

Growth and fruit quality of ‘Braeburn’ apple (*Malus domestica*) trees as influenced by fungicide programmes suitable for organic production

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Abstract Organic pipfruit growers in New Zealand have reported decreased yield and fruit size and poorer quality of foliage of ‘Braeburn’ apple (*Malus domestica*) with fungicidal programmes based on sulfur. This project aimed to quantify the effect of several fungicide programmes compatible with organic production on the tree growth, yield, and fruit quality of ‘Braeburn’. The spray programmes included Kocide DF, lime sulfur, Kumulus, slaked lime, Kocide DF + slaked lime, and Kocide DF + Kumulus compared to an Integrated Fruit Production (IFP) compatible programme based on dodine, polyram, and captan. The spray programmes were applied from pink tip until harvest, with a total 19 spray applications made to 5-year-old ‘Braeburn’/MM.106 trees. Spray treatments did not influence shoot growth, leaf area development, or increment in trunk cross-sectional area. Leaf photosynthesis was significantly reduced by all treatments which included sulfur (lime sulfur or Kumulus) with reductions of up to almost 50% in January compared to the non-sulfur treatments. At

harvest, the pooled data for the treatments containing sulfur showed a significant yield per tree reduction of 12% compared to the non-sulfur treatments, largely as a result of decreased fruit numbers per tree. Treatments containing Kocide DF resulted in a higher proportion of fruit with russet. The addition of Kumulus or slaked lime to Kocide DF resulted in some amelioration of russet. All treatments resulted in less blush development on the fruit compared to the IFP control, except for slaked lime. Slaked lime treatments, however, tended to reduce sunburn. The Kocide DF + Kumulus treatment produced the highest reject rate for low colour. Black spot (*Venturia inaequalis*) incidence on fruit at harvest was significantly higher on trees treated with either Kocide DF or slaked lime compared to the control treatment. When Kocide DF and slaked lime were used together, however, control of black spot was not significantly different from the control. In contrast, dry eye rot (*Botrytis cinerea*) incidence was significantly higher on the trees treated with lime sulfur.

Keywords organic production; disease control; leaf photosynthesis

INTRODUCTION

Over the past decade there has been an increasing interest in, and adoption of, organic production of pipfruit in New Zealand. One of the main components of successful organic pipfruit production in a humid environment is the disease control programme used to combat fungal diseases such as black spot (*Venturia inaequalis*), powdery mildew (*Podosphaera leucotricha*), and dry eye rot (*Botrytis cinerea*). There are several organically certified chemical compounds used in disease control programmes, mainly based on either sulfur or copper.

Unfortunately there have been some undesirable responses of trees to organic production systems. Survey work in Hawke’s Bay (Walker & McArtney 2001) suggested that for similar crop loadings, the

mean fruit weight from organic orchards of 'Braeburn' apple (*Malus domestica* Borkh.) was 50 g below that of conventional orchards. There have also been reports of poor leaf health, particularly on 'Braeburn'. For the further development of organic production systems it is imperative that we quantify the effects of fungicides compatible with this system of production on the growth and fruit quality of apple orchards, both when applied alone or as mixtures with other products.

This work aimed to quantify the effects of various spray programmes, including copper and sulfur, on the leaf area development, leaf photosynthesis, disease control, and fruit quality of 'Braeburn'. To our knowledge this has not been done to date but is an essential prerequisite to devising suitable organic fungicide programmes to minimise negative effects on the tree performance.

MATERIALS AND METHODS

Five-year-old 'Braeburn' trees on MM.106 rootstock planted at the Horticulture and Food Research Institute of New Zealand Ltd Nelson Research Orchard at 5 × 3 m spacing were sprayed using six different combinations of organic compatible fungicides or standard Integrated Fruit Production (IFP) (ENZA 1996) disease control materials throughout the 2000/01 growing season. A total of 19 spray applications were made, weekly from mid September (pink tip stage) until late December, then at 3–4-week intervals, depending on rainfall, until harvest. Applications were made with a hand gun connected to a motorised, non air assisted, experimental sprayer at high volume almost to run-off, using c. 3 litres of spray per tree. The period after late December in Nelson was very dry with little rainfall but during the period before late December there were three severe and six moderate black spot infection periods (Beresford & Spink 1992).

The seven spray programmes were: (1) Kocide DF, cupric hydroxide (400 g copper/kg) applied at 32 g/100 litres; (2) lime sulfur, 15% sulfur as polysulphides of calcium, applied at 1 litre/100 litres; (3) Kumulus, wettable sulfur (800 g sulfur/kg), applied at 180 g/100 litres; (4) slaked lime, calcium hydroxide, applied at 1.5 kg/100 litres; (5) Kocide DF + slaked lime, tank mixed at rates above; (6) Kocide DF + Kumulus, tank mixed at rates above; and (7) IFP control trees were sprayed with dodine (first and second applications only, 18 ml/100 litres), then polyram until late December (150 g/100 litres), and finally with captan (75 g/100 litres) until harvest.

An unsprayed control was not included in the trial because of the high anticipated disease level of black spot, with an associated release of inoculum onto neighbouring trees. The trial was arranged as a randomised block with single tree plots and four blocks. As the trees were clearly physically separated, there were no guard trees between treatment trees. Care was taken in directing the spray plume towards the target tree and away from neighbouring trees and to apply the materials, if possible, in the early morning when there was little wind. All trees received the normal IFP compatible insecticidal and nutritional programme. All trees were hand thinned to a normal commercial standard in early January.

Vegetative growth

Leaf area per spur was measured on eight randomly selected spurs per tree after full expansion of the primary leaves, but before leaves had begun to fall. Bourse shoot number, leaf number, and leaf area were also measured.

Leaf area development was assessed by counting the number of leaves on five randomly selected extension shoots per tree at 14-day intervals during shoot growth. After shoot termination, these shoots were removed and the leaf area per shoot measured with a leaf area meter (Type Mk 2, Delta-T Devices, Burwell, Cambridge, United Kingdom).

Total shoot growth per tree was measured after leaf fall. Trunk circumference (20 cm above the graft union) was measured at 14-day intervals during the growing season.

Fruit set

Fruit set was determined by counting flower clusters on two marked major limbs per tree at full bloom, then re-counting the number of fruit on the same limbs at 1 month (initial set) and 3 months (final set) after full bloom. Spur and terminal clusters were counted separately from axillary clusters.

Leaf photosynthesis

Leaf gas exchange was measured using an ADC LCA-3 portable leaf gas exchange system (ADC, Hoddesdon, United Kingdom) under saturating light conditions ($>1000 \mu\text{mol m}^{-2} \text{s}^{-1}$) using sunlight as a light source. Entire leaves fully exposed to the light were selected for measurement and, within any one block, selected on the same side of the tree. Gas exchange was measured on 10, 18, 24 October, 3, 24 November, 5, 12, 26 January, 8 February, and 15 March. Where possible several leaf types were

measured, depending on the stage of canopy development, to include a range of leaf ages. Measurements were, however, restricted to two fully expanded mature leaves of each leaf type per tree. Primary spur leaves, subtending the flowers, were measured only over the first five dates because beyond that time these leaves became very shaded by the bourse leaves. Leaf gas exchange was measured on vegetative spur leaves from 24 November to 15 March, on basal extension shoot leaves from 24 October to 15 March, on mid-position extension shoot leaves from 5 January to 15 March and terminal extension shoot leaves on 15 March. Later formed leaves obviously received less chemicals and therefore might have responded differently to leaves that had emerged earlier.

Disease control

The incidence of black spot and powdery mildew on leaves and attached fruit was assessed on 7 December 2000 following methods developed by Beresford & Manktelow (1995). Ten terminal extension shoots and 10 fruit clusters on each tree were selected at random and examined for disease incidence. The number of expanded leaves on two of the 10 shoots per tree were counted and averaged to provide an estimate of the number of leaves per shoot. This figure was used to calculate the number of diseased leaves as a percentage of the total number of leaves per shoot. The number of fruit in each cluster and the number of fruit with lesions were counted to calculate the percentage of fruit with black spot. At harvest 100 picked fruit per treatment tree were examined for the incidence of black spot and dry eye rot.

Yield and fruit quality

Fruit were select harvested on two occasions (2 and 19 April). Yield and number of fruit per tree were recorded for each harvest. At harvest, fruit were assessed for russet, sunburn, and other defects according to ENZA grade standards (ENZA specifications manual 2001). The proportion of low colour fruit was also assessed on the final harvest. A random sample of 10 fruit per tree per harvest were assessed in detail for fruit quality, including percentage blush, background colour, fruit firmness, soluble solids, and starch-pattern index.

Statistical analysis

All data were analysed using analysis of variance and, where appropriate, covariance, using Genstat. Where plots of residuals versus fitted values showed that the errors were not consistent across treatments, data were transformed prior to analysis of variance.

RESULTS

Vegetative growth

There was no significant effect of treatment on either spur leaf area, bourse shoot development, extension shoot leaf area, increment in trunk cross-sectional area (TCA), or total shoot growth (data not shown).

Fruit set

There were no statistically significant differences among the individual treatments in terms of initial or final fruit set (Table 1). Further analysis dividing

Table 1 Effect of fungicide programmes on fruit set of 'Braeburn' apple (*Malus domestica*). (Dates: initial set, 20 October; and final set, 21 December). (IFP, integrated fruit production.)

	Initial set (%)		Final set (%)	
	Spur and terminal	Axillary	Spur and terminal	Axillary
Kocide	64.0	78.7	48.5	52.4
Lime sulfur	53.8	51.5	49.0	31.5
Kumulus	63.8	67.5	43.7	49.0
Slaked lime	61.7	54.9	59.1	37.7
Kocide + Kumulus	57.6	58.2	44.5	38.9
Kocide + slaked lime	63.5	71.1	51.2	48.2
IFP	61.6	65.8	55.5	49.3
5% LSD	14.20	23.76	14.08	18.51
<i>P</i>	0.702	0.252	0.270	0.213

the treatments into those containing sulfur (lime sulfur, Kumulus, and Kocide + Kumulus) and those not containing sulfur, revealed a statistically significant effect of sulfur reducing the final set on spurs from 54 to 46% ($P = 0.035$).

Leaf gas exchange

There was a small significant reduction in photosynthetic rate on all sulfur-based treated leaves on 18 October but this effect became more pronounced later in the season (Table 2), with a maximum difference of 50% between sulfur-based and non sulfur-based treatments in January. This effect of sulfur was largely irrespective of the form of sulfur or the material it was applied with (Table 3). There was a general trend of sulfur to induce a smaller reduction in leaf photosynthesis on younger leaves, although this effect was not always statistically significant; an example is given in Table 4. The observed reduction in leaf assimilation rate was always accompanied by a smaller stomatal conductance (data not shown).

Yield and fruit quality

Overall yield per tree, adjusted by the covariate of spring TCA, was significantly reduced by the lime sulfur and Kocide + Kumulus treatments compared to the IFP treatment, largely as a result of effects on fruit number per tree rather than on mean fruit weight (Table 5). The control trees carried the largest mean yields per tree. When the statistical analyses for total

number of fruit and yield per tree were re-run with the treatments separated into sulfur-based and non sulfur-based treatments, the sulfur-based treatments reduced mean yield per tree by 12% ($P = 0.020$) and fruit number per tree by 12% ($P = 0.040$). This reduction in fruit numbers per tree was caused by the reduction in fruit set observed earlier before hand thinning (Table 1).

The Kocide + Kumulus treatment tended to delay maturity of the fruit, with 28% of the crop removed in the first pick compared to 44% with the control trees (Table 5).

To better understand the direct effect of the treatments on variates such as russet and sunburn, the grading for export defects ignored the incidence of black spot. There was a significant increase in the percentage of reject fruit because of increased russet incidence on all treatments containing copper compared with the control (Table 6), although there was some amelioration of russet incidence where Kocide was mixed with Kumulus or with slaked lime.

Sunburn incidence decreased compared with the control in both treatments containing slaked lime. Trees and fruit sprayed with slaked lime showed a marked white deposit, although not as pronounced as we have seen with the use of "Surround™". This deposit wiped off reasonably easily from the fruit cheek during the grading process, but the fruit would require further washing before being packed for market.

Table 2 Effect of sulfur-based (lime sulfur, Kumulus, and Kumulus + Kocide) versus non sulfur-based (Kocide, slaked lime, Kocide + slaked lime, and IFP (Integrated Fruit Production)) fungicide programmes on mean light-saturated net CO₂ exchange (NCE) ($\mu\text{mol m}^{-2} \text{s}^{-1}$) of 'Braeburn' apple (*Malus domestica*) leaves at different stages during the season. Measurements were made on a range of leaf types and averaged for the table. (PSL, primary spur leaf; BEL, basal extension shoot leaf; MEL, mid-position extension shoot leaf; TEL, terminal extension shoot leaf; VSL, vegetative spur leaf.)

Date	NCE		P	5% LSD	Leaves
	Sulfur	No sulfur			
10 Oct	13.8	15.2	0.106	1.95	PSL
18 Oct	12.4	14.7	<0.001	0.44	PSL
24 Oct	12.8	15.5	0.006	1.23	PSL, BEL
3 Nov	13.0	15.1	0.056	2.26	PSL, BEL
24 Nov	11.5	13.4	0.028	1.54	PSL, BEL, VSL
5 Jan	7.8	14.5	<0.001	1.13	BEL, MEL, VSL
12 Jan	7.6	14.8	0.002	2.09	BEL, MEL, VSL
26 Jan	7.2	13.2	0.017	3.96	BEL, MEL, VSL
8 Feb	8.7	14.3	0.032	4.64	VSL
15 Mar	7.7	12.1	0.002	1.45	VSL, BEL, MEL, TEL

Table 3 Effect of fungicide programmes on early and mid-season mean light-saturated net CO₂ exchange (NCE) ($\mu\text{mol m}^{-2} \text{s}^{-1}$) of 'Braeburn' apple (*Malus domestica*) leaves. Data are means of different leaf types on the tree as detailed in Table 2. (IFP, Integrated Fruit Production.)

	NCE	
	24 Nov	12 Jan
Kocide	13.3	14.6
Lime sulfur	10.2	8.2
Kumulus	12.3	7.1
Slaked lime	13.1	13.9
Kocide + Kumulus	11.9	7.5
Kocide + slaked lime	13.9	14.8
IFP	13.5	16.2
5% LSD	1.45	1.57
<i>P</i>	<0.001	<0.001

Although neither Kocide nor Kumulus used separately had an effect on the percentage of fruit graded out for low colour, when mixed together they increased the percent of poorly coloured fruit compared to the control (Table 6).

In terms of overall reject assessments, ignoring black spot, the lime sulfur, Kumulus, and slaked lime treatments achieved comparable or better results than the control. All treatments containing Kocide, however, resulted in significantly higher incidence of downgrading as a result of increased russet incidence compared to the control.

Although there were significant treatment differences in blush percentage, flesh firmness, soluble solids, and starch pattern index (Tables 7 and 8), blush percentage was the only variate which

Table 4 Effect of sulfur-based (lime sulfur, Kumulus, and Kumulus + Kocide) versus non sulfur-based (Kocide, slaked lime, Kocide + slaked lime, and IFP (Integrated Fruit Production)) fungicide programmes on light-saturated net CO₂ exchange (NCE) ($\mu\text{mol m}^{-2} \text{s}^{-1}$) of different leaf types of 'Braeburn' apple (*Malus domestica*) on 15 March. (5% LSD = 1.88 for comparisons between sulfur and non-sulfur treatments of the same leaf type. *P* = 0.010 for interaction.)

	NCE			
	Vegetative spur leaf	Basal extension shoot leaf	Mid-position extension shoot leaf	Terminal extension shoot leaf
Sulfur	6.3	5.9	7.9	10.7
No sulfur	11.5	11.7	13.0	12.1

Table 5 Effect of fungicide programmes on yield and fruit size of 'Braeburn' apple (*Malus domestica*). Means for fruit number and fruit weight per tree have been adjusted for covariate (spring trunk cross-sectional area (TCA)). (IFP, Integrated Fruit Production.)

	Total fruit number	Total fruit weight (kg)	Mean fruit weight (g)	% of crop removed in Harvest 1	Crop load per TCA (no. cm ⁻²)
Kocide	236	42.9	181	37.7	10.5
Lime sulfur	204	36.6	179	44.7	9.2
Kumulus	264	46.2	178	46.0	11.4
Slaked lime	275	49.1	183	46.0	11.7
Kocide + Kumulus	229	40.8	177	27.7	10.5
Kocide + slaked lime	270	47.7	177	45.3	11.8
IFP	297	51.3	174	44.3	12.4
5% LSD	51.9	8.42	12.1	15.04	2.31
<i>P</i>	0.035	0.035	0.791	0.155	0.144

Table 6 Effect of fungicide programmes on incidence of disorders of external fruit quality of 'Braeburn' apple (*Malus domestica*). Fruit were downgraded on the basis of the incidence of russet, sunburn, low colour, misshapen, and marking, according to export standards (ENZA) and the table shows the overall reject percentage and the breakdown of the major defects. (IFP, Integrated Fruit Production.)

	Russet (%)	Sunburn (%)	Low colour (%)	Overall reject (%)
Kocide	28.5	22.5	4.6	57
Lime sulfur	6.7	20.0	3.4	35
Kumulus	2.7	22.0	5.2	36
Slaked lime	4.1	16.6	4.4	28
Kocide + Kumulus	23.4	19.7	9.9	55
Kocide + slaked lime	17.9	16.7	5.9	44
IFP	2.8	27.3	3.2	36
5% LSD	4.11	6.25	3.40	7.5
<i>P</i>	<0.001	0.027	0.011	<0.001

Table 7 Effect of fungicide programmes on internal fruit quality of 'Braeburn' apple (*Malus domestica*) on the first select harvest. (IFP, Integrated Fruit Production.)

Harvest 1	Blush (%)	Background colour	Flesh firmness (kgf)	Soluble solids (% Brix)	Starch pattern index
Kocide	61.5	5.38	8.57	13.5	2.35
Lime sulfur	61.9	5.33	8.15	12.7	2.90
Kumulus	64.1	5.51	8.50	12.8	2.78
Slaked lime	71.7	5.28	8.76	13.2	2.30
Kocide + Kumulus	63.5	4.83	8.25	13.3	2.30
Kocide + slaked lime	73.5	5.20	8.74	13.3	1.93
IFP	72.9	4.88	8.54	12.7	2.25
5% LSD	8.52	0.441	0.309	0.52	0.756
<i>P</i>	0.017	0.088	0.004	0.033	0.177

Table 8 Effect of fungicide programmes on internal fruit quality of 'Braeburn' apple (*Malus domestica*) on the second select harvest. (IFP, Integrated Fruit Production.)

Harvest 2	Blush (%)	Background colour	Flesh firmness (kgf)	Soluble solids (% Brix)	Starch pattern index
Kocide	63.0	5.09	8.36	12.8	2.57
Lime sulfur	65.4	5.33	8.13	12.6	2.95
Kumulus	63.0	5.53	8.12	12.3	3.38
Slaked lime	71.3	5.52	8.51	12.5	2.84
Kocide + Kumulus	60.5	4.98	7.95	12.8	3.25
Kocide + slaked lime	71.9	5.60	8.54	12.8	2.58
IFP	75.5	5.15	8.30	12.7	2.88
5% LSD	8.77	0.623	0.497	0.52	0.479
<i>P</i>	0.039	0.283	0.177	0.293	0.016

Table 9 Effect of fungicide programmes on black spot incidence (*Venturia inaequalis*) on fruit and leaves of 'Braeburn' apple (*Malus domestica*) trees during the early part of the season (assessed 7 December 2000). (IFP, Integrated Fruit Production.)

	% of leaves with black spot	% of fruit with black spot
Kocide	1.18	5.50
Lime sulfur	0.14	3.06
Kumulus	0.71	3.32
Slaked lime	0.92	6.71
Kocide + Kumulus	0.00	1.39
Kocide + slaked lime	0.17	1.14
IFP	0.00	2.09
5% LSD	0.752*	4.952
<i>P</i>	0.040*	0.211

*Leaf black spot incidence on all replicates of Kocide + Kumulus and IFP was zero and the 5% LSD and *P* value refer to comparisons between the non-zero treatments. For comparisons between zero and non-zero treatments 5% LSD = 0.532.

showed these differences consistently over both harvests. Sprays containing slaked lime were the only treatments not to significantly reduce blush percentage when compared with the control. There was a general tendency of higher flesh firmness with the slaked lime treatments in both harvests and lower flesh firmness with treatments containing sulfur (a significant decrease over the control in the first pick).

Disease control

There was no detectable powdery mildew in any of the treatments. Good control of black spot was achieved by both Kocide + Kumulus and the control treatments in the early part of the season (Table 9). Kocide and slaked lime were significantly less effective than lime sulfur at reducing black spot on leaves in the early assessment. At that time there was no significant treatment effect on black spot infection of fruitlets, although slaked lime and Kocide had the highest incidence of infection.

Black spot incidence on fruit at harvest was significantly higher on trees treated with either Kocide or slaked lime than on the control trees (Table 10), although a mixture of Kocide and slaked lime gave very good control of black spot. Lime sulfur was the only treatment not to achieve reduction of dry eye rot levels similar to that achieved by the control.

Table 10 Effect of fungicide programmes on black spot (*Venturia inaequalis*) and dry eye rot (*Botrytis cinerea*) on fruit of 'Braeburn' apple (*Malus domestica*) at harvest. Means presented are arc-sine transformed with back-transformed data in parenthesis. (IFP, Integrated Fruit Production.)

	Black spot		Dry eye rot	
Kocide	0.293	(8.3%)	0.075	(0.6%)
Lime sulfur	0.178	(3.1%)	0.193	(3.7%)
Kumulus	0.166	(2.7%)	0.129	(1.7%)
Slaked lime	0.381	(13.8%)	0.025	(0.1%)
Kocide + Kumulus	0.075	(0.6%)	0.086	(0.7%)
Kocide + slaked lime	0.210	(4.3%)	0.061	(0.4%)
IFP	0.148	(2.2%)	0.061	(0.4%)
5% LSD	0.1025		0.0788	
<i>P</i>	<0.001		0.007	

DISCUSSION

Although growers have reported poorer leaf appearance under organic management, this trial showed no significant effects of fungicide treatments compatible with organic production systems on leaf area development or shoot growth. Although the trial showed pronounced effects of sulfur-based products on leaf photosynthetic rate, the greatest effects were observed after shoot growth had terminated in early January. It is possible that over several years of sulfur use, decreased leaf photosynthesis may have a cumulative effect on leaf area and shoot growth.

Lime sulfur has shown some promise as a flower thinner and certainly the results in this trial show a decrease in fruit set with sulfur treatments. When used as a thinner, however, lime sulfur is used at higher concentrations and more frequently during flowering.

Leaf photosynthesis showed a pronounced reduction in the later part of the season with sprays containing sulfur. Although care was taken to compare leaf assimilation rates on similar leaf types, as these can differ (Table 4), the whole tree carbon dioxide uptake was not measured. Consequently the averaging across the different leaf types in Table 2 may not accurately reflect differences between treatments in terms of whole tree carbon dioxide

exchange. Nevertheless, Tables 2–4 indicate a pronounced effect of sulfur-based products on leaf assimilation. Ferree (1979) in a review, summarised work in the 1930s and 1940s, which showed that sulfur and lime sulfur could reduce leaf assimilation rate. In later work, Ferree et al. (1999) found that a single spray of sulfur resulted in a significant decrease in leaf photosynthesis of greenhouse grown MM.106 trees after 11 days and a 50% reduction after 20 days which persisted for the 45 days of the trial. The nature of the greenhouse environment may have accentuated the adverse effects of sulfur.

Sprays based on sulfur caused a significant reduction in yield per tree, largely mediated by a reduction in fruit numbers. The earlier thinning and reduced fruit numbers resulting from sulfur applications might have induced an increase in fruit size (McArtney et al. 1996) but this was not observed, presumably because the decreased photosynthesis due to sulfur-based products negated this effect.

Kocide sprays led to an increase in fruit russet on 'Braeburn', a cultivar that is not regarded as russet sensitive. The addition of slaked lime to the Kocide did cause some amelioration of russet incidence, confirming the results of Beresford et al. (1995). Still, however, the degree of russet was much higher than that observed with the non-Kocide containing programmes. Copper sprays have frequently been found to induce russet, even where such sprays were restricted to early season applications up until tight cluster on a russet sensitive cultivar 'Golden Delicious' (Ellis et al. 1994). Beresford et al. (1995) found that even at rates as low as 12.5 g/100 litres, which are too low to control black spot, Kocide could induce russet on 'Royal Gala'. The effect of copper on russet and its build up in the soil makes its long-term use questionable. In contrast slaked lime, Kumulus and lime sulfur all gave a low incidence of russet.

Despite the deposit of slaked lime on the fruit, it had no negative effect on fruit colour compared to the sulfur or IFP treatments, confirming the results of Beresford et al. (1995). Slaked lime did, however, give some reduction in sunburn incidence, perhaps acting in a similar way to kaolin sprays (Glenn et al. 2001).

The mixture of Kocide and Kumulus tended to delay colour development as evidenced by decreased blush and less fruit harvested in the first pick, although the mechanism is not clear as other aspects of fruit maturity such as background colour and starch pattern index did not show the same trend.

Even at the time of the early black spot incidence assessment on fruit, at the end of the primary infection period, slaked lime and Kocide were showing a higher incidence of black spot than the other treatments. This was more pronounced at harvest with significantly poorer control, particularly with slaked lime. The two sulfur treatments gave much better black spot control. Beresford et al. (1995) showed that slaked lime did have some activity against black spot. In contrast to the situation with black spot, dry eye rot incidence was similar to the control level with slaked lime and Kocide but significantly worse with lime sulfur.

In an attempt to reduce the damaging effect of sulfur, slaked lime could be substituted for sulfur in the later part of the season when the risk of new infections is reduced. The alternative strategy of slaked lime early in the season followed by sulfur later in the season might also reduce the adverse effect of sulfur on photosynthesis by: (1) decreasing the total sulfur input; and (2) ensuring that most of the sulfur was applied to mature leaves. However, this strategy may compromise black spot control.

CONCLUSIONS

Spray treatments did not influence shoot growth, leaf area development or increment in TCA. Leaf photosynthesis was significantly reduced by all treatments which included sulfur (lime sulfur or Kumulus) with reductions of up to almost 50% in January. At harvest, yield per tree showed a significant reduction of 12% with the pooled data from the sulfur-based treatments, largely as a result of decreased fruit numbers per tree. All treatments containing Kocide resulted in a higher proportion of fruit with russet. The addition of Kumulus or slaked lime to Kocide resulted in some amelioration of russet. All treatments resulted in less blush development on the fruit compared to the IFP control, except for slaked lime. Slaked lime treatments tended to reduce sunburn. The Kocide + Kumulus treatment produced the highest reject rate for low colour. Black spot incidence on fruit at harvest was significantly higher on trees treated with either Kocide or slaked lime compared to the controls. When used together, however, control of black spot was as good as in the control. Eye rot incidence was significantly higher on the trees treated with lime sulfur.

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