Effects of copper–calcium sprays on fruit cracking in sweet cherry (Prunus avium)

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Abstract

An effective and potentially commercial reduction of cracking in sweet cherries is reported from experiments conducted on five sites over three seasons. The treatment, Cu(OH)$_2$ at 200 g per 100 l plus Ca(OH)$_2$ at 3 kg per 100 l applied at 3 and 6 weeks after full bloom, resulted in a significant and consistent reduction in the proportion of cracked fruit from susceptible cultivars after moderate crack-inducing rainfall. On the three sites where rain-induced cracking occurred, calcium hydroxide was ineffective but copper hydroxide alone, at a low concentration or in combination with calcium hydroxide, significantly reduced fruit cracking. On the remaining two sites cracking of immersed fruit confirmed the field results. The increase in number of intact fruit for the copper hydroxide–calcium hydroxide mixture ranged from 27 to 36% in trials where rain-induced fruit cracking occurred.

The treatments were ineffective in controlling cracking during an extended rain period of 12 days.

Keywords: Cherry; Copper; Calcium; Cracking; Splitting; Prunus avium

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1. Introduction

In most sweet cherry producing areas of the world, rain near harvest causes fruit cracking and a reduction in marketable fruit. Crack-resistant cultivars or rain covers are the most commonly recommended methods of protection. Calcium sprays applied 2–3 weeks before harvest also have been effective in some areas. Experimental results for calcium sprays, however, have ranged from no control (Looney, 1985) to a 75% reduction in cracking (Meheriuk et al., 1991).

A positive relationship between foliar copper and fruit firmness in apricots was reported by Brown (1990), suggesting that copper nutrition may influence fruit cellular integrity and hence fruit cracking. There are reports suggesting that copper containing sprays may reduce cracking, or if applied with calcium, enhance the expected calcium effect. Christensen (1972) applied copper sulphate by itself at a low concentration (0.02%). Despite foliar damage he found that the treatment resulted in a 13% reduction in cracking. Foster (1937) found that Bordeaux spray (a mixture of copper sulphate and calcium hydroxide) applied 6 weeks before harvest reduced cracking in cherries from 80% in controls to 4% in the treated trees. Verner (1939) studied this effect further and concluded, without adequate evidence, that calcium was the active ingredient in Bordeaux mixture.

The objective of this study was to further evaluate the effects of copper sprays on cherry fruit cracking.

2. Materials and methods

The following field trials were carried out in commercial sweet cherry orchards in Tasmania, Australia. A series of small trials at several locations over three seasons ensured evaluation of results under a variety of conditions.

Trial 1 (1990/1991) was near Hobart (147°15'E, 43°12'S) and used 8-year-old 'Bing' trees that were of a large frame and free standing. The trees were grown in a clay loam soil under sod culture and with drip irrigation. Two treatments were randomly allocated to each of the 16 single tree replicates. Treatments consisted of an unsprayed control and 50 g of copper hydroxide per 100 l, which was applied to one quarter of each tree. The spray was applied to runoff using a hand-operated knapsack sprayer at 3 weeks after full bloom.

Precipitation of 23.5 mm occurred over 4 days from 7 December. Field cracking was assessed on 17 December, 20 days before commercial harvest, by counting the number of split fruit from 15 consecutive fruit on a lower limb from the sprayed and unsprayed portions of each tree.

Trial 2 (1991/1992) was at Legana (147°20'E, 41°21'S) and trial 3 (1991/1992) was in the 1990/1991 orchard above. Trees at the Legana orchard were grown on a red clay soil with sod culture and drip irrigation. At both sites 7-year-old 'Bing' trees that were of a large frame and free standing were used. Foliar mineral analysis of unsprayed trees showed that background levels of foliar cop-
per were considered 'excessive' (32 ppm) for site 1, and 'high' (26 ppm) for site 2 (Reuter and Robinson, 1986).

These two trials had identical designs with five treatments: control (no spray) and calcium hydroxide at 3 kg per 100 l mixed with copper hydroxide at 0, 50, 100 and 150 g per 100 l. In trial 2 sprays were applied with a motorised air-shear knapsack sprayer applying 1.4 l of spray per tree while in trial 3 sprays were applied with a motorised pneumatic sprayer to run-off. Copper hydroxide alone was not applied owing to severe phytotoxicity at similar application rates in a preliminary trial. The treatments were applied 3 and 6 weeks after full bloom to whole tree plots on five replicates in a randomised complete block design.

Rain occurred at the trial 3 site on the following dates during December, from 22 days before commercial harvest (15, 22 mm; 16, 82 mm; 17, 1 mm; 18, 2.8 mm; 19, 2 mm; 20, 4.2 mm; 21, 4 mm; 27, 2 mm; 28, 2.5 mm; 29, 3 mm). Treatment effects on fruit cracking were evaluated from the average number of intact fruit from four sampling dates each of 50 randomly chosen fruit per tree. Sampling occurred at 18, 14, 7 and 3 days before commercial harvest on 6 January.

Rainfall was not recorded for trial 2; however, there was no field cracking. On 4 January at commercial maturity, 30 fruit per tree of the same size and colour were selected for cracking assessment. Treatment effects were assessed by immersing detached fruit in distilled water at 18°C the day after harvest. After 20 h of immersion the fruit with apparent skin failure were counted.

Trial 4 (1991/1992) was conducted on 'Lambert' trees that were 7 years old and trained on a Tatura trellis at the Legana orchard described above. Two treatments were applied to five replicates of whole tree plots in a completely random design: an unsprayed control and copper-calcium with Cu(OH)$_2$ at 200 g per 100 l and Ca(OH)$_2$ at 3 kg per 100 l. Sprays were applied once at 3 weeks after full bloom using the equipment described for trial 2. On 4 January, 7 days before commercial maturity, 30 fruit per tree of the same size and colour were selected for cracking assessment. Fruit were assessed for resistance to cracking by immersion in water as described above except that the immersion time was reduced to 8 h for 'Lambert', which is a cracking-prone variety.

Trial 5 (1993/1994) was carried out near Margate, Tasmania (147°15'E, 43°02'S) on 5-year-old trees of cultivar 'Van' which had been trained on a Tatura trellis and grown under sod culture with drip irrigation. There were three treatments, an unsprayed control and calcium hydroxide at 3 kg per 100 l either alone or mixed with copper hydroxide at 200 g per 100 l. Sprays were applied at 3 and 6 weeks after full bloom to five tree plots with an airblast sprayer delivering 1.6 l per tree. There were four replicates in a randomised complete block design.

Fruit wetness was recorded using an air-mounted fibreglass moisture transducer fabricated in our laboratory. Continuous fruit wetness was recorded on 11 December (13 h), 14 December (11 h) and 15 December (17 h). The trials were terminated after almost continuous rain from 26 December to 10 January. Cracking was assessed on a sample of 100 fruit of the same size and colour per tree that were randomly harvested on 20 December, 21 days before commercial maturity. The number of fruit with no visible signs of skin failure was recorded. Fruit sam-
Regressions of applied copper concentration against percent intact fruit were calculated for trials 2 and 3. Student's $t$-test was used for mean separation of the unsprayed and the calcium only treatments in these two trials and for copper and copper–calcium effects for trial 4. For trial 5 treatment effects were analysed by analysis of variance.

3. Results and discussion

Copper applied as a spray either alone or in a mixture with calcium hydroxide significantly ($P < 0.05$) increased the percentage of intact fruit in each of the trials (Table 1, Fig. 1). The reduction in cracking at the three sites where rain occurred represents increases of 27–36% in the harvest of first grade fruit from the crops in these commercial orchards. Across sites, cultivars and seasons, the copper response was consistent. The response to copper concentration for both field cracking and immersed fruit was linear over the range tested, with the proportion of cracked fruit decreasing with increased copper concentrations in the sprays (Fig. 1). Calcium hydroxide applied alone had no significant ($P > 0.05$) effect on cracking in any of the trials (data not shown). This early-season application was not comparable with commercial practice involving calcium sprays closer to harvest. Following the extended period of rain in trial 5, cracking for both treated and control fruit approached 100%.

These observations, and Brown's (1990) findings of increased firmness in copper-treated apricots, raises questions about the physiological effects of foliar applied copper on developing fruit. Although copper is essential for normal plant development, it can cause severe toxicity at higher concentrations. Its exact role is not fully understood but it is known to be essential to the activities of many

<table>
<thead>
<tr>
<th>Trial</th>
<th>Spray treatment</th>
<th>Cultivar</th>
<th>Cracking test</th>
<th>% intact fruit SED</th>
<th>SED</th>
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<td>Unsprayed</td>
<td>Sprayed</td>
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<tr>
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<td>50 g per 100 l</td>
<td>'Bing'</td>
<td>Rain</td>
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<td>71</td>
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<td>Cu(OH)$_2$</td>
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<td>Cu + Ca*</td>
<td>'Lambert'</td>
<td>Immersion</td>
<td>69</td>
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<tr>
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<td>Cu + Ca*</td>
<td>'Van'</td>
<td>Rain</td>
<td>45</td>
<td>61</td>
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*This treatment comprised 200 g Cu(OH)$_2$ plus 3 kg Ca(OH)$_2$ per 100 l.

All means shown for each site were significantly different at $P = 0.05$. Standard errors of the difference between each pair of means are shown.
oxidase enzymes including those involved in photosynthesis (Fernandes and Henriques, 1991).

At sites where background foliar copper levels were determined, trees had high levels of copper, according to accepted standards (Reuter and Robinson, 1986). The standards for leaf copper levels were set on the basis of fruit yield and not quality and it is notable that the survey work of Leece (1975), used to establish the standards, included only two orchards with high levels of foliar copper and none with excessive levels. Although there are no reports of rain cracking as a symptom of copper deficiency, our results suggest a re-examination of foliar copper levels in relation to the incidence of fruit cracking.

An alternative explanation for the copper response may relate to the phytotoxicity of copper applied as a foliar spray. The copper concentrations in the spray mixes are well above threshold levels for foliar damage if applied alone, but when mixed with calcium hydroxide no visible symptoms occur. The protective effect of calcium in the copper and calcium mix of Bordeaux spray appears to be accepted without the mechanism having been studied. Applied at this early stage in fruit development, there is a possibility that the copper and calcium induces biochemical or structural changes in the fruit. While these changes do not induce visible symptoms of toxicity, they may induce a stress reaction which later increases resistance to cracking.

Overall, the reduction in the incidence of field cracking in our experiments
represents an increased financial returns to growers. Early applications of copper–calcium sprays left minimal residues on the fruit at harvest and there was no obvious effect on other fruit quality factors. This suggests that the application of a copper hydroxide and calcium hydroxide mixture may be safely adopted by commercial growers. The amount of copper applied in these treatments was no more than that applied in a normal fungicide spray programme on other fruit crops.

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References