Tree sprays and root pruning fail to control rain induced cracking of sweet cherries

W. Koffmann[A], **N.L. Wade**[B], and **H. Nicol**[C]
[A]NSW Agriculture, Agricultural Research Station, Bathurst, New South Wales 2795, Australia.
[B]NSW Agriculture, Horticultural Research and Advisory Station, Gosford, New South Wales 2250, Australia.
[C]NSW Agriculture, Agricultural Research and Veterinary Centre, Orange, New South Wales 2800, Australia.

Abstract
Several sprays and one cultural treatment were evaluated for effects on cracking of sweet cherry fruit (*Prunus avium* L.) in either the Orange or Young districts of New South Wales.

Screening of chemical treatments was carried out on trees of cvs. Early Lyons, Merton Heart and Ron's Seedling. Mobileaf®, ethyl oleate, calcium nitrate and wetting agents (Citowett® and BS 100®) proved phytotoxic to cherry leaves and fruit and failed to reduce cracking. Gibberellic and naphthalene acetic acids delayed or advanced maturity respectively but failed to reduce cracking.

Experimental work carried out on cherries cv. Supreme and Ron's Seedling included the use of several calcium compounds, (-chloride, -hydroxide), proprietary calcium formulations (Calcium Poly®, Seniphos® plus Stopit®), an antitranspirant (VaporGard®) and root pruning of Ron's Seedling trees on Mazzard and Mahaleb stock. All treatments failed to reduce fruit cracking or to increase soluble solids, fruit weight or calcium content of fruit flesh.

Supreme fruit were smaller and more susceptible to cracking than Ron's Seedling fruit. Ron's Seedling fruit grown on Mazzard stock were firmer and had higher soluble solids than when grown on Mahaleb stock.

Introduction
Fruit cracking caused by rain at harvest is a serious economic problem of the sweet cherry industry. In the main cherry growing district of New South Wales, Young, (34° 19'S, 148° 18'E), most of the crop is harvested in November and December. November has an average of six rain days (precipitation ≥0.2 mm), with average and median rainfall of 49 mm and 52 mm respectively (Anon. 1975). December averages five rain days, with mean and median rainfall of 44 mm and 41 mm respectively. Therefore the risk of rain near harvest, when the fruit is most susceptible to cracking, (Christensen 1973) is, high.

Various treatments have been used in attempts to reduce cracking. Callan (1986) found calcium hydroxide sprays useful to control cracking and proved more effective than other calcium compounds, possibly because the poorly soluble hydroxide provides a reservoir of available calcium on the fruit surface. Most (80–90%) of the calcium applied by sprays to the surface of a cherry is recovered in the skin (Christensen 1976), particularly in the epidermal region (Glenn and Poovaiah 1989), and this may be the site where calcium acts to reduce cracking.

Other studies report on the use of antitranspirants as water proofing agents (Davenport *et al.* 1972), of the desiccant, ethyl oleate, that assisted turgor loss after wetting (Harrington *et al.* 1978), of wetting agents that may reduce water uptake by improving run-off (Christensen 1976), and of growth regulators such as naphthalene acetic acid (Bullock 1952, Callan 1986), gibberellic acid (Looney 1985) and ethephon (Callan 1986), and soil or foliar applied boron (Powers and Bollen 1947, Bullock 1952, Callan 1986). Despite the antiquity of some of these methods, especially calcium hydroxide sprays, a reliable commercial treatment based upon field sprays of protective substances has not been developed. Ways of improving crack reduction are still under study, and the control achieved varies between orchards and seasons (Callan 1986, Looney 1985).

A method of increasing calcium in fruit tissues other than by spraying was shown by Schupp and Ferree (1987). They found increased levels of calcium in the flesh of apples when the tree-roots had been pruned during the dormant season.

In this paper we report on studies that were undertaken to explore the use of protective sprays and root pruning to control cracking in the New South Wales cherry crop. The major experimental work was carried out on cvs. Supreme and Ron's Seedling. Supreme is the first cultivar of the season to produce fruit of high quality and receives premium prices but is very susceptible to cracking. Ron's Seedling, a later cultivar than Supreme, produces a large attractive cherry and is also susceptible to cracking. These two Australian cultivars have not been included in other studies to investigate control of rain induced fruit cracking.

Materials and methods

Antitranspirants
Mobileaf®, a wax emulsion, from Mobil Oil Australia Ltd., PO Box 4507, Melbourne 3000, Australia. VaporGard®, a high viscosity non ionic terpenic polymer from Miller Chemicals and Fertilizer Corporation, PO Box 333, Hannover, PA 17337, USA.

Desiccants
Ethyl oleate, 777g L^{-1}, formulated as Shelltana® grape drying rack spray by Shell Chemical (Australia Pty. Ltd., GPO Box 4316, Sydney 2001, Australia.

Calcium formulations for foliar application
Calcium Poly®, a solution of calcium polyphenate chelate, 56 g kg^{-1} Ca by assay, from Pen Chem, Warehouse 1, 50 Peninsula Avenue, Rye, Victoria, 3941. Seniphos®, a solution of calcium phosphate, 230 g kg^{-1} Ca by assay, and Stopit®, a solution of calcium chloride and adjuvants, 160 g L^{-1} Ca according to the manufacturer, Phosin International, PO Box 1386, Orange 2800, Australia.

Surfactants
BS 100®, 100 g L^{-1} modified alcohol ethoxylate and Tween 20®, 1000 g L^{-1} polyoxyethylene sorbitan monolaurate, both from ICI Australia Operations Ltd., 1 Nicholson Street, Melbourne 3001, Australia. Citowett®, 1000 g L^{-1} alkylarypolyglycol ether surfactant distributed by Hoechst Australia Ltd., GPO Box 4300, Melbourne 3001, Australia and Pulse®, 100 g L^{-1}, oxyethylene methylsiloxane, an organosilicone block copolymer surfactant, distributed by Monsanto Australia Ltd., 151 Flinders Street, Melbourne 3001, Australia.

Calcium compounds
Reagent grade calcium chloride dihydrate, 273 g kg^{-1} Ca, calcium hydroxide anhydrous, 541 g kg^{-1} Ca, and calcium nitrate tetrahydrate, 170 g kg^{-1} Ca, from chemical supply houses.

Growth regulators
Grocel®, 100 g kg^{-1} of gibberellic acid and Phyomone®, 20 ml L^{-1} of naphthalene acetic acid, both from ICI Australia Operations.

Preliminary screening
Ten treatments sprayed to run-off were applied to two single limbs of mature cherry trees (cvs. Early Lyons, Merton Heart, Ron's Seedling and Supreme) in commercial orchards at Young and Orange, New South Wales, using a knapsack spray unit fitted with a pressure regulator valve. Each limb to be sprayed was isolated with a plastic curtain. Treatments

were assessed for percentage cracking, based on the fruit harvested from those limbs and for visual symptoms of phytotoxicity on leaves and fruit.

Experiments 1 and 2

The experimental work was carried out in collaborating grower orchards in the Young district on Supreme and Ron's Seedling cherry trees. The treatments used were:

i. Nil
ii. Calcium chloride, 5 g L^{-1} plus 1 mL L^{-1} of Tween 20 first applied four weeks before harvest and repeated twice at 10-day intervals
iii. Calcium hydroxide, 5 g L^{-1} plus 0.12 mL L^{-1} of Tween 20 four weeks before harvest
iv. Calcium Poly 5 mL L^{-1} applied twice, the first application four weeks before and the second two week before harvest
v. Seniphos, 10 mL L^{-1} applied three times at four, three and one week before harvest. Stopit, 10 mL L^{-1}, was added to the third application
vi. VaporGard, 10 mL L^{-1} applied four weeks before harvest.

The experimental design was three replications of a split plot with cultivars as main plots and treatments randomized within cultivars. The experimental unit was a single tree and assessments were carried out on two randomly chosen limbs per tree. Treatments were applied to run-off, with the spray unit already described.

In the first year (Experiment 1), the proportion of fruit from each treatment with cracked skins was determined at harvest. The soluble solids content of juice from a random sample of 10 fruit was measured with an Atago PR1 digital refractometer. Total calcium content of the flesh and skin was determined by atomic absorption spectroscopy on acid digests (Simpson and Blay 1966) of subsamples drawn from 0.5 kg random samples of fruit from each treatment. Half the samples were washed in acidified detergent (Leece and Dirou 1979) to remove surface residues of calcium before digestion.

The same treatments were applied in the following year (Experiment 2), but only the average fruit weight and proportion of fruit cracked at harvest were determined.

Experiment 3

The experimental work was carried out in a commercial orchard in the Young district on mature cherry trees cvs. Supreme and Ron's Seedling in a split plot design with four replications, cultivars being the main plots. A comparison of five treatments were made:

i. Nil
ii. Calcium hydroxide 5 g L^{-1} plus 0.12 mL L^{-1} of Tween 20 applied four weeks before harvest
iii. as before, but applied four and three weeks before harvest
iv. as before, but applied four, three and two weeks before harvest
v. VaporGard 10 mL L^{-1}, applied four weeks before harvest.

The chemicals were applied as described previously.

Table 1. Preliminary screening of treatments to reduce skin cracking in cherry fruit.

Chemical	Rate per L	Cultivar	Comments
Antitranspirant			
Mobileaf®	17 mL	Early Lyons	Visible residue on fruit, sticky leaves
VaporGard®	2.5–10 mL	Early Lyons Supreme Ron's Seedling	Sticky fruit, gritty taste when used 4 weeks before harvest
Desiccants			
Ethyl oleate	40 mL	Merton Heart Early Lyons Ron's Seedling	Severe burn on leaves and fruit
Wetting agents			
Citowett®	1 mL	Merton Heart Early Lyons	Ring burn at drip end of fruit
BS100®	1 mL	Ron's Seedling	Rind burn at drip end of fruit
Calcium compounds			
$Ca(NO_3)_2$	47 g	Merton Heart Early Lyons Ron's Seedling	Severe burn on leaves, sticky fruit
$Ca(OH)_2$	2.5–15 g	Merton Heart Early Lyons Ron's Seedling	Visible residues at concentrations higher than 10 g L^{-1}
Mixtures			
VaporGard® plus $Ca(OH)_2$	5–10 mL 10 g	Ron's Seedling	Visible residues on leaves and fruit
Growth regulators			
Gibberellic acid	10 mg	Merton Heart Early Lyons	No phytoxicity Delayed maturity
Naphthalene acetic acid	0.5 mL	Ron's Seedling	No phytoxicity Accelerated maturity

Experiment 4

The experimental work was carried out in a commercial orchard in the Young district on mature cherry trees cv. Ron's Seedling on Mazzard and Mahaleb rootstocks in adjacent blocks. On the Mazzard rootstock a factorial combination of three-root pruning by three calcium treatments was compared. On Mahaleb rootstock we compared the three-root pruning treatments. On both rootstocks the experiments were designed as randomized complete blocks with three replications. Root pruning was carried out with a chisel plough (one tyne) to a depth of 0.6 m approximately 0.6 m from the tree trunk.

The root pruning treatments were:

i. Nil
ii. One side
iii. Two sides along the tree row.

Calcium treatments were:

i. Nil
ii. Calcium hydroxide, 5 g L^{-1} plus 10 mL L^{-1} Pulse
iii. Calcium chloride, 5 g L^{-1} plus 10 mL L^{-1} Pulse.

After harvest the proportion of fruit with cracked skins was determined. Soluble solids and calcium (washed samples only) were measured as before and fruit firmness was measured with an electronic pressure tester system (Lake City Technical Products Inc., Kelowna, British Columbia, Canada).

Statistical methods

All experiments, with the exception of Experiment 4, were designed as split plots, with cultivars as main plots and treatments as sub plots randomized within cultivars. All experiments were analysed using ANOVA procedure in Genstat 5 (Genstat Committee 1987).

Results and discussion

Preliminary screening

The effect on fruit and leaves of the various spray treatments are shown in Table 1. Several treatments were phytotoxic to fruit, leaves, or both. These were the wetting agents BS100 and Citowett, the desiccant ethyl oleate, and calcium nitrate. Both BS100 and Citowett usually increased cracking and ethyl oleate did not prevent cracking in Early Lyons. Calcium nitrate (47 g L^{-1}), was sprayed on Merton Heart, Early Lyons and Ron's Seedling trees, had little effect on cracking and was phytotoxic to leaves and fruit. Naphthalene acetic acid and gibberellic acid affected the time of fruit maturity (Table 1). This outcome would usually be unwanted. These two compounds had little or no effect on cracking.

Calcium hydroxide was not phytotoxic, did not affect maturity, but did reduce cracking in Early Lyons, Supreme, but not Ron's Seedling fruit. Increasing the calcium hydroxide concentration above 10 g L^{-1} was of no benefit, and left a visible residue on treated fruit.

Two antitranspirants were also tested. Mobileaf (17 mL L^{-1}) left an unsightly, sticky residue on fruit and leaves, without reducing fruit cracking of Early Lyons. VaporGard approximately halved cracking in Early Lyons at concentrations that did not leave an excessive visible residue on fruit. Both VaporGard and calcium hydroxide, applied singly or in combination, reduced cracking by similar amounts. VaporGard had no effect, however, on cracking of Ron's Seedling fruit.

These preliminary findings from the treatment of single limbs suggested that calcium hydroxide, other calcium compounds and formulations, and VaporGard should be included in further experiments.

Experiments 1 and 2

These experiments examined the effects of calcium hydroxide, other calcium formulations, and VaporGard on cracking. The amount of cracking that occurred in the orchard in Experiment 1 (Table 2) was very low for both cultivars, because of the absence of rainfall at harvest time. The differences between treatments were not significant, except that Supreme fruit treated with VaporGard had significantly less total calcium than all treatments other than calcium hydroxide (Table 2). While VaporGard might have reduced the uptake of calcium in the transpiration stream of Supreme cherries, the lower calcium in unwashed fruit treated with calcium hydroxide may have arisen from sampling error. Seniphos caused slight phytotoxicity (small necrotic lesions on the fruit skin). Abundant residues of Calcium Poly were visible on the fruit and leaves after application, but this residue had disappeared by harvest time. Fruit treated with calcium chloride, calcium hydroxide and VaporGard was firm, attractive and had green stems. The incidence of cracking in the orchard was higher in Experiment 2 (Tables 2), but no significant ($P<0.05$) effects of treatment on cracking incidence or fruit weight were observed. Trees treated with calcium hydroxide had conspicuous white residues on fruit and leaves. VaporGard treated fruit was slightly sticky. In both cases the residues had disappeared at harvest time.

Experiment 3

When different numbers of calcium hydroxide sprays and VaporGard treatments were compared, no significant ($P<0.05$) differences were found between treatments within cultivars, but there were significant differences between cultivars (Table 3). The fruit of Supreme was smaller ($P<0.001$) and more susceptible to splitting ($P<0.01$) than Ron's Seedling fruit.

None of the calcium treatments applied to the Supreme or Ron's Seedling fruit used in Experiments 1, 2 and 3 were able to reduce fruit cracking, increase the calcium content of the fruit flesh, alter fruit soluble

Table 2. Effect of sprays containing calcium or an antitranspirant on fruit cracking, weight, calcium and soluble solids content of fruit. Experiments 1 and 2, cvs. Supreme and Ron's Seedling

Treatment	Experiment 1				Experiment 2	
	Fruit cracked (%)	Calcium (mg 100 g^{-1} flesh)		Soluble solids (%)	Fruit cracked (%)	Fruit weight (g)
		Washed	Unwashed			
cv. Supreme						
Nil	9.1	81.3	66.7	14.8	53.9	7.8
$CaCl_2$	2.3	57.3	70.7	14.8	46.2	7.3
Ca Poly	10.9	60.7	58.7	14.8	52.4	6.9
$Ca(OH)_2$	8.7	63.3	54.7	15.6	46.5	7.2
Seniphos	7.5	71.3	64.0	15.4	52.7	7.4
VaporGard	5.1	69.3	41.3	14.9	56.8	7.6
LSD ($P<0.05$)	NS	NS	16.4	NS	NS	NS
cv. Ron's Seedling						
Nil	0.9	62.0	50.7	17.9	66.6	8.2
$CaCl_2$	0.0	61.3	78.0	16.9	64.6	7.9
Ca Poly	0.6	69.3	48.0	17.4	60.0	8.1
$Ca(OH)_2$	0.3	68.7	43.3	17.9	69.3	8.3
Seniphos	0.1	44.7	44.0	18.5	71.6	8.2
VaporGard	0.5	50.7	44.0	17.7	64.6	8.2
LSD ($P<0.05$)	NS	NS	NS	NS	NS	NS

Table 3. Effect of 1–3 sprays of calcium hydroxide and one spray of an antitranspirant on fruit cracking in the orchard, and on the average weight of cracked, sound and all fruit. Experiment 3, cv. Supreme and Ron's Seedling.

Treatment	Fruit cracked (%)		Fruit weight (g)		Cracked fruit weight (g)		Sound fruit weight (g)	
	Supreme	Ron's Seedling	Supreme	Ron's Seedling	Supreme	Ron's Seedling	Supreme	Ron's Seedling
Nil	52.5	22.5	5.9	8.0	5.6	7.6	6.2	8.1
$Ca(OH)_2 \times 1$	58.0	27.3	6.0	8.2	5.9	7.7	6.3	8.2
$Ca(OH)_2 \times 2$	61.0	18.8	6.2	7.8	5.9	7.5	6.6	7.8
$Ca(OH)_2 \times 3$	60.7	16.2	6.0	7.6	5.7	7.2	6.4	7.7
VaporGard®	67.4	29.3	6.1	8.5	5.9	7.7	6.5	8.9
Mean	59.9	22.8	6.0	8.0	5.8	7.5	6.4	8.2
LSD ($P<0.05$)[A]	12.3		0.38		0.35		0.33	

[A] Between cultivar means.

solids content or alter the fruit weight. Several workers have reduced cherry fruit cracking with calcium sprays, although some negative results have occasionally been reported. Looney (1985) described the failure of calcium chloride sprays to reduce cracking in the cultivars Lambert and Van. In contrast, Verner (1938) found that calcium hydroxide, alone or in Bordeaux mixture, reduced cherry fruit cracking in both laboratory and field studies. Swales (1982) reduced cracking in Stella and 2D-28-26 cherry fruit with calcium chloride sprays. The concentration of fruit calcium was increased by calcium sprays in 2D-28-26 but not Stella. In 2D-28-26, fruit firmness increased and soluble solids decreased as a result of calcium treatment, while in Stella both soluble solids and titratable acidity were reduced. Tukey (1984) recommended the use of calcium chloride sprays to prevent cracking of cherries. Callan (1986) showed a reduced susceptibility to cracking and increased soluble solids content in Lambert cherries sprayed with either calcium hydroxide or calcium chloride.

We also found that Supreme fruit are smaller and more susceptible to splitting than Ron's Seedling fruit. This agrees with the opinion held by local cherry growers, but runs contrary to the general statements of Westwood and Bjornstad (1970) and Sekse (1987), who claimed that large-fruited cultivars are more susceptible to splitting than smaller-fruited ones. Using data collected from 41 cherry cultivars, Christensen (1975) concluded that cracking susceptibility is highly correlated with fruit size within, but not between, cultivars. Although VaporGard is an effective antitranspirant agent that also increased fruit weight and soluble solids when used on other fruit tree crops (Albrigo 1977), it had no effect on fruit cracking, weight or soluble solids when applied to Supreme and Ron's Seedling cherries.

Experiment 4

The possibility that root pruning might affect tree and perhaps fruit calcium contents was studied with Ron's Seedling grafted onto rootstocks with different rooting systems. Mazzard forms abundant surface roots while Mahaleb has a deeper rooting habit (Perry 1987). No significant effects of the two levels of root pruning were found on the cracking, calcium content, firmness or soluble solids content of the fruit, so the means of all treatments across root pruning are presented in Table 4.

The failure of root pruning to affect fruit calcium content is consistent with other evidence that calcium uptake need not necessarily depend on young, growing roots. Experiments on root pruned apple seedlings showed greater uptake (on a root volume increase basis) of labelled calcium into the shoot of unpruned control seedlings (Faust 1980), suggesting that root growth itself may not be essential for calcium uptake.

The uptake (on a root surface area or volume basis) of labelled calcium by woody roots of cherry trees was slightly higher than that by white roots, while in apple trees both types of root had similar uptakes (Atkinson and Wilson 1980).

Calcium chloride sprays significantly increased the amount of cracking in the orchard (Table 4). Circular cracks occurred at the stem end, the drip end, or at both ends of the fruit, and the skin was often severely burnt and maturity delayed. The leaves of trees sprayed with calcium chloride were unusually small, and had a cupped habit and necrotic margins. New leaf growth did not have these symptoms. Christensen (1976) observed that surfactants applied before rainfall increased fruit cracking by increasing water uptake through the fruit skin. The severe phytotoxic effects of the calcium chloride spray may have been caused by excessive chloride uptake mediated by the organosilicone wetter Pulse. Leece and Dirou (1979) found that urea sprays containing this surfactant completely wetted both surfaces of prune-tree leaves, and penetrated stomates on the lower surface of the leaf. Evidence that the phytotoxicity arose from the combination of an efficient wetter and a readily-soluble toxic salt is provided by the effect on trees of the spray containing poorly-soluble calcium hydroxide and Pulse. This spray did not increase fruit cracking (Table 4), affect leaf size or cause marginal necrosis of leaves.

Table 4. Effect of root pruning, rootstock and calcium sprays on fruit cracking in the orchard; on calcium content, soluble solids content and firmness of fruit, and the average weight of cracked and sound fruit. Experiment 4, cv. Ron's Seedling on Mahaleb and Mazzard rootstocks.

	Ca (mg 100 g^{-1} flesh)	Firmness (kg cm^{-2})	Soluble solids (%)	Fruit Weight (g) Cracked	Fruit Weight (g) Sound	Fruit cracked (%)
Rootstocks						
Mahaleb	71.7	4.69	17.3	7.5	8.3	20.1
Mazzard	63.6	5.61	19.6	7.8	7.8	A
Treatments						
Nil	57.9	5.53	19.2	8.2	8.9	27.5
$CaCl_2$	63.9	5.56	20.1	7.8	8.1	60.5
$Ca(OH)_2$	68.9	5.75	19.5	7.3	7.9	30.8
LSD ($P<0.05$)[B]	NS	NS	NS	NS	NS	9.3

[A] Not given because of significant treatment effect.
[B] Between treatments.

Conclusion

Lack of rain before harvest, when the fruit is susceptible to cracking, hampered the evaluation of treatment efficacy. We did not attempt to induce cracking by spraying the trees with water, since dissolved salts, particularly divalent cations, could influence cracking incidence (Ackley and Krueger 1980).

The treatments were tested, therefore, under conditions of either very low or high cracking occurrence on two cultivars very susceptible to fruit cracking. This limits the inferences that can be drawn, but within these limitations calcium chloride, calcium hydroxide, Seniphos plus Stopit, CalciumPoly and VaporGard were unable to reduce cracking or affect soluble solids or fruit weight. Neither calcium sprays nor root pruning increased the calcium content of the fruit.

Our results illustrate the difficulties of using surfactants in cracking control. Surfactants added to calcium sprays in an attempt to increase the uptake and distribution of calcium increased cracking. Since the effects of surfactants on water uptake cannot be separated from the effects on uptake of the solute, this problem is unlikely to be overcome. The results also suggest that rain cracking of cherry fruit might be exacerbated by the surfactants in pesticide or foliar nutrient sprays applied close to harvest.

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