COPPER AND SLAKED LIME FOR THE CONTROL OF BLACK SPOT AND POWDERY MILDEW IN APPLES

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ABSTRACT

Cupric hydroxide and slaked lime (calcium hydroxide) were tested for the control of black spot (*Venturia inaequalis*) and powdery mildew (*Podosphaera leucotricha*) in apples in Canterbury, Central Otago and Hawke's Bay. As the application rate of cupric hydroxide increased from 12.5 to 125 g Cu/100 litres, black spot incidence on fruit and powdery mildew on leaves decreased logarithmically, and fruit russet showed a reciprocal increase. Control of both diseases was poor at low rates of cupric hydroxide. As the rate of slaked lime increased from 0.4 to 2.2 kg/100 litres, black spot on fruit decreased, there was no increase in fruit russet, and fruit colour did not appear to be adversely affected. Powdery mildew was not controlled by slaked lime. Mixing slaked lime with cupric hydroxide reduced black spot and powdery mildew control but caused less fruit russet than did the same rate of cupric hydroxide mixed with sulphur. Slaked lime shows promise for black spot control during and after flowering when fruit are sensitive to russeting.
Keywords: apple disease control, *Venturia inaequalis*, powdery mildew, cupric hydroxide, calcium hydroxide

INTRODUCTION

Disease control is a major problem for the production of apples without synthetic fungicides. This is partly because of the predominance in New Zealand of apple cultivars which are highly susceptible to black spot and powdery mildew, and partly because of the low fungicidal efficacy of many of the alternatives to synthetic fungicides. Some alternative fungicides have been investigated in field trials in New Zealand (Beresford *et al.* 1991). Cupric hydroxide controlled black spot and powdery mildew, but caused severe russeting of fruit. Sulphur had low fungicidal efficacy compared to cupric hydroxide, but caused very little fruit russet. Field trials reported in this paper investigated the effects on black spot, powdery mildew and fruit russet caused by different application rates of cupric hydroxide to determine if there was an optimum rate which gave good disease control without inducing russet.

Slaked lime, or hydrated lime, (calcium hydroxide) has been reported in Tasmania to be effective for black spot control (Wong *et al.* 1993). The present paper also reports the effects of different rates of slaked lime on black spot and powdery mildew control and on fruit russet. As spraying slaked lime causes a white deposit on fruit, there was a particular interest in its effect on fruit colour.

MATERIALS AND METHODS

Five trials were conducted, three at Winchmore Research Station, mid-Canterbury, one at Clyde Research Orchard, Central Otago and one at Havelock North Research Orchard, Hawke's Bay (Table 1). Experimental treatments were applied in replicated blocks with buffer rows between plots. Application of chemicals was by dilute

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spraying to run-off using hydraulic nozzles. Sprays were applied between September and February, generally at 7-10 day intervals during the primary infection season of *V. inaequalis* (September-November) (Brook 1976) and at 14-21 day intervals from December to harvest.

TABLE 1: Sites and years for disease control trials in apples, showing cultivars, treatments, numbers of sprays and times for disease and fruit quality assessments.

	Winchmore 1991-92	Winchmore 1993-94	Winchmore 1994-95	Clyde 1993-94	Havelock Nth 1993-94
Apple cultivars	Royal Gala	Royal Gala	Royal Gala	Fuji, Royal Gala, Braeburn	Fuji Royal Gala Braeburn
Treatments	5 rates of C[1]	4 rates of SL_2	4 rates of SL	1) SL 2) SL+C[3] 3) C+S[4]	1) SL 2) SL+C 3) C+S
No. spray applications	13	9	9	12	12
Black spot on fruit	Harvest (11 March)	Harvest (7 March)	Harvest (3 March)	At harvest for each cv.	At harvest for each cv.
Fruit russet	Harvest (11 March)	Harvest (7 March)	*Not assessed*	At harvest for each cv.	At harvest for each cv.
Fruit colour	*Not assessed*	Harvest (7 March)	Harvest (3 March)	At harvest for each cv.	*Not assessed*
Powdery mild. on leaves	9 Dec, 13 Feb	20 Jan	21 Dec	26 Nov,	15 Jan 11 Jan

[1]C= cupric hydroxide; [2]SL= slaked lime (calcium hydroxide);
[3]SL+C= slaked lime plus cupric hydroxide; [4]C+S= cupric hydroxide plus sulphur;
(see text for chemical application rates)

At Winchmore in 1991-92 the five application rates of cupric hydroxide (Shell Kocide 101, 50% Cu) were: 12.5, 25, 50, 75 and 125 g Cu/100 litres of water (four replicates). At Winchmore in 1993-4 and 1994-95, the four application rates of slaked lime (supplied by Austin Chalk Ltd, Kaiapoi, Canterbury) were: 0.4, 0.8, 1.6 and 2.2 kg/100 litres of water (four replicates). The highest rate of slaked lime was initially planned to be 3.2 kg/100 litres, however the sprayer pump could not handle a suspension of this concentration, so the rate was reduced to 2.2 kg/100 litres.

At Clyde and Havelock North in 1993-94 the rates of chemicals used in the three treatments were:

1) Slaked lime (1.6 kg/100 litres),
2) Slaked lime and cupric hydroxide mixed (1.6 kg $Ca(OH)_2$, 16 g Cu/100 litres),
3) Cupric hydroxide and sulphur mixed (16 g Cu and 144 g S/100 litres).

The cupric hydroxide formulation was Shell Kocide 101 (50% Cu) and the sulphur was BASF Kumulus DF (80% sulphur).

At Clyde, no cupric hydroxide was applied to Treatments 2 and 3 (only slaked lime or sulphur) for three sprays from 15 October to 2 November, during the period when fruit were thought to be most susceptible to russeting. Each cultivar (Table 1) was in a separate block and each treatment appeared only once in each cultivar block.

Therefore, statistical analysis required the three cultivar blocks to be treated as replicates. At Havelock North in 1993-94, there were two replicates of each treatment in each cultivar block (Table 1).

Disease and fruit quality measurements

Black spot incidence was assessed in all trials on 100-300 fruit per plot at harvest. Powdery mildew was assessed as percentage of leaves per shoot affected on ten terminal shoots per tree and 3-5 trees per plot. Fruit russet was measured as the percentage of fruit not suitable for export due to russeting, and included all categories of non-exportable russet. Fruit colour was assessed according to New Zealand Apple and Pear Marketing Board colour charts and export grade standards.

RESULTS

Winchmore

Black spot incidence on fruit decreased logarithmically with increasing application rate of cupric hydroxide and there was a reciprocal increase in fruit russet (Fig.1A). Powdery mildew on leaves also decreased logarithmically with increasing cupric hydroxide rate, for both the 9 December and 13 February assessments (Fig.1B). However, there was a substantial increase in powdery mildew incidence between the two assessment dates, particularly at the lower application rates, emphasizing the loss of disease control as the rate decreased.

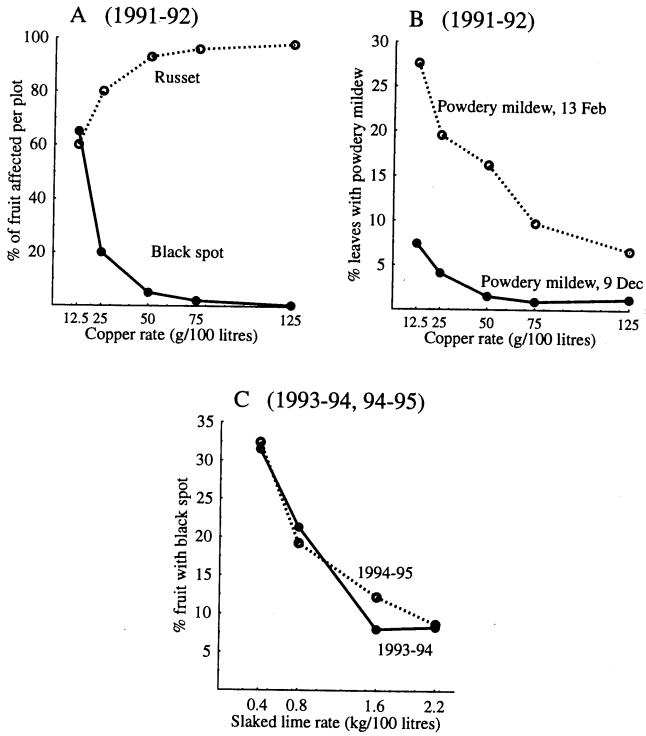

FIGURE 1: Responses of disease and fruit russet to different application rates of cupric hydroxide in 1991-92 (A,B) and slaked lime in 1993-94 (C) at Winchmore.

Black spot incidence on fruit decreased markedly with increasing slaked lime application rate, in both 1993-94 and 1994-95 (Fig.1C). It appears from the response that the optimum rate of slaked lime had not been reached. In 1993-94, slaked lime rate had no effect on fruit russet (P= 0.730). Mean russet incidences for the 0.4, 0.8, 1.6 and 2.2 kg/100 litres rates respectively were 3.5, 3.8, 3.3 and 3.4%. Russet was not measured in 1994-95, but observations suggested that even the highest rate of slaked lime did not cause russeting.

For fruit colour in 1993-94, only the 0.4 and 2.2 kg/100 litres treatments were assessed, and there was no significant difference between these (P=0.633, mean percentage red colour= 52% and 54% respectively). Again in 1994-95, there was no significant fruit colour effect among the treatments (P= 0.425, mean percentage red= 71, 74, 69 and 72% for the rates 0.4, 0.8, 1.6 and 2.2 kg/100 litres respectively).

Powdery mildew in 1993-94 did not vary significantly among the slaked lime application rates (P= 0.665). The mean percentages of leaves per shoot with powdery mildew for the 0.4, 0.8, 1.6 and 2.2 kg slaked lime/100 litres treatments respectively were 22.3, 23.3, 22.8 and 22.4%. In 1994-95 powdery mildew was only assessed for the highest and lowest application rates, and again, there were no significant differences with means of 45.3% and 44.3% of leaves per shoot for 0.4 and 2.2 kg/100 litres treatments respectively.

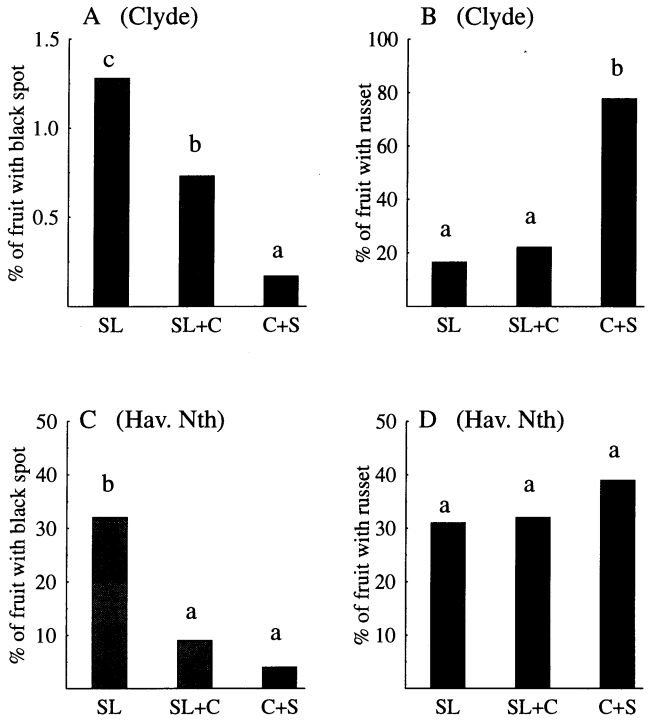

FIGURE 2: Effects of slaked lime (SL), slaked lime plus cupric hydroxide (SL+C) and cupric hydroxide plus sulphur (C+S) on black spot and russet on fruit at Clyde (A,B) and Havelock North (C,D) in 1993-94. Bars with the same letters are not significantly different (LSD P<0.05).

Clyde

Cupric hydroxide plus sulphur gave the best control of black spot on fruit, but caused the most russet (Fig. 2A,B). Powdery mildew at both assessment dates was significantly less in the cupric hydroxide plus sulphur treatment than in the other two treatments (Fig. 3A). The three cultivars differed in amounts of disease and russet, but treatment trends were the same in each case.

There were differences in fruit colour among the treatments for Fuji and Royal Gala, but not for Braeburn. The results were not able to be analyzed statistically because there was no replication. For Fuji, the slaked lime treatment had 15% of fruit with export-grade colour, which was more than the slaked lime plus copper treatment (5%) and than the copper plus sulphur treatment (2%). For Royal Gala, the trend was reversed with less export-grade colour in the slaked lime treatment (8%) than in the slaked lime plus copper (18%) or the copper plus sulphur treatments (30%). It was a poor season for fruit colour and the importance of these results cannot be interpreted.

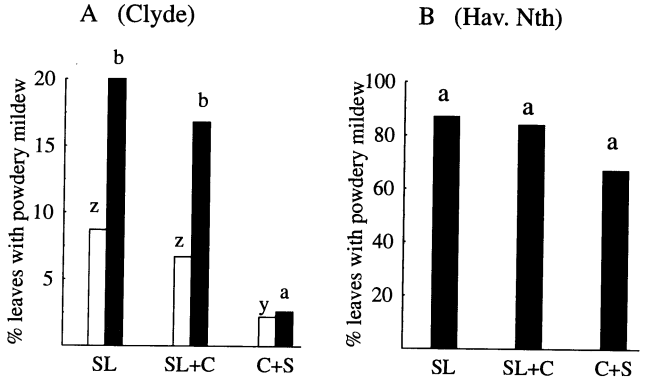

FIGURE 3: Effects of slaked lime (SL), slaked lime plus cupric hydroxide (SL+C) and cupric hydroxide plus sulphur (C+S) on powdery mildew on leaves at Clyde (A) and Havelock North (B) in 1993-94. For Clyde, unshaded bars are the 26 November assessment, shaded bars are for 11 January. Bars with the same letters are not significantly different (LSD P<0.05).

Havelock North

The trends in the means for black spot and russet incidence were the same as for the Clyde trial, but there were fewer significant differences (Fig. 2C,D). Black spot control was better in the two treatments with cupric hydroxide than in the treatment with slaked lime alone. The russet effect was not significant. Fuji tended to have more russet than either Royal Gala or Braeburn.

For powdery mildew (Fig. 3B) the treatment effect was not significant, but the values for the means showed the same trend as at Clyde (Fig. 3A). Each of the three cultivars also showed the same trend for their means, with the slaked lime treatment being greater than slaked lime plus copper, which was greater than copper plus sulphur.

DISCUSSION

Cupric hydroxide was the most effective fungicide of those tested against both black spot and powdery mildew. However, the results of this study reveal that even at low concentrations, cupric hydroxide induces severe fruit russeting. Application rates which were low enough to avoid russet (below about 50 g Cu/100 litres), gave poor

control of both black spot and powdery mildew. In the Clyde trial, cupric hydroxide was not applied between 15 October and 8 November in an attempt to avoid the period when fruit are most susceptible to russeting. However, russeting still occurred, and it is not possible to determine if this strategy helped to reduce it.

Slaked lime gave control of black spot, and the higher the application rate, the better the control achieved. The upper rate limit was determined by the ability of the sprayer to pump the slaked lime suspension as there was a tendency for it to settle in the spray tank. Slaked lime did not cause fruit russet and consequently it can be recommended as a valuable apple black spot fungicide during the russet-sensitive period during and after flowering. Slaked lime gave no control of powdery mildew, and alternatives to copper are still required for powdery mildew control during and immediately after flowering.

The fruit colour results were difficult to interpret, but it appeared that slaked lime did not have a major adverse effect on fruit colour, despite the presence of a white chalky deposit on slaked lime-sprayed apples. This deposit was partially washed off by heavy rain, but was present at harvest. It could be wiped off easily by hand and might be washed off in the water dump used to move fruit into the packhouse. Any residual deposit is likely to be an important consideration when grading fruit for market.

Adding cupric hydroxide to slaked lime increased fungicidal efficacy against black spot over that of slaked lime alone, while not drastically increasing russet. However, the fungicidal efficacy was less than for the same rate of cupric hydroxide mixed with sulphur. For powdery mildew, adding cupric hydroxide to slaked lime appeared to give disease control more similar to slaked lime alone than to cupric hydroxide plus sulphur.

The mixing of sulphur with cupric hydroxide in the Clyde and Havelock North trials confounded the effect of cupric hydroxide with that of the sulphur. Earlier results (Beresford *et al.* 1991; Wearing and Beresford 1991) suggested that sulphur caused virtually no russeting in Braeburn, Cox's Orange, Fuji and Royal Gala, and it appears that the russeting in the cupric hydroxide plus sulphur treatment was due to the copper, not the sulphur.

The cost of the slaked lime used in the trials was $0.22/kg, and at the most effective rate tested of 2.2 kg/100 litres would cost $0.484 /100 litres applied. At an application rate of 2,000 litres/ha the cost would be $9.68/ha. The cost of the cupric hydroxide formulation used was $8.70/kg. If the optimum application rate to minimize russet and maximize disease control of 32 g of formulated product/100 litres (16 g Cu/100 litres) was used, the cost would be $0.278/100 litres applied, or $5.56/ha at 2000 litres/ha. Slaked lime is therefore relatively expensive to apply. Slaked lime would appear to be environmentally safe, as it degrades to calcium carbonate in the air.

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