ASSESSING THE EFFECT OF *ESSIGELLA CALIFORNICA* ON *PINUS RADIATA* AT TWO SITES IN NEW ZEALAND

M.C. WATSON¹, D.J. KRITICOS^{1,2}, G.M. DRAYTON³, D.A.J TEULON³
and E.G. BROCKERHOFF⁴

¹Scion, Private Bag 3020, Rotorua, New Zealand

²Current address: CSIRO Forest Biosciences, PO Box E4008, ACT 2604, Australia

³Crop & Food Research, Private Bag 4704, Christchurch, New Zealand

⁴Scion, PO Box 29237, Christchurch, New Zealand

Corresponding author: Michelle.Watson@scionresearch.com

ABSTRACT

The impact of the exotic aphid, *Essigella californica* (Essig), on the health and growth of *Pinus radiata* D.Don in New Zealand was examined by comparing trees treated with a systemic insecticide with untreated trees at two climatically contrasting sites over three seasons (2006-2008). Upper crown yellowing, thought to be associated with *E. californica*, was not affected by insecticide treatment. However, on insecticide-treated trees aphid numbers were reduced and tree diameter increased in the final year at both sites. Significantly more aphids were recorded at McLeans Island Forest than Kaingaroa Forest in all years. The incidence of the needlecast fungus (*Cyclaneusma minus*) was also greater at McLeans Island, in support of a possible relationship between *E. californica* and *C. minus*. Compared with its effect in Australia, *E. californica* appears to have a low pest status in New Zealand.

Keywords: Monterey pine aphid, *Essigella californica*, American pine aphid, Californian pine-needle aphid, monitoring, *Pinus radiata*, tree growth, fungus, *Cyclaneusma minus*, insecticide.

INTRODUCTION

The Monterey pine aphid, *Essigella californica* Essig (Hemiptera: Aphididae), is native to North America, Mexico and Canada where it feeds primarily on *Pinus* and occasionally *Pseudotsuga* species (Pinaceae), but is not considered an economic pest (Sorensen 1994). It was first recorded outside its native range in France in 1989, where it caused localised damage and needle yellowing (Turpeau & Remaudiere 1990). *Essigella californica* has since become established in Spain (Seco Fernandez & Mier Durante 1992), southern Brazil (Zonta de Carvalho & Noemberg Lazzari 2000), Australia and New Zealand (Carver & Kent 2000).

In Australia, where the climate is generally warmer and dryer than New Zealand, *E. californica* has been associated with severe upper crown yellowing and premature needle senescence, particularly in pruned mid-rotation *Pinus radiata* forests in south-eastern Australia. Growth losses have been recorded for affected trees in Australia (Smith et al. 2000; May & Carlyle 2003; Hopmans et al. 2008), with the aphid estimated to cause losses of up to AUD \$21 million per year to the Australian forestry industry (May 2004). However, a causal relationship between the aphids presence and growth losses has been difficult to demonstrate, as both drought and needle cast fungus (*Cyclaneusma minus* (Butin) DiCosmo, Peredo & Minter) are known to cause defoliation in areas with *E. californica*.

Essigella californica, was first recorded in New Zealand in 1998 in Whangarei and was found to be widespread (Flynn et al. 2003). Studies of the aphid in New Zealand forests

have recorded relatively low numbers and little visual evidence of aphid damage to trees, in comparison with Australia (Carver & Kent 2000; Appleton & Gresham 2003; Teulon et al. 2003). However, high aphid numbers were recorded soon after it was discovered in New Zealand (Teulon & Stufkens 2002). In this study the effect of the removal of *E. californica* on tree growth and health under different climatic conditions in New Zealand was investigated by comparing insecticide-treated trees with untreated trees.

MATERIALS AND METHODS

Study sites

Essigella californica was sampled monthly from December 2005 to June 2006, March to May 2007 and March to April 2008 in two unpruned *Pinus radiata* stands at two climatically contrasting locations in New Zealand. These were McLeans Island Forest on the Canterbury Plains in the South Island (5748460N, 2461220E, 80 m above sea level) and Kaingaroa Forest in the Bay of Plenty, in the central North Island (6298050N, 2818150E, 550 m asl). Trees were planted in 1997 at McLeans Island Forest and in 1998 at Kaingaroa Forest. No sampling was carried out in the earlier months of 2007 and 2008 because few aphids are found at that time (Appleton & Gresham 2003; Teulon et al. 2003).

Insecticide treatment

Forty pairs of trees at each site were randomly selected within a 1 ha area. One tree in each pair was randomly assigned as the treatment tree, and the other as the untreated control. Treated trees were injected with the insecticide methamidophos (Tamaron, Bayer) using a Sidewinder™ backpack stem injector in November 2005 and 2006. In 2007, the organophosphate insecticide acephate (Orthene, Monsanto) was used because of user safety concerns with methamidophos. For both insecticides, 15 ml of undiluted product was injected into each of two 8 mm holes drilled into the stem near the base of the tree.

Sampling and tree measurement

Both sites were sampled for aphids using a beating method developed in Australia (Kent & Carnegie 2000), to provide a basis for comparison. Six branches per tree between 0 and 2 m were beaten three times each from ground level, two of the highest branches able to be reached, two of the lowest and two from between these, whilst holding a 365 mm diameter net underneath the branch, pooling the beatings for each tree. All aphids were collected and later identified under a microscope. Attempts were made to only sample when the foliage was dry but this was not always possible.

The diameter over bark at 1.4 m using standard methodology and tree height (using a Vertex™) were measured in November 2005, 2006 and 2007.

Assessments of tree health, including the presence of upper and lower yellowing and percentage of the crown defoliated, were conducted in November each year beginning in 2005, prior to the treatment of trees. Particular note was made of upper crown defoliation, which is thought to be related to *E. californica* feeding damage (Kent & Carnegie 2000). Defoliation was visually estimated as a percentage of the total unsuppressed crown volume that was diseased or removed.

Twenty needles were collected from each tree at both sites in November 2005 and analysed for the presence of *Cyclaneusma minus*. One-year old needles were selected from towards the base of branchlets, with yellowing needles preferentially collected. Ten needles from each tree were plated onto 2% malt extract agar and a representative culture was sub-sampled to visually confirm the presence of *C. minus*.

Statistical analysis

Analysis of covariance was used to test for differences in diameter and height between control and treated trees. In all analyses the pre-treatment value assessed in November 2005 was used as the covariate. The analysis included site, block (tree pair), treatment, and the interaction between treatment and site as experimental factors. Analysis of aphid (treatment) effects was performed using the SAS (version 9) General Linear Model. Both tree diameter and height were adjusted to a common 2005 mean for control and treated trees. For aphid counts, a Poisson regression model, using the procedure GENMOD, was used.

RESULTS

The numbers of *E. californica* collected were highest in the 2005-2006 sampling period at both sites. Aphid numbers peaked in March 2006, with a mean of 17.2 aphids/tree at McLeans Island. No aphids were found in June 2006. Fewer aphids were found in all subsequent sampling periods (2007 and 2008), with the highest mean at McLeans Island in May 2007 of 0.33 aphids on untreated trees and 0.23 from injected trees. As expected, significantly fewer aphids were found on insecticide-treated than untreated trees in all months from December 2005 to April 2006 (Fig. 1). Counts in subsequent years were too low for meaningful analysis.

FIGURE 1: Numbers of *Essigella californica*/tree collected from December 2005 to April 2006. Values are the mean ($\pm$ SE) for insecticide-treated and untreated trees across both sites (* $P < 0.0036$, *** $P < 0.0001$).

Aphid numbers at McLeans Island were significantly higher than at Kaingaroa in March and April 2006, but higher at Kaingaroa in January 2006 (Fig. 2). During the peak in aphid numbers in March and April 2006 over 100 individuals were collected from each of two trees at McLeans Island, with no aphids collected from 5 other trees. Aphid numbers were not correlated with within-stand location ($P > 0.05$).

FIGURE 2: Numbers of *Essigella californica*/tree collected from December 2005 to April 2006. Values are the mean ($\pm$ SE) for McLeans Island and Kaingaroa Forests across treatments (*** $P < 0.0001$).

Insecticide treatment did not affect the incidence of either upper ($P=0.36$) or lower crown yellowing ($P=0.57$). No signs of foliage phytotoxicity from the insecticide treatment were observed. A significant positive effect of treatment on tree diameter was found in 2007 ($P<0.01$), but not in 2006 ($P=0.54$), with a mean diameter for treated trees of 233 mm (SE 0.2) compared with 226 mm (SE 0.2 mm) for untreated trees. The average diameter and height of trees in November 2007 at Kaingaroa were 237 mm/13.43 m (untreated) and 249 mm/13.86 m (treated), compared with 211 mm/10.92 m (untreated) and 221 mm/11.24 m (treated) at McLeans Island. Tree height showed no treatment response in either 2006 ($P=0.13$) or 2007 ($P=0.28$). No significant interactions were found between site and treatment ($P>0.05$). The health of infested trees varied greatly with defoliation ranging from 5 to 31% during the trial. There was no significant association between tree health (using the canopy defoliation score) and aphid numbers in any year ($P>0.05$).

All trees at McLeans Island showed signs of lower to mid-crown yellowing during the trial, a significantly greater incidence than at Kaingaroa ($P<0.0001$). Upper crown yellowing was minor and accounted for no more than 5% of the canopy in all years, with no site difference found ($P>0.05$). Needles collected in November from all 80 trees at McLeans Island tested positive for *C. minus*. None of the Kaingaroa trees gave a positive result.

DISCUSSION

Essigella californica populations in this study were found to vary greatly from year to year and between sites and individual trees, although numbers were low overall. In New Zealand, high variability in numbers between years and locations has been recorded in suction traps (Flynn et al. 2003) and in beat samples (Appleton & Gresham 2003, Teulon et al. 2003). One of the highest recorded populations was of more than 500 aphids on heavily infested trees in 2002 using the same sampling method as this study (Appleton & Gresham 2003). High numbers of aphids were collected in suction traps in Canterbury from 1998 to 1999, followed by a sudden decline (Teulon & Stufkens 2002; Flynn et al. 2003).

The effect of regular insecticide treatment on increasing tree diameter suggests that insect herbivory does decrease tree growth over time, even when other symptoms of insect attack were largely absent. Due to low aphid populations during the study period, and the only partial removal of aphids from trees, it is unlikely *E. californica* was the only pest contributing to this effect. Other herbivores were also reduced by the insecticide, as illustrated by lower numbers of Lepidoptera larvae found in beating samples from insecticide-treated than untreated trees (data not shown).

This study provides no evidence that the presence of *E. californica* is related to upper crown yellowing. Upper crown yellowing observed in this study was most likely Upper Mid Crown Yellowing (UMCY) and possibly related to nutrient deficiencies (I. Hood, Scion, pers. comm.). However, higher aphid numbers at McLeans Island did correspond with a greater incidence of *C. minus* associated yellowing at that site. Wharton (2005) found evidence that wingless *E. californica* are preferentially attracted to yellow needles suggesting the aphids may be attracted to senescing foliage with its higher nutrient availability. Simpson (2000) suggested an association between *C. minus* and aphids may occur. This is based on the similarity in susceptibility of trees to both agents, that high numbers of *E. californica* can cause sooty mould with little needlecast evident, and the observation that *C. minus* ascocarp initials preferentially develop in *E. californica* feeding lesions in the laboratory. In addition, the greater severity of attack in Australia has been linked with drought stress, which favours the expression of *C. minus*. Drought stress has also been implicated in the susceptibility of trees to aphid attack (Carver & Kent 2000; Simpson 2000).

The higher number of *E. californica* recorded at McLeans Island most likely reflects the more suitable climate at this site, as projected by a CLIMEX model of climate suitability for *E. californica* (Wharton & Kriticos 2004). The model indicates that temperature at the North Island site is more favourable than the South Island; but the dominant rainfall patterns at the South Island site are more preferable for *E. californica* than at the North Island site (data not shown).

Wharton & Kriticos (2004) predicted that *E. californica* is likely to be a pest only in plantations in lower rainfall areas, although it can persist in other areas. *Essigella californica* numbers in south-eastern Australia have been recorded to be much higher than in New Zealand, with average counts of up to 500 to 750 aphids per beating sample (Wharton 2005) and high variability between years, stands and trees (May & Carlyle 2003). It is likely that low winter and spring temperatures and higher rainfall in New Zealand prevent *E. californica* populations from building to the damaging numbers seen in Australia. Based on the present findings as well as previous studies (Appleton & Gresham 2003; Teulon et al. 2003), *Essigella californica* is unlikely to attain major pest status in New Zealand under current climatic conditions. However, the predicted future climate (Mullan et al. 2008) indicates that some regions of New Zealand will experience conditions that are analogous to those areas in Australia where problems with *E. californica* exist. This suggests the aphid could become more problematical in the future. Whilst in this study numbers of *E. californica* (and other insects) were mostly low and few trees showed signs of upper crown yellowing that could have been caused by *E. californica*, the insecticide exclusion experiment indicated that insect herbivory still had an impact on *P. radiata* tree health and growth. It should be of considerable interest to explore the effects of climate change in New Zealand on the climate suitability for *E. californica*.

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