Copper 8-Quinolinolate for Control of *Corynebacterium michiganense* pv. *sepedonicum* on Potato Seed Pieces and Handling Equipment

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ABSTRACT

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Every year, *Corynebacterium michiganense* pv. *sepedonicum* (Cms) from infected certified seed potatoes and previously contaminated seed-handling equipment and storages is spread to clean seed. Aqueous sprays of the relatively noncorrosive copper 8-quinolinolate at 0.5^{-3} kg a.i./L controlled Cms on contaminated wood, polyurethane foam, and urethane rubber surfaces found on potato seed-handling equipment in 6 yr of trials. When the chemical was sprayed on contaminated seed-piece surfaces, it failed to control the bacteria and was phytotoxic. The registered rate (0.5^{-3} kg a.i./L) would be considered nonphytotoxic if sprayed on surfaces of seed-handling equipment. This rate eliminated most Cms on seed-handling equipment in commercial potato culture but did not guarantee against ring-rot contamination in a certified seed program.

Every year, there are reports that certified seed potatoes become infected with *Corynebacterium michiganense* pv. *sepedonicum* (Spieckermann & Kotthoff) Dye & Dempt (Cms), the causal agent of potato ring rot. Bacteria from infected or diseased potatoes have contaminated surfaces in railcars, trucks, storages, seed cutters, seed-handling equipment, and potato planters.

Since 1972, when bulk handling of whole and cut certified potato seed began in Washington, ring rot has occurred in 1,600–2,500 ha of potatoes annually. Yields may be reduced more than 50% by this disease (6). Expense and labor are required to clean and disinfest contaminated equipment because there is a zero tolerance for ring rot in most certification programs. Many thousands of dollars are spent in litigation as a result of losses from this disease. Commercial potatoes are rejected from foreign markets because of the threat of ring rot.

Sanitation practices probably are incapable of eliminating all ring rot from certified potatoes, but electric heat, boiling water, antibiotics, various chemicals, and fumigations have reduced yield loss from this disease in commercial potatoes (3,4,7–12,16,17). Some antibiotics applied to contaminated surfaces were reported to control ring-rot bacteria but were either phytotoxic (3,9,11), caused delayed symptom expression (9), or were uneconomical (9). Sodium hypochlorite, a well-known disinfestant, has been used but was not satisfactory because of its rapid degradation in the presence of sunlight and organic matter and its corrosiveness to the metal surfaces of potato-handling equipment. Copper 8-quinolinolate (C8Q), a relatively noncorrosive disinfestant, became available in the 1970s and was found to be equal to sodium hypochlorite and Physan 20, *n*-alkyl (60% C_{14}, 30% C_{16}, 5% C_{12}, 5% C_{18}), 10% dimethyl benzyl ammonium chlorides *n*-alkyl (68% C_{12}, 32% C_{14}), 10% dimethyl ethylbenzyl ammonium chlorides, and better than formaldehyde and Roccal II, alkyl (50% C_{14}, 40% C_{12}, 10% C_{16}), 10% dimethyl ethylbenzyl ammonium chlorides, 1.25% ethyl alcohol in controlling ring-rot bacteria that contaminated wood surfaces (5,6). In 1981, C8Q was registered as a disinfestant for potato seed-handling equipment to control ring-rot bacteria (1).

Surfaces of burlap, concrete, metal, paper, polyurethane, and rubber are involved in storing, hauling, conveying, cutting, and planting potato seed. Cms survived for 7–24 mo on burlap, concrete, paper, and polyethylene surfaces, depending upon the storage temperature and relative humidity (13,14). Cms was viable for less than 4 mo on steel.

Wood and metal surfaces of truck beds are often coated with polyurethane foam to reduce bruising of tubers during loading operations and to insulate tubers against freezing during winter hauling. A urethane rubber coating has been added to reduce physical abrasion and ultraviolet deterioration of the polyurethane.

Reported herein are the results of a 6-yr study (1976, 1977, 1979–1982) to determine if C8Q could be used effectively to control ring-rot bacteria on cut surfaces of seed potatoes and on various surfaces that contact bulk-handled seed potatoes.

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Mention of a product used in these studies does not constitute a recommendation of the product by Washington State University over other products.

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MATERIALS AND METHODS

Experiments were designed to simulate methods that might be useful to control Cms on seed pieces and surfaces of seed-handling equipment. Metal surfaces were not tested because very few infected plants resulted from contact of seed pieces with contaminated metal bars, even when no chemical disinfestants were applied (5,6). Disinfestants were evaluated on treated surfaces a few minutes after their contamination by ring-rot bacteria. In a preliminary trial, longer periods of drying considerably reduced the number of infected plants resulting from seed pieces rubbed even on nondisinfested, contaminated surfaces. Surfaces of unpainted wooden lath 1.9 cm wide × 15.2 cm long; polyurethane foam 2.5 cm wide × 15.2 cm long (907-g-density polyurethane foam coated on 0.32-cm-thick fiberboard); and urethane rubber (Elastal 900 fast-cure 2 component catalized thermal setting urethane rubber, Cozy Bear Insulation/Roofing, Grandview, WA) coated on both sides of metal bars 2.5 cm wide × 15.2 cm long × 0.32 cm thick were dipped into a thin watery tuber slurry of Cms. The slurry was prepared by grinding four to six infected tubers in a food blender with water to make a total of 4 L as described by Bonde and Covell (2). After dipping, the various infested surfaces were allowed to drain 3–5 min, sprayed with disinfestants by a hand sprayer at about 20 psi until runoff, and allowed to drain for another 3–5 min. Twenty healthy, freshly cut cultivar Norgold Russet potato seed pieces (56–70 g) were rubbed vigorously on the surfaces (five seed pieces per surface) and placed in double paper bags. Control treatments consisted of seed pieces rubbed on various surfaces previously contaminated with Cms but not sprayed with disinfestants or not contaminated but sprayed with disinfestants. All bagged seed pieces were planted within 1 hr of treatment. New disposable plastic gloves were changed between each treatment.

Healthy, sprouted, freshly cut Norgold Russet potato seed pieces (56–70 g) were selected for seed-piece treatments. Seed pieces in a wire mesh basket were dipped into a Cms tuber slurry as prepared before. The seed pieces were allowed to drain 3–5 min, sprayed with the disinfestants, allowed to drain another 3–5 min, and planted. Control treatments consisted of seed pieces not contaminated and not sprayed, not contaminated but sprayed with disinfestants, and contaminated but not disinfested with chemicals. These seed pieces were also bagged and planted.

The disinfestants and rates applied were aqueous sodium hypochlorite 0.525% and aqueous C8Q, 0.5^{-3} kg a.i./L (Mitrol PQ-57, 0.05 kg a.i./L, Chapman Chemical Company, Memphis, TN). In the 1975 and 1976 trials, water alone sprayed on wooden surfaces contaminated with Cms showed no effect on the subsequent incidence of ring rot, thus this treatment was not included in these trials (6).

The treated seed pieces were planted in three rows per plot (2.7 m wide × 6.1 m long) arranged in a randomized, complete block design with six replicates. Seed pieces were planted by hand 30.5 cm apart into an open furrow and covered with disks. There were 60 seed pieces in each replicate. Ammonium sulfate (448 kg N/ha) was banded at planting. The 1976, 1977, 1980, and 1981 plots were planted in April near Prosser, WA, and the 1979 plots were planted in May near Mt. Vernon, WA. Plants showing ring-rot symptoms were counted in July or August each year, and the center row of each plot was harvested in late fall.

Tuber samples were saved from the 1979 and 1981 trials and replanted to determine if control by C8Q was effective in preventing seed-piece transmission of Cms and to assess possible carryover phytotoxicity. On 13 September 1979, 10 randomly selected hills (90–115 tubers) per replicate of each 1979 treatment were hand-dug, placed separately in new cardboard boxes, and stored at 4.4 C. On 2 April 1980, whole tubers of each replicate were planted in single-row plots. Plants emerging and those expressing ring rot were counted during the growing season.

On 1 September 1981, 60 tubers per replicate of each treatment of the 1981 trials were hand-dug and stored for replanting in 1982. On 7 May 1982, these whole tubers were hand-planted 30.5 cm apart in open furrows of three 3.1-m rows, 10 tubers per row, in a randomized, complete block design with six replicates. Ring-rot incidence was calculated for all three rows of each plot, and the center row was harvested on 27 August.

Digging forks were disinfested with C8Q at 2.5^{-3} kg a.i./L and rinsed with water. In all trials, disposable plastic gloves were changed between treatments during digging and planting.

In most years, plant emergence, incidence of plants with ring rot, total tuber weight, weight of U.S. No. 1 tubers, and weight of tubers with ring rot were determined. Results are presented in Tables 1–5.

RESULTS

C8Q at 0.5^{-3} kg a.i./L sprayed on all three bacteria-contaminated surfaces appeared to prevent subsequent contamination of seed pieces by Cms (Table 1). Tuber yields were lower from seed

Table 1. Plant emergence, ring rot in plants and tubers, and yields of potatoes after treatment of copper 8-quinolinolate (C8Q) on various potato-handling surfaces infested with *Corynebacterium michiganense* pv. *sepedonicum*

Treatments	C8Q (kg a.i./L)	Plant emergence (%)	Ring-rot plants (%)	Ring-rot tubers (%)	U.S. No. 1 tubers (%)	Yield (g/ha)	
		Wooden surfaces					
Untreated	None	87[p] a[q]	0[r] b	0[s] b	77[t] a	591[t] a	···
RRC[u] only	None	91 a	14 a	6 a	76 a	523 b	···
C8Q + RRC	0.5^{-3}	93 a	1.3 b	0.4 b	77 a	562 a	···
		Polyurethane foam surfaces					
Untreated	None	85[v] a	0[w] b	0[x] b	75[y] a	626[y] a	504[z] a
RRC only	None	85 a	18 a	4 a	78 a	576 a	397 b
C8Q + RRC	0.5^{-3}	80 a	0 b	0 b	75 a	561 a	414 b
		Urethane rubber surfaces					
Untreated	None	85[v] a	0[w] b	0[x] a	75[y] a	626[y] a	542[z] a
RRC only	None	83 a	8 a	2 a	72 a	496 b	519 a
C8Q + RRC	0.5^{-3}	85 a	0 b	0 a	76 a	544 a	454 a

[p] Vertical means of 1976, 1977, 1979, 1980, and 1981 data for number of plants emerged in June per 60 seed pieces per three 6.1-m rows.

[q] Means within the main effects with the same letter are not significantly different according to Duncan's multiple range test ($P = 0.05$).

[r] Vertical means of combined 1976, 1977, 1979, and 1980 data for number of plants expressing ring rot out of 60 plants per three 6.1-m rows.

[s] Vertical means of combined 1976, 1977, 1979, 1980, and 1981 data for weight of tubers with ring rot out of total weight per 6.1-m row.

[t] Vertical means of combined 1976, 1977, 1979, and 1980 data for either weight of tubers graded U.S. No. 1 or total weight of tubers per 6.1-m row.

[u] Ring-rot contamination (RRC) was by a slurry of four to six infected tubers ground with water.

[v] Vertical means of 1980 and 1981 data for number of plants emerged in June per 60 seed pieces per three 6.1-m rows.

[w] Vertical means of 1980 data for number of plants expressing ring rot out of 60 plants per three 6.1-m rows.

[x] Vertical means of combined 1980 and 1981 data for weight of tubers with ring rot out of total weight per 6.1-m row.

[y] Vertical means of 1980 data for either weight of tubers graded U.S. No. 1 or total weight of tubers per 6.1-m row.

[z] Vertical means of 1981 data for weight of tubers per 6.1-m row.

pieces rubbed on wooden and urethane rubber surfaces treated with C8Q but not significantly less than those from seed rubbed on untreated surfaces. Significantly lower yields were harvested from the C8Q polyurethane foam surface treatments in 1981 but not in 1980. The C8Q treatment had no effect on plant emergence or tuber grade.

In the 1977 trials, C8Q sprayed on non-Cms-treated seed pieces reduced plant emergence (Table 2). Although C8Q did not reduce emergence in the 1979 trials, it did reduce emergence when seed from the 1979 trials was replanted in 1980. C8Q with and without Cms contamination reduced plant emergence in the 1981 trials but not when seed from 1981 trials was replanted in 1982.

Contamination with Cms reduced yields compared with uncontaminated controls in the 1977, 1979, and 1981 trials but not when seed from the 1981 trial was replanted in 1982 (Table 3). In trials of these three years and the 1982 replant of the 1981 trials, yields were not significantly less in treatments where C8Q was sprayed on contaminated and uncontaminated seed pieces than in respective treatments not receiving C8Q. C8Q sprayed on contaminated seed pieces did not reduce disease incidence among plants or tubers. Seed pieces contaminated with Cms only and contaminated with Cms and sprayed with C8Q reduced the percentage of U.S. No. 1 tubers in 1977 but not in 1979. C8Q only sprayed on uncontaminated seed had no effect on the percentage of U.S. No. 1 tubers.

C8Q at 0.5^{-3} kg a.i./L sprayed on wooden surfaces additionally contaminated by Cms reduced numbers of plants and tubers with ring rot (Table 4). Plants but not tubers with ring rot recurred from tubers of seed replanted from the previous years' trials. C8Q had no effect on plant emergence, percentage of U.S. No. 1 tubers, or yield in these trials (Tables 4 and 5). Plants from seed pieces rubbed on wooden surfaces with ring-rot contamination yielded significantly less than the untreated controls in 1976 and 1977 but not in 1979, 1980, 1981, and replants of the 1981 trials (Table 4).

DISCUSSION

It has been reported that even small numbers of ring-rot bacteria can remain undetected for more than three generations of potato culture (15). C8Q at 0.5^{-3} kg a.i./L, the registered rate, did not prevent ring rot when sprayed on seed pieces contaminated with Cms but did eliminate most but not all of the Cms on the wooden, polyurethane foam, and rubber surfaces tested (Tables 1, 3, and 4). Therefore, even with the recommended rate of C8Q, some spread of Cms by contaminated potato-handling equipment could occur in commercial and certified seed production. Use of C8Q, however, should lead to a substantial reduction in losses from ring rot in commercially handled potatoes.

Plant emergence and yields were not reduced by seed-piece contact with wooden surfaces sprayed with C8Q. Moreover, seed produced in such trials did not suffer any deleterious effects. When sprayed on seed pieces at the 0.5^{-3} rate, however, C8Q reduced plant emergence and yield in 1981 trials but did

Table 2. Plant emergence both the year of treatment with copper 8-quinolinolate (C8Q) on potato seed-piece surfaces[w] infested with *Corynebacterium michiganense* pv. *sepedonicum* and the next year from seed replanted from the previous year's trial

		Percent plant emergence				
Treatments	**C8Q (kg a.i./L)**	**1977**	**1979**	**Replant of 1979 (1980)**	**1981**	**Replant of 1981 (1982)**
Untreated	None	90 b[x]	100 a	88 a	85 a	83 b
RRC[y] only	None	93 ab	100 a	84 a	70 a	81 b
C8Q + RRC	0.5^{-3}	97 a	100 a	74 b	50 b	98 a
C8Q only	0.5^{-3}	72 c	100 a	...[z]	50 b	88 ab

[w] Healthy, cut seed pieces were dipped into a ring-rot tuber slurry and sprayed with C8Q.
[x] Means with the same letter are not significantly different according to Duncan's multiple range test ($P = 0.05$).
[y] Ring-rot contamination (RRC) was by a slurry of four to six infected tubers ground with water.
[z] Data not collected.

Table 3. Ring rot in plants and tubers and grade and yields of potatoes both the year of treatment with copper 8-quinolinolate (C8Q) on potato seed-piece surfaces[v] infested with *Corynebacterium michiganense* pv. *sepedonicum* and the next year from seed replanted from the previous year's trial

				Yield (q/ha)				U.S. No. 1 tubers (%)	
Treatments	**C8Q (kg a.i./L)**	**Ring-rot plants[w] (%)**	**Ring-rot tubers[x] (%)**	**1977**	**1979**	**1981**	**Replant of 1981 (1982)**	**1977**	**1979**
Untreated	None	0 c[y]	0 c	723 a	462 a	527 ab	595 a	81 a	72 a
RRC[z] only	None	25 a	9 a	511 b	340 b	357 c	603 a	71 c	60 a
C8Q + RRC	0.5^{-3}	24 a	7 ab	568 b	349 b	308 cd	582 a	78 b	60 a
C8Q only	0.5^{-3}	0 c	0 c	666 a	430 a	389 b	571 a	87 a	66 a

[v] Healthy, cut seed pieces were dipped into a ring-rot tuber slurry and sprayed with C8Q.
[w] Mean of combined 1977 and 1979 data and replant of 1979 and 1981 trials for number of plants expressing ring rot out of 60 plants per three 6.1-m rows.
[x] Mean of combined 1977, 1979, and 1981 data and replant of 1981 trials for weight of tubers with ring rot out of total weight per 6.1-m row.
[y] Means with the same letter are not significantly different according to Duncan's multiple range test ($P = 0.05$).
[z] Ring-rot contamination (RRC) was by a slurry of four to six infected tubers ground with water.

Table 4. Ring rot in plants and tubers and grade and yields of potatoes both the year of treatment with copper 8-quinolinolate (C8Q) on wooden surfaces infested with *Corynebacterium michiganense* pv. *sepedonicum* and the next year from seed replanted from the previous year's trial

		Ring-rot plants (%)			Ring-rot tubers (%)			Yield (q/ha)						
Treatments	**C8Q (kg a.i./L)**	**1979**	**Replant of 1979 (1980)**	**Replant of 1981 (1982)**	**1979**	**Replant of 1979 (1980)**	**Replant of 1981 (1982)**	**1976**	**1977**	**1979**	**1980**	**1981**	**Replant of 1981 (1982)**	**U.S. No. 1 tubers[v] (%)**
Untreated	None	0[w] b[x]	0 c	0 b	0[y] b	0 b	0 b	682 a	691 a	439 a	626 a	519 a	585 a	77 a
RRC[z] only	None	14 a	23 a	14 a	6 a	3 a	1 a	552 b	553 b	414 a	626 a	471 a	603 a	76 a
C8Q + RRC	0.5^{-3}	1.3 b	5 b	0.5 b	0.4 b	0 b	0 b	706 a	675 a	439 a	618 a	519 a	630 a	77 a

[v] Means of combined 1976, 1977, 1979, and 1980 data for weight of tubers graded U.S. No. 1 per 6.1-m row.
[w] Vertical means of combined 1976, 1977, 1979, and 1980 data for number of plants expressing ring rot out of 60 plants per three 6.1-m rows.
[x] Means with the same letter are not significantly different according to Duncan's multiple range test ($P = 0.05$).
[y] Vertical means of combined 1976, 1977, 1979, 1980, and 1981 data for weight of tubers with ring rot out of a total weight per 6.1-m row.
[z] Ring-rot contamination (RRC) was by a slurry of four to six infected tubers ground with water.

Table 5. Plant emergence both the year of treatment with copper 8-quinolinolate (C8Q) on wooden surfaces infested with *Corynebacterium michiganense* pv. *sepedonicum* and the next year from seed replanted from the previous year's trial

		Percent plant emergence				
Treatments	**C8Q (kg a.i./L)**	**1977**	**1979**	**Replant of 1979 (1980)**	**1981**	**Replant of 1981 (1982)**
Untreated	None	92 a[x]	95 a	86 a	85 a	88 a
RRC[y] only	None	90 a	100 a	89 a	85 a	93 a
C8Q + RRC	0.5^{-3}	92 a	100 a	92 a	90 a	91 a
C8Q only	0.5^{-3}	93 a	100 a	...[z]	85 a	86 a

[x] Means with the same letter are not significantly different according to Duncan's multiple range test ($P = 0.05$).
[y] Ring-rot contamination (RRC) was by a slurry of four to six infested tubers ground with water.
[z] Data not collected.

not affect the subsequent performance of seed produced in such trials (Tables 2 and 3). Why treating seed with C8Q caused no reduction in emergence in 1979 but evidently carried over in daughter tubers in the next year's planting to reduce emergence by 10% cannot be explained. As a precaution, C8Q should not be inadvertently sprayed on potato seed.

C8Q, sodium hypochlorite, and other disinfestants when sprayed and allowed to remain on freshly cut, contaminated potato seed before planting have never effectively controlled ring-rot bacteria (6). Possibly the chemicals are neutralized by cellular products on the cut seed surface or the bacteria are quickly taken into intercellular spaces.

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