Mancozeb and Kaolin Applications Can Reduce Russet of 'Comice' Pear

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SUMMARY. Mancozeb (Manzate 200) and kaolin (Surround WP) were applied individually and in combination in a commercial pear (*Pyrus communis*) orchard by air-blast sprayer in two growing seasons and in a research orchard by handgun sprayer in four growing seasons. Mancozeb was applied at 50% bloom, petal fall (PF), PF + 2 weeks and PF + 4 weeks, while kaolin and mancozeb + kaolin were applied at PF, PF + 2 weeks and PF + 4 weeks. Both materials reduced russet in both years of the commercial orchard trial and in 2 years of the research orchard trial. In one trial, kaolin treatment reduced russet to a greater extent than did mancozeb, and in one trial the combination of mancozeb plus kaolin reduced russet to a greater extent than either material alone. The year with the greatest amount of russet was the year with the most rainfall, and the year with the least russet was the year with the least rainfall. Considering that mancozeb may be used in pear orchards for suppression of pear scab (*Venturia pirina*) and pear psylla (*Cacopsylla pyricola*), and kaolin may be used for suppression of pear psylla, russet reduction by each of these materials adds to their multipurpose utility.

In the major green-skinned pear cultivars grown for the fresh market in the United States ('Bartlett', 'd'Anjou', and 'Comice'), fruit surface russet is considered a defect and can be a cause for downgrading or cullage at the packinghouse. Successful marketing of 'Comice' pear typically requires low incidence of russet on the fruit surface outside of the calyx bowl.

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Russet results when periderm tissue replaces the epidermis and cuticle in specific areas or the entire fruit surface (Faust and Shear, 1972). In normally green-skinned pears, periderm formation and russet may develop in response to frost, pest or chemical injury, or to environmental conditions such as moisture and temperature. Fruit cultivars vary in their inherent propensity to russet in response to russetting agents or conditions, which may involve the thickness or structure of the cuticle and its ability to protect underlying cells from potential russetting agents (Jackson, 2003). Regardless of the degree of russet susceptibility, the most vulnerable period appears to be during the period of intensive cell division within approximately 30 d of full bloom (Creasy, 1980; Faust and Shear, 1972; Gil et al., 1994). During this period of rapid fruit growth, the cuticle is relatively thin, and in some cultivars may develop cracks during fruit expansion (Faust, 1989).

Increased fruit russet is associated with wetter conditions during the period of vulnerability. Epidermal cells may be injured by excessive uptake of water that contacts the cells via cuticular cracks, causing them to rupture and stimulating the surrounding cells to produce periderm (Faust and Shear, 1972). Bagging fruit to prevent water from contacting the fruit surface generally reduces russet (Amarante et al., 2002; Creasy and Swartz, 1981). In addition, bacteria that may be present in a water film on the fruit surface can produce indole acetic acid (IAA), which stimulates periderm formation (Lindow et al., 1998). Russet development in apple (*Malus × domestica*) fruit has also been associated with surface populations of the yeasts *Aureobasidium pullulans* and *Rhodotorula glutinis* (Matteson Heidenreich et al., 1997), although these yeasts did not appear to be major contributors to russet development in 'd'Anjou' pear (Spotts and Cervantes, 2002).

Cuticle thickness and elasticity also may be affected by environmental conditions. Comparing two pear growing areas in Chile, Gil et al. (1994) found that 'Bosc' pear cuticles were thicker in the area with less rainfall, and less russet developed. They also reported that fruit surface russet increased with duration of exposure to moist conditions. Fruit elongation is stimulated by gibberellic acid (GA), which also

promotes greater cuticle elasticity and reduced tendency to russet (Jackson, 2003; Taylor, 1975). Pear fruit grown in areas with cooler spring temperatures tend to be more elongated than those grown in warmer regions (Tufts and Hansen, 1931). Incidence of russet in pear tends to be relatively low in fruit produced in dry-summer areas with cool spring temperatures, with thicker cuticles and less frequent presence of water on the fruit surface (Faust, 1989; Gil et al., 1994).

Grower-applied treatments may reduce incidence of fruit russet. GA₄₊₇ applied after bloom reduced russet in 'Packham's Triumph' pears, but reduced bloom in the subsequent growing season (Yuri and Castelli, 1998). GA treatment of pears during the post-bloom period may also cause excessive fruit elongation (Griggs and Iwakiri, 1961). Mancozeb is used as a protectant against pear scab in the western United States (Pscheidt and Ocamb, 2004), and also in management of the pear psylla (Hilton and Reidl, 2004). Mancozeb combined with sulfur reduced russet in 'Packham's Triumph' pear at a level similar to GA₄₊₇, without the adverse effects on return bloom (Yuri and Castelli, 1998).

Kaolin applications form particle films that have been effective in reflecting UV radiation, reducing fruit surface temperatures and reducing solar injury in apple (Glenn et al., 2002). In pear, kaolin is applied for suppression of the pear psylla (Puterka et al., 2000). Soon after kaolin treatments were introduced, it was observed that fruit from some orchards of 'Comice' pear treated with kaolin had less russet than fruit from non-treated orchards.

The objective of this study was to evaluate the effects of mancozeb and kaolin sprays during the post-bloom period, alone and in combination, on incidence of russet in 'Comice' pears.

Materials and methods

Experimental treatments for russet control were applied to 'Comice' pears in large plots in a commercial orchard near Medford, Ore., in 1999 and 2000, and to single-tree replicate plots at the Southern Oregon Research and Extension Center (SOREC) in 1999–2002. Large plot treatments were applied using an air-blast sprayer delivering 935.4 L·ha⁻¹ (100 gal/acre) for mancozeb and 1870.7 L·ha⁻¹ (200

gal/acre) for kaolin or mancozeb + kaolin. Single-tree plots were applied using a powered handgun sprayer delivering 1870.7 L·ha⁻¹.

Treatments consisted of 1) mancozeb (Manzate 200; DuPont, Wilmington, Del.) applied at the rate of 3.4 kg·ha⁻¹ (3 lb/acre); 2) kaolin (Surround WP; Englehard Corp., Iselin, N.J.) applied at the rate of 28.0 kg·ha⁻¹ (25 lb/acre) in 1999 and at 56.0 kg·ha⁻¹ (50 lb/acre) in 2000–02; 3) mancozeb + kaolin combined in a tank-mix; and 4) an untreated control. Mancozeb was applied at 50% bloom, petal fall (PF), PF + 2 weeks, and PF + 4 weeks. Kaolin and mancozeb + kaolin were applied at PF, PF + 2 weeks, and PF + 4 weeks. The kaolin treatment rate was increased after the 1999 season following the general recommendation of the manufacturer. In single-tree plots in 2000–02, additional mancozeb treatments at each timing alone as well as a treatment consisting of repeated applications at all timings were included. Additional kaolin treatments were similarly included in 2001–02.

In the commercial orchard, the plot area consisted of four replicate units of four rows each, randomly arrayed in an orchard block of 8.1 ha (20 acres). Because the length of rows varied, individual replicate size ranged from 0.04 to 0.40 ha (0.1 to 1.0 acre), with a total treated area for each treatment (sum of four replicates) of approximately 0.85 ha (2.1 acres). The orchard trees had been planted in 1966 at a spacing of 4.6 × 2.7 m (15 × 9 ft). At SOREC, trees had been planted in 1983 at a spacing of 5.5 × 2.29 m (18 × 7.5 ft). All trees at both locations were grafted on quince (*Cydonia oblonga*) rootstock.

At maturity, approximately 200 fruit were gathered at random from the center two rows of each replicate in the commercial orchard and from each replicate tree at SOREC. All fruit were stored in air at 0.0 °C (32 °F) until evaluated. Russet was estimated visually on each individual fruit and assigned to a category of 0% to 3%, 3% to 6%, 6% to 12%, 12% to 25%, 25% to 50%, 50% to 75%, 75% to 87%, 87% to 94%, 94% to 97%, 97% to 100%, or 100% of the fruit surface covered in russet (Horsfall and Barratt, 1945).

For clarity in expressing the results and uniformity among years, the percentage of the total number of fruit that individually had 6% or more

of the fruit surface covered in russet was used in comparing treatments. This corresponds approximately to the level at which fruit may be downgraded commercially. Treatment means were separated by applying Fisher's Protected least significant difference test using Minitab software (Minitab Inc., State College, Pa.).

Results and discussion

In commercial air blast sprayer plots, fruit from trees receiving all four mancozeb applications or all three kaolin applications had less russet than fruit from untreated trees in both years of study (Table 1). The combination of mancozeb and kaolin applied at all timings in 2000 reduced russet to a level similar to that of either material alone. In handgun-sprayed plots, fruit from trees receiving all mancozeb or all kaolin applications had less russet than fruit from unsprayed trees in 1999 and 2000, but not in 2001 or 2002. The combination of mancozeb and kaolin applied at all timings reduced russet in 2000 and 2002. However, only in 2000 was russet incidence in the treatment combining mancozeb and kaolin significantly less than that in treatments consisting of either material alone. In 2001, the year of least russet incidence, no differences were observed among treatments. Individual treatment timings presented more variable results, but russet was reduced by mancozeb application at 50% bloom alone in 2000, and by kaolin application at 2 or 4 weeks after petal fall in 2002.

Daily rainfall and maximum temperatures during the 30 d following full bloom in each year of this study are shown in Fig. 1. Cumulative rainfall during this period was 17.0, 82.7, 12.3, and 27.2 mm (0.67, 3.26, 0.48, and 1.07 inches) in 1999–2002, respectively. The year with the greatest amount of rainfall (2000) was the year with the most russet in untreated fruit, while the year with the least rainfall (2001) had the least russet (Table 1). Creasy (1980) found a similar relationship between higher rainfall years and russet in 'Golden Delicious' apples.

In light of the reported associations of russet with environmental conditions, microorganisms on fruit surfaces, and fruit cuticle structure, it is unclear whether mancozeb and kaolin act through an effect on the surface microflora, surface conditions, or through an effect on the host. Inclu-

Table 1. Effects of mancozeb and kaolin sprays on russet of 'Comice' pears grown in Medford, Ore.

Treatment ^z	Timing	Airblast sprayer plots		Handgun sprayer plots			
		1999	2000	1999	2000	2001	2002
<i>Percentage of fruit with ≥6% russet^y</i>							
Untreated	---	22.3 a ^x	38.0 a	34.2 a	42.7 a	15.8 a	34.0 a
Mancozeb	50% bloom				20.8 b	14.5 a	
	Petal fall (PF)				31.3 ab	11.4 a	32.0 ab
	PF + 2 weeks				31.1 ab	10.5 a	28.9 abc
	PF + 4 weeks				41.4 a	13.9 a	36.4 a
	All ^w	12.5 b	9.1 b	11.0 b	21.9 b	11.0 a	27.1 abc
Kaolin	Petal fall					9.3 a	27.9 abc
	PF + 2 weeks					8.9 a	15.1 c
	PF + 4 weeks					13.5 a	17.4 bc
	All	5.3 c	13.1 b	14.9 b	20.3 b	11.1 a	25.9 abc
Mancozeb + kaolin	All		16.8 b		7.5 c	8.1 a	16.2 c

^aMancozeb was applied as Manzate 200 at the rate of 3.4 kg·ha⁻¹ (3 lb/acre). Kaolin was applied as Surround at the rate of 28.0 kg·ha⁻¹ (25 lb/acre) in 1999 and at 56.0 kg·ha⁻¹ (50 lb/acre) in 2000–02.

^bThe percentage of fruit surface covered with russet was estimated visually using the Horsfall-Barrat scale. Values indicate the percentage of individual fruit that had $\geq 6\%$ of the surface covered with russet.

^cMean values followed by the same letter are not significantly different according to Fisher's protected LSD test ($P > 0.05$).

^wTreatments applied at all timings were treated at all individual timings listed for the treatment, except that mancozeb was not applied at 50% bloom in 2002.

sion of mancozeb in treatment mixtures has improved bacterial disease control (Pernezny et al., 2002); it may directly or indirectly affect bacteria associated with pear russet. Captan and other fungicides reduced incidence of prune russet scab, a condition with no known pathogen involvement that is associ-

ated with thin areas of cuticle lacking epicuticular wax (Michailides, 1991). Russet scab was reduced although there was no evidence that captan affected fruit cuticles. Captan and other fungicides reduced russet in apples (Reuveni et al., 2001), and captan treatment during bloom resulted in

greater cuticle thickness in harvested 'Bartlett' pears (D. Sugar, unpublished data), although it is not currently registered for orchard applications in pear. Some fungicides can inhibit the fruit elongation effects of GA. Fenarimol, an ergosterol biosynthesis inhibitor, reduced the length:diameter ratio of 'Bartlett' pears, although an associated increase in russet was not observed (Sugar et al., 2000).

An earlier formulation of kaolin for use on fruit had hydrophobic properties, and reduced contact between moisture and fruit surfaces (Glenn et al., 1999). However, the wettable powder formulation currently used in pear pest management

and used in this study is not considered hydrophobic. Nonetheless, this formulation has been reported to suppress fabraea leaf spot (*Fabraea maculata*), a fungal disease of pear (Puterka et al., 2000). Kaolin applications to pear blossoms have also provided moderate suppression of fire blight (*Erwinia*

Fig. 1. Daily rainfall (columns) and maximum temperature (lines) during the 30 d following full bloom for 'Comice' pear in Medford, Ore., in (A) 1999, (B) 2000, (C) 2001, and (D) 2002. Full bloom dates were 18, 7, 12, and 6 Apr., respectively. 25.4 mm = 1 inch; 1.8 (°C) + 32 = °F.

amylovora), a bacterial disease (K.B. Johnson, personal communication). Repeated application of kaolin in combination with borax and sulfur was reported to reduce russet in 'Golden Delicious' apples (Vogel, 1985).

Treatment of 'Comice' pears with mancozeb, kaolin, or the two materials in combination at PF, PF + 2 weeks, and PF + 4 weeks appears to be a useful approach to reducing russet incidence. Since the efficacy of applications at specific timings within that period is variable, and may depend on as yet unpredictable interactions between environmental conditions and fruit cuticle structure, coverage throughout the period of greatest susceptibility seems appropriate. Considering the activity of both mancozeb and kaolin against pear psylla and of mancozeb against pear scab, russet reduction adds to the multipurpose utility of these materials.

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