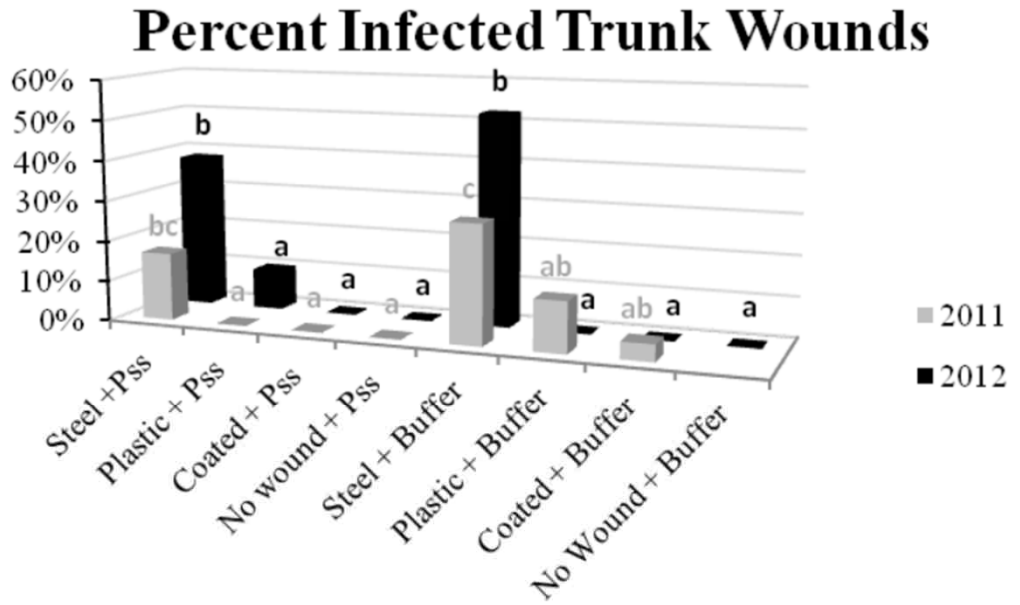


Figure 1. Percent infected sweet cherry trunk wounds, by wire type (high tensile plastic, plastic-coated steel, and high tensile steel), following wounding and inoculation (PSS) or no inoculation (buffer) conditions over 2 years (grey bars 2011 and black bars 2012). Years were analyzed separately for statistics. Bars with the same letter were not significantly different from each other with a P-value of 0.05.

(Lillrose et al. 2017. *Acta Horticulturae* 73:1161)

- **Bacterial canker management by cultural practices**

  - Use double drip line and trunk protected with white paint

(Washington State University Tree Fruit Extension)

Table 3. Effect of nitrogen, benomyl, and white trunk paint treatments on Cytospora canker, bacterial canker, and mortality of sweet cherry trees from 1982 to 1986

Treatment	Level	Percent trees infected with *C. cincta*	Percent trees infected with *P. syringae*	Dead (%)
Nitrogen[a]	0	18[b]	23	14
	113 g/tree	20	30	12
	453 g/tree	16	24	11
Dormant benomyl[c,d]	+	21	29	11
	−	15	22	13
Spring benomyl[c,d]	+	18	26	11
	−	18	25	13
White paint[c]	+	12**	20**	4**
	−	24	31	20

[a] Each value represents 128 trees.
[b] Values followed by ** indicate effect of factor is significant at $P = 0.01$. Numbers indicate cumulative values from 1982 to 1986.
[c] Each value represents 192 trees.
[d] Dormant benomyl applied immediately after pruning; spring benomyl applied at popcorn, petal fall, and shuck split.

"Recommended to avoid winter freeze damage. White paint can maintain T of cambium 8–16 C lower than unpainted trees and can reduce the sudden drop in T following a sunny winter day"

(Spotts et al. 1990. *Plant Disease* 74:577-580)

SUMMARY (Multidisciplinary Approach)

- Site selection (areas with low risk of frost, avoid sandy soils, control nematode populations)
- Do not interplant new trees with old trees as they are a major source of inoculum
- Optimal fertilization (careful with excess N late in the season as promote extra growth)
- Drip/microsprinkler better than overhead irrigation (avoid water in tree parts in young trees)
- Avoid any type of injury (special attention to injury caused by wire and trellises)
- Pruning in summer = less disease (prune always in dry conditions)
- Rootstock selection. Tolerance = Mahaleb > Colt > Mazzard
- Sanitation. Remove infected trees or parts of the tree (control of weeds, grasses)
- Chemical control can reduce disease if properly applied (known epidemiology in the area)
- Knowledge of resistance (copper, antibiotics)
- Further research needed in biological controls and breeding programs

(Adapted from: Spotts et al. 2010. *Plant Disease* 94:345-350 and UC Davis IPM https://ipm.ucanr.edu/agriculture/prune/bacterial-canker/#gsc.tab=0)

- **Bacterial canker in Germany**

  - Studied in plum in southwest Germany (Baden-Württenberg)

  - Control strategies adapted to the disease cycle knowledge

  - Copper compounds applied during leaf fall and bud burst were not effective

  - Presence of *Pseudomonas syringae* resistant isolates to copper in plum trees

  - Leaf scar infections during dormancy are rare and do not induce cankers

  - Infections of dormant trees through frost injuries (freezing and thawing) and pruning

  - Management focus on the dormant period (early frost in fall) and ending with bud burst

(Hinrichs-Berger 2004. Journal of Phytopathology 152:153-160)

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