EVALUATION OF FIVE APPLE CULTIVARS FOR THEIR RESISTANCE TO BLACK SPOT AND POWDERY MILDEW IN THREE REGIONS OF NEW ZEALAND

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ABSTRACT

Five disease-resistant apple cultivars ('Dayton', 'Jonafree', 'Liberty', 'Prima' and 'Redfree') were evaluated from 1992-95 for their resistance to black spot, (*Venturia inaequalis*), and powdery mildew (*Podosphaera leucotricha*), in three regions of New Zealand. High resistance to black spot was confirmed by absence of fruit infections in all regions and absence of leaf infections in Nelson and Otago under conditions of no fungicides or limited use of sulphur sprays. Black spot lesions on the foliage were recorded only on four unsprayed cultivars in Hawkes Bay in 1994-95 when disease inoculum from adjacent susceptible conventional apples was very high. 'Prima' showed greater resistance to powdery mildew than the other cultivars, which would require additional management measures for control of this disease.

Keywords: black spot, powdery mildew, disease resistance, apple cultivars

INTRODUCTION

A survey of organic growers throughout New Zealand in 1990 (Wearing and Walker 1990) showed that the most important practical problem affecting the biological or organic production of conventional apple cultivars was disease control. Growers were experiencing severe difficulties with the control of black spot (BS), and powdery mildew (PM), using copper and sulphur fungicides, which were the best available fungicides for this purpose. While formulations of copper and sulphur continue to be improved and alternatives are being evaluated (eg. Beresford *et al.* 1995), the problems of BS and PM control remain because of a direct correlation between the efficacy of copper products and the russetting of fruit (Beresford and Spink 1993). The development of disease-resistant apple cultivars of export quality is an essential component of future integrated disease management and biological production of pipfruit.

There are breeding programmes in a number of countries to produce apple cultivars resistant to BS, PM and fireblight, *Erwinia amylovora* (Crosby *et al.* 1992). The cultivars reported in this paper originate from the North American breeding programmes. Before they can be recommended for use in New Zealand, they require evaluation in our major apple-growing regions for their disease resistance and fruit quality characteristics. This paper reports the results of field evaluation of five apple cultivars for their resistance to BS and PM in Hawkes Bay, Nelson and Otago.

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METHODS

Trial blocks

Three cultivars, 'Dayton', 'Redfree' and 'Prima', (each in separate blocks 11 trees x 11 rows, 3.5 x 5.0 m) were planted at Clyde Research Centre in winter 1991 and the further cultivars 'Liberty' (11 x 9) and 'Jonafree' (11 x 6) were planted in winter 1993. All trees were on M793 rootstocks. A smaller block on M793 was planted 3.5 x 5.0 m at Appleby Research Orchard, Nelson containing 45 trees each of the cultivars 'Dayton' and 'Prima' (1991, 9 x 5), 25 trees of 'Jonafree' (1993, 5 x 5), and 50 trees of 'Liberty' (1993, 10 x 5). At Havelock North, 24 trees (12 x 2) of 'Dayton' and 26 trees (13 x 2) of 'Prima' were planted in 1991, 60 'Liberty' trees (12 x 5) in 1992, and 47 'Jonafree' trees (13 x 3) in 1993. All cultivars were on MM106 rootstocks at 4.0 x 4.8 m spacing, except 'Jonafree' at 4.8 x 4.8 m.

Black spot and powdery mildew assessments

BS and PM infections were assessed on terminal shoots over three seasons at Clyde (1992-95). One terminal shoot was selected at random from individual trees, with a group of ten shoots from the same row of trees comprising one replicate sample. Half of the rows of each cultivar plot were sampled (replicates) on each occasion and this was alternated between rows 1, 3, 5, 7, 9 and rows 2, 4, 6, 8, 10. The numbers of expanded leaves were counted on a random sub-sample of two shoots out of each group of ten and all expanded leaves were examined on every shoot for the presence of infections. In hand-spray trials in 1994-95 (see below) comparing five treatments for PM control in each cultivar (4 x 5 randomised block), the samples consisted of four shoots in each of the 20 plots. The sampling occasions for 'Dayton', 'Redfree' and 'Prima' are given in Table 2.

The entire first crop of all trees of 'Dayton', 'Redfree' and 'Prima' in 1994, and of 'Liberty' and 'Jonafree' in 1995, were examined for BS. In 1995, the entire crop of a random sample of 25 trees of each of the first three cultivars was examined. The harvest dates were: 'Redfree' 21-24.2.94, 21.2.95, 'Dayton' 24.2.94, 28.2.95, 'Prima' 7.3.94, 7.3.95, 'Jonafree' 17.3.95, 'Liberty' 30.3.95.

At Nelson, terminal shoots were examined on every row (replicate) of all four cultivars in 1993-94 and 1994-95, using the same procedure as in Clyde. The sampling dates are given in Table 3. The entire crop of every tree of 'Dayton' and 'Prima' was examined for BS in 1992-93 and 1993-94. In 1994-95, the same number of fruit clusters were examined for BS as terminal shoots on 15.12, 11.1, and 9.2.; four ('Jonafree'), eight ('Liberty') or ten ('Dayton' and 'Prima') replicate samples of 100 fruits were examined for BS at harvest. The harvest dates were: 'Dayton' 28.2.93, 28.2.94, 28.2.95; 'Prima' 15.2.93, 15.2.94, 17.2.95; 'Jonafree' 22.3.95; 'Liberty' 22.3.95.

Foliar BS infection was first assessed at Havelock North on 14.12.94 by examining every leaf of each of 10 leaf clusters on each of five trees selected at random from each cultivar. Two days later, fruit infection by BS was recorded on a random sample of 30 fruit on each of five trees per cultivar. Random samples of at least 600 (1994) or 350 (1995) fruits per cultivar were examined for BS infection after harvest on the following dates: 'Dayton' 17.2.94, 22.2.95; 'Prima' 9.2.94, 22.2.95; 'Liberty' 11.3.94, 30.3.95. 'Jonafree' had insufficient fruits for assessments. The presence/absence of PM was assessed on terminal shoots of each cultivar once per season using a random sample of four terminals per tree (on 25 trees, 10.1.94) or ten terminals per tree (on five trees, 19.12.94).

Black spot infection periods

All three Research Centres operate BS monitoring services to identify primary infection periods and their level of risk (marginal (MA), light (L), moderate (M), severe (S)). These services identified the following risks: Clyde 1992-93 3MA, 1L, 2M; 1993-94 2MA, 5L, 1M, 1S; 1994-95 4MA, 1M, 1S. Nelson 1992-93 6L, 6M, 12S; 1993-94 2L, 5M, 6S; 1994-95 1L, 4M, 10S; Havelock North 1994-95 2MA, 2L, 3M.

Fungicide applications

At Clyde, no sprays were applied to the 'Liberty' or 'Jonafree' trees. On other cultivars, the sampling of terminal shoots was used to determine the need for fungicide (sulphur (BASF Kumulus DF) at 187.5 (1992-93) or 180 g/100 litres) applications

when either BS or PM reached a threshold of 1% infected leaves on any cultivar in 1992-93. Sprays were applied on 9.11. and 14.12. A 2% threshold was used on individual cultivars in 1993-94, resulting in sprays to 'Redfree' on 29.11 and to 'Redfree' and 'Dayton' on 21.12, 7.1 and 26.1. After the first spray had been applied, the threshold for PM referred to new infections. Sprays were applied by Cropliner Airblast sprayer, except in 1994-95 when hand spraying was used. In 1994-95, sulphur and four other 'organic' fungicides were tested for PM control. However, the 2% spray threshold was applied to the whole block ensuring that all treatments and cultivars received the same number of spray applications (30.11, 12.12, 29.12, 12.1). All sprays were in response to PM in every season.

No sprays were applied at Nelson in 1992-93. Six sprays of sulphur (Sulflo 180 g/100litres) were applied high volume to all cultivars by Cropliner Airblast sprayer on 15.10, 22.10, 4.12, 22.12, 10.1 and 27.1 after PM infections exceeded 1% on any cultivar. The same methodology was used in 1994-95, with sprays on 23.9, 30.9, 11.10, 25.10, 4.11, 10.11, and 22.12.

In 1993-94 at Havelock North, all cultivars were sprayed with sulphur on 28.12.93 (SuperSix 170 ml/100 litres) and 28.2.94 (Kumulus 400 g/100 litres) using a Cropliner Air-blast sprayer. One third of the block was left untreated in 1994-95 and data are presented from only this area.

Statistical analysis

The percentage infection data were angular transformed before analysis of variance using Solo (Hintze 1989) to compare cultivars. The validity of these comparisons was limited by the experimental design in which cultivar blocks were separate; conclusions concerning the relative disease-resistance of cultivars could be made only where similar relationships were found across the three regions.

RESULTS

Black spot

No BS infection of leaves or fruit was observed on any cultivar throughout the course of the trials in Clyde and Nelson, despite the high risk of infection and the number of primary infection periods, especially in Nelson. The fruits of six rogue 'Fuji' trees in the 'Redfree' block at Clyde had $12.6 \pm 6.8\%$ infection with black spot at harvest 1993. Sulphur has very limited efficacy against BS (eg. Beresford *et al.* 1995) and, where it was used, would have made little contribution to this result. No BS-infected fruit were observed at Havelock North but foliage lesions were recorded on all cultivars, particularly 'Liberty', in the untreated block in 1994-95. A high percentage of these lesions were inactive on all cultivars (Table 1).

TABLE 1: Mean percentages of leaves infected by black spot and the percentages of inactive lesions on the leaf clusters of four cultivars at Havelock North in 1994-95. Means on the same line followed by the same letter are not significantly different ($P < 0.05$).

Sampling date		Dayton	Prima	Jonafree	Liberty
1994-95	Infection	5.46 b	6.89 b	3.43 b	27.24 a
December	Inactive lesions	76.00 a	90.00 a	80.00 a	93.60 a

Powdery mildew

At Clyde, PM was frequently lower on 'Prima' than either 'Dayton' or 'Redfree' (Table 2), even in 1993-94 when 'Prima' alone was not sprayed at Clyde. The spray threshold was not reached on 'Prima' on any sampling occasion from 1992-95. On the other hand, 'Dayton' and 'Redfree' had similar levels of infection over the three seasons and each required spraying.

The terminal shoots of 'Liberty' (unsprayed) had a mean of 21.8% and 6.2% leaves infected respectively on 11 February 1994 and 17 February 1995. The equivalent data for 'Jonafree' in 1994 was 13.4%.

TABLE 2: Mean percentages of leaves infected by powdery mildew on the terminal shoots of three cultivars over three seasons at Clyde. Means on the same line followed by the same letter are not significantly different ($P < 0.05$).

Sampling date		Dayton	Prima	Redfree
1992-93	Nov 13	0.82 a	0 b	0.45 ab
	Dec 9	0.99 a	0.81 a	0.71 a
	Jan 6	0.25 b	0.27 b	1.10 a
	Feb 18	1.64 a	0.18 b	1.12 a
1993-94	Nov 29	1.07 a	1.02 a	2.77 a
	Dec 20	3.67 b	1.80 c	6.21 a
	Jan 28	0.41 a	0.38 a	0.80 a
1994-95	Nov 14	1.67 a	0.25 b	0.74 ab
	Nov 29	5.99 a	1.00 b	4.15 ab
	Dec 21	4.79 a	0.89 b	3.78 a
	Jan 17	3.18 a	1.24 b	1.07 b

Preliminary observations at Nelson for the presence of PM showed that 12% of 'Prima' trees carried infections compared to 68% of 'Dayton' trees at harvest 1993. No sprays had been applied. The lower incidence of PM on 'Prima' was confirmed in 1993-94 and 1994-95 despite the use of six and seven sulphur sprays respectively on all cultivars (Table 3). The low infection on 'Prima' was matched by 'Jonafree' and 'Liberty' on some sampling occasions. 'Dayton' continued to have high leaf infection compared to the other cultivars.

TABLE 3: Mean percentages of leaves infected by powdery mildew on the terminal shoots of four cultivars over two seasons at Nelson. Means on the same line followed by the same letter are not significantly different ($P < 0.05$).

Sampling date		Dayton	Prima	Jonafree	Liberty
1993-94	Nov 15	49.2 a	11.2 b	14.3 b	14.8 b
	Dec 2	15.6 a	4.2 b	13.1 a	14.6 a
	Jan 6	19.3 a	3.7 bc	1.3 c	6.0 b
	Feb 8	24.4 a	4.6 b	0.4 b	2.2 b
1994-95	Nov 11	13.5 a ¹	4.9 a ¹	5.2 a ¹	3.0 a ¹
	Dec 15	28.6 a	0.8 c	2.7 bc	10.7 b
	Jan 11	21.4 a	2.2 b	6.6 b	8.3 b
	Feb 9	21.5 a	2.4 c	2.6 c	8.2 b

¹All primary infections affecting the total shoots.

TABLE 4: Mean percentages of terminal shoots infected by powdery mildew on four cultivars over two seasons at Havelock North. Means on the same line followed by the same letter are not significantly different ($P < 0.05$).

Sampling date		Dayton	Prima	Jonafree	Liberty
1993-94	Jan 10	55.2 b	40.0 c	72.0 a	54.4 b
1994-95	Dec 19	22.0 ab	6.0 b	44.0 a	0.0 b

The sampling method based on presence/absence of PM on entire terminal shoots at Havelock North produced higher infection percentages than when individual leaves were recorded. Nevertheless, 'Prima' again had lower infection than other cultivars (Table 4) except for the absence of PM on the 'Liberty' samples in 1994-95.

DISCUSSION AND CONCLUSIONS

The absence of any BS-infected fruits in all three regions, with or without the assistance of sulphur fungicides, has confirmed the high level of resistance of all five cultivars to this disease, as reported overseas (eg. Crosby *et al.* 1992). The occurrence of lesions on the leaves of all four cultivars in Havelock North in 1994-95 may have been related to carry-over of exceptionally high BS inoculum from the previous two seasons. The 1992-93 season, in particular, was extraordinary in Hawkes Bay for the high number of either moderate or severe infection periods, and this led to a serious BS outbreak which defoliated conventional cultivars adjacent to the trial trees. This high inoculum continued through to spring 1994. The high BS inoculum at this site is in contrast to the low inoculum levels prevailing on adjacent conventional cultivars at the Nelson and Clyde sites. There is no justification for assuming that the foliar infection at Havelock North indicates resistance breakdown because leaf infection has also been recorded overseas under high inoculum conditions (Lepinasse 1994). Even though sulphur has limited efficacy against BS, it still prevented the development of infections in the treated blocks at Havelock North. All BS lesions on the treated foliage were inactive. This confirms the recommendation of Lepinasse (1994) to spray BS-resistant cultivars with fungicide when infection pressure is high to reduce the risk of resistance breakdown. The situation at Havelock North is being monitored closely for the occurrence of different strains of the pathogen (*V. Bus pers. comm.*). The high proportion of dead lesions on the Havelock North trees (Table 1) in the absence of sprays may be indicative of cultivar resistance to the infection and/or dry conditions limiting development of the disease.

The interpretation of cultivar response to PM is more complex in the absence of high levels of resistance. Variation in inoculum, weather, and control measures in the three regions and years resulted in different exposure of the cultivars to infection. However, the data from all three regions was consistent enough to confirm that 'Prima' exhibits resistance to this disease compared to the other cultivars, as reported by Crosby *et al.* (1992). The Clyde trials suggested that spraying for PM control would rarely be required on this cultivar, particularly if infected terminals are pruned off each winter. The other four cultivars showed susceptibility which would probably require intervention with fungicides every season in all three regions, even with assistance from winter pruning. The only exception to this conclusion was the absence of PM infection on 'Liberty' in 1994-95 at Havelock North. The reason for this result remains obscure.

While all five cultivars provide the advantage of disease resistance over conventional apple cultivars, the quality and storage ability of their fruit will be a primary determinant of their suitability for commercial production. This is being assessed each season and will be the subject of a further paper.

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