RELATIONSHIP BETWEEN ARMOURED SCALE INFESTATIONS ON KIWIFRUIT LEAVES AND FRUIT

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SUMMARY

The relationship between armoured scale infestations on leaves and fruit was investigated for data collected at harvest from insecticide and scale threshold trials from 1986 to 1990. At high scale levels, an exponential model derived from data pooled from all insecticide trials predicted ratios of 8:1 and 2.5:1 scale infested leaves to fruit at 40 and 80% infested leaves respectively. At lower scale levels a linear model for the pooled data predicted a ratio of 17:1 scale infested leaves to fruit. However, the 95% predictive intervals show that the model has little value for the prediction of individual observations. Furthermore, the choice of spray threshold cannot be more precisely determined until the precision of packhouse scale grading procedures is quantified.

Keywords: armoured scale, kiwifruit, leaf, fruit, infestation, spray threshold

INTRODUCTION

Armoured scales are important quarantine pests of kiwifruit which have, until recently, been controlled by prophylactic insecticide applications applied on a calendar schedule. During 1988 to 1991 the New Zealand Kiwifruit Marketing Board (NZKMB) sponsored trials to develop a spraying threshold procedure using scale infested leaves (Steven *et al.* 1991). The NZKMB subsequently sponsored scale threshold sampling using selected growers in the Bay of Plenty in a programme aimed at producing residue-free fruit to avoid possible trade barriers by Italy (Anon 1993; Richardson 1993; Stevens *et al.* 1993).

The scale threshold was developed by setting an arbitrary range of leaf infestation levels from 1-16% and applying sprays when these levels were exceeded. Sampling was carried out at regular intervals (2-4 weeks) following the application of two post-blossom sprays. The effectiveness of thresholds was assessed by determining scale infestation levels detected during commercial grading of fruit in packhouses and by laboratory examination of 300 fruit per plot. No scale problems were detected by the packhouses. Further testing evaluated scale infested leaf thresholds of 4 and 8% as these were considered to give a reasonable margin of safety. Again no scale problems were detected by packhouses.

A 4% threshold has been used to try to reduce the frequency of insecticide applications, implying that this is a scientifically validated level. Unfortunately, this is not the case and several problems remain. The validation of scale thresholds using packhouse grading systems which are insensitive and have unknown and variable scale recoveries means it is impossible to know what levels of scale infested fruit were present. Furthermore, at some sites there was little or no scale present in samples so thresholds were untested. The precision and reliability of scale sampling procedures is unknown so we do not know what sample size is required to accurately estimate scale populations which may be contagiously distributed within orchards. We do not even know if scale infested leaves reflect contamination of fruit with scale.

This paper reports a preliminary investigation to determine whether there is a relationship between scale infestations on leaves and fruit.

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METHODS

Scale infestations of leaves and fruit were assessed at harvest (late April-June) from a series of insecticide and scale threshold trials conducted at nine orchards in Kerikeri and Whangarei over 5 years giving 23 separate trials (Table 1). Leaves and fruit were picked randomly across plots. Samples from each plot were bulked in plastic bags and cool-stored (5°C) until assessment. Samples were examined under a stereo microscope for live and dead scale.

TABLE 1: Numbers of individual plots from which scale leaf and fruit infestation data were available, showing the location, year and type of trial.

Year	Trial	Whangarei		Kerikeri	
		Sites	Plots/site	Sites	Plots/site
1986/87	insecticide	1	42	-	-
1987/88	insecticide	1	40	1	48
	threshold	1	24	-	-
1988/89	insecticide	1	24	1	40
	threshold	1	6	1	6
1989/90	insecticide	1	42	1	120
	threshold	3	3-6	3	3-6
1990/91	threshold	4	3	3	3

The insecticide trials evaluated the effects of various insecticide treatments applied to individual plots consisting of 1-2 vines. Sites were chosen because they had a high risk of scale invasion (Blank *et al.* 1990). Vines used in these trials received an intensive dormant season spray programme of at least three insecticide sprays over the winter and early spring period to clean up over-wintering scale populations, except at one site at Kerikeri in 1989/90 when scale clean-up sprays were omitted from half of the trial plots. Each site had 8-40 treatments which were replicated 3-6 times giving 24-120 plots/site or a total of 396 plots available from these insecticide trials. Each plot was assessed using 25-50 leaves and 50-100 fruit.

The scale leaf threshold trials evaluated the effects of applying insecticides at a range of leaf infestation thresholds (1-16%) at various times following the application of two post-blossom insecticides. Sites were selected which had a range of low to high risk of scale invasion. The 1987/88 trial used six vine plots and six treatments replicated four times. However, to give comparable weightings and plot sizes to the later threshold trials, means of the four replicates were used giving six data points. Later trials used large plots (40-350 vines) and had six or three treatments without replication giving a further 63 plots. Each plot was assessed using 50 leaves and 100-300 fruit.

A fruit or leaf which had one or more scale present was defined as scale infested. The percentage of scale infested fruit was plotted against percentage of scale infested leaves for various combinations of sites, years and trials. The regression curve giving the best fit, 95% confidence intervals (mean values), 95% predictive intervals (individual observations) and co-efficients of determination were calculated. Data from the insecticide trials were $\log_e(x + 1)$ transformed and a straight line fitted.

RESULTS

Insecticide trials

Regression analyses using data sets selected on the basis of site, year and previous spray history were able to achieve significant relationships. However, the relationship between scale infested leaves and fruit was often found to vary between data sets. For example, in the 1989/90 season at a Kerikeri site, plots which received an intensive winter scale clean-up spray programme had lower fruit infestations at a given scale leaf infestation level than plots where winter clean-up sprays were omitted (Fig. 1).

Figure 1: The relationship between scale infested leaves and fruit for individual plots used in an insecticide trial at Kerikeri in 1990. The effect of an intensive dormant season spray programme applied across half the plots has changed the relationship compared to plots which did not receive dormant season sprays.

Figure 2: The regression relationship and 95% confidence limits and 95% predictive intervals between scale infested leaves and fruit for all insecticide trial plots at seven sites used over 1987 to 1990, excluding plots heavily infested with scale in 1990 which did not receive dormant season sprays.

Combining the data for all sites and years also gave a significant relationship between scale infested leaves and fruit (Fig. 2). This regression curve showed that the relationship varied depending on the scale infestation levels. Hence at 40% infested leaves the curve estimated an average of 10% infested fruit (ie. 4:1 ratio) whilst at 80% infested leaves it estimated an average of 30% infested fruit (ie. 2.5:1 ratio).

Combining replicated plots which had similar spray histories to give mean values did not markedly affect these relationships.

Scale threshold trials

Regression analyses using selected data sets of the scale threshold trials also showed significant relationships. However, fewer plots were available from the scale threshold trials and so data sets generally had to be combined between years or sites to obtain meaningful curves. For example, combining the data from the Kerikeri and Whangarei sites in 1989 gave a significant linear regression (Fig. 3). The slope of this line shows a ratio of 18% scale infested leaves : 1% scale infested fruit.

Combining all the data from the scale threshold trials also gives a scatter which is best fitted by a linear regression (Fig. 4). The slope of this line predicts 1% scale infested fruit for every 17% scale infested leaves.

Figure 3: The relationship between scale infested leaves and fruit for the 1989 threshold trials at two sites.

DISCUSSION

The relative proportion of scale species involved in this study was similar to those identified in other studies for Kerikeri and Whangarei (Lo and Blank 1989; Blank *et al.* 1990; Blank *et al.* 1992), with greedy scale *Hemiberlesia rapax* (Comstock) comprising 96% or more of the scale at Whangarei and *lataniae* scale *H. lataniae* (Signoret) 81-84% of the scale from Kerikeri. We found no evidence to suggest that scale species markedly affects relationships between scale infested leaves and fruit.

This study avoided problems associated with packhouse assessments by directly assessing scale fruit infestation levels using a microscope. However, fruit sample size was smaller than was desirable, particularly at low scale infestations.

Figure 4: The regression relationship with 95% confidence intervals and 95% predictive intervals between scale infested leaves and fruit for threshold trials at 16 sites from 1988-1991.

These analyses show that the relationship between scale infested leaves and fruit, both sampled at harvest, may vary between sites, seasons, insecticide spray histories and trials. Some of this variability can be attributed to known differences between sites, including the levels of scale infestation of the kiwifruit vines as shown by the comparison with and without intensive dormant season insecticide sprays. The exponential model derived from the insecticide trial data also demonstrates that the level of scale infestation of leaves is important in predicting fruit infestation. The influence of other factors such as risk of invasion from adjacent host plants (Blank *et al.* 1990) or the different spray histories due to different frequency and timing of insecticide sprays in combination with the persistency of insecticides, scale age structure and leaf canopy density, may also be expected to have some effect.

The insecticide trials were carried out on sites which were selected for their high scale populations. Consequently these analyses were useful for demonstrating the relationships at high scale infestations. It is of interest that at 95% leaf infestations 100% saturation of fruit occurred where high levels of scale were allowed to overwinter on the wood but only 50% infestation of fruit occurred where overwintering scale had been removed with sprays. The aerially invading scale crawlers thus appear to have a greater probability of settling on the exposed leaf canopy than on the fruit, which are protected by the leaf canopy.

The scale threshold regression model may be used to estimate average fruit infestations at the low scale levels normally encountered in commercial orchards. Interpolation of the linear model from low scale densities and taking into account 95% confidence intervals suggests that, at 14% scale infested leaves, fruit infestations on average should be 1% or less. However, the 95% predictive intervals show that the model is not able to accurately predict scale fruit infestations below 2% even at low leaf infestations for individual sites. Consequently these relationships are of little use for predictive purposes. Moreover, at these low scale infestation levels commercial packhouses appear unable to detect appreciable numbers of scale infested fruit, so that

any threshold up to about 20% scale infested leaves could be chosen depending more on the sensitivity of packhouse grading systems than actual level of fruit infestation. This is alluded to in another study which evaluated an 8% scale leaf threshold at nine sites and detected, using microscope examination, fruit infestation levels of up to 5% and "all lines of fruit successfully reached export standards when graded through commercial packhouses" (Stevens *et al.* 1993).

Further research using more intensive sampling at known levels of precision are urgently required if we are to precisely determine relationships at low scale densities. In the meantime considerable care must be exercised in relying on leaf counts to reflect the risk of scale infesting the fruit. Acceptable standards for scale fruit detection limits at grading also need to be determined before the scale thresholds can be further refined.

No upper threshold has been demonstrated at which scale problems will occur in spite of several years' trial work. Until this is done it could be suggested that almost any low scale leaf threshold may be adequate to give confidence to growers to omit sprays, particularly in an industry in which most growers were over-spraying because they were following the recommended calendar export spray programme designed to avoid insect damage and contamination under high risk situations. In spite of the scientific difficulties associated with validating the scale sampling technique and chosen threshold, these methods have assisted growers to move from calendar to managed spraying regimes.

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