NEGATIVE ASSOCIATION BETWEEN CHORUS CICADA, *AMPHIPSALTA ZELANDICA*, AND ARMILLARIA ROOT DISEASE IN KIWIFRUIT

D.P. LOGAN[1] and P.A. ALSPACH[2]

[1]*HortResearch, 412 No. 1 Rd, Te Puke, New Zealand;*
[2]*HortResearch, Nelson Research Centre, PO Box 220,Old Mill Road, Motueka, New Zealand*

Corresponding author: dlogan@hortresearch.co.nz

ABSTRACT

Armillaria root disease is a serious fungal disease of kiwifruit that can ultimately end in the death of infected vines. One commercially-available treatment for infected vines is to inject compost teas into subsoil with compressed air. Compost teas are applied to improve soil and hence plant health, and their use is based on the generalisation that 'healthy plants have fewer pests'. Accordingly, there is a suggestion that healthy kiwifruit vines, free of armillaria root disease, support fewer cicadas. Exuviae of the dominant cicada species in kiwifruit, *Amphipsalta zelandica* (Boisduval), were counted and symptoms of armillaria root disease scored for 300 contiguous vines in a commercially-managed block of kiwifruit. More *A. zelandica* exuviae were found on healthy vines than on vines with symptoms of armillaria root disease and in this instance, the generalisation that 'healthy plants have fewer pests' was not true.
Keywords: cicadas, *Armillaria*, kiwifruit, organic.

INTRODUCTION

Armillaria root rot is a serious disease of woody plants in both temperate and tropical areas of the world. In New Zealand, armillaria root disease occurs in native and exotic forest (Hood & Sandberg 1987; Sweet 1989) and in kiwifruit and some shelterbelt species (Horner 1991). Kiwifruit vines infected with *Armillaria* lose vigour, shed leaves prematurely, can have stunted new season canes and small fruit, and often die. Horner (1991) identified the causal agent of armillaria root disease in kiwifruit as *Armillaria novae-zelandiae* (Stevenson) Herink. Once established on a vine, *A. novae-zelandiae* can infect adjacent vines and this leads to a strong spatial pattern of disease symptoms. Treatment of armillaria root disease in kiwifruit is based largely on preventative hygiene with removal of infected vines and shelter trees, and 'sluicing' to remove soil and expose the base of the vine bole (Horner 2006). A treatment for armillaria root disease promoted to growers is the application of compost teas following injection of compressed air into the subsoil, but this treatment is unproven scientifically. Compost teas, used by organic and some conventional producers, may restore or improve soil and plant health by encouraging the growth of beneficial soil flora (Scheuerell & Mahaffee 2002). Their use for the treatment of *Armillaria*-infected vines is based on the view that creating healthy soil will result in healthy plants with few pests and diseases.

A claim that kiwifruit vines with armillaria root disease tend to have high numbers of cicada nymphs is an extension of this view (Air8tors 2006; C. Umbers & C. Corney, unpubl. data). Cicadas are a minor and nuisance pest in kiwifruit. Egg laying results in damage to fruit-bearing canes; late-instar cicada nymphs damage roots by removing the epidermis and phloem tissue to gain access to xylem bundles. The most common cicada species in kiwifruit is the chorus cicada, *Amphipsalta zelandica* (Boisduval), a relatively large insect with final instar nymphs typically 20-25 mm in length (Logan & Connolly

2005). Feeding scars from nymphs can be substantial and it has been suggested that these areas may be infection sites for *Armillaria* (C. Umbers & C. Corney, unpubl. data).

Cicadas and armillaria root disease are present in the same blocks of kiwifruit at the HortResearch research orchard at Te Puke. As part of a spatial study of cicadas in kiwifruit at this site, the hypothesis that healthy kiwifruit vines have fewer cicada nymphs than *Armillaria*-infected vines was tested.

METHODS

The study site was a 0.75 ha block of kiwifruit cv. Hayward grown on Te Puke sandy-loam soil at the HortResearch research orchard at Te Puke. The block had a history of sporadic vine death associated with armillaria root disease. In March, each vine was scored for the following symptoms of armillaria root disease: (a) bark cracked at base of vine, (b) cracks with wet pulp under the bark, (c) weak, open canopy, (d) uniformly small fruit, (e) white mycelial growth present under trunk bark with detectable mushroom smell and (f) vine dead and/or without leaves and fruit. Severity of *Armillaria* infection was rated as '0' if vines showed none of the symptoms, '1' if they showed two of the first three symptoms, and '2' if three or more symptoms were found, particularly the presence of a distinct mushroom smell associated with white mycelium. At the same time, the number of fifth-instar exuviae of *A. zelandica*, and vine trunk circumference at breast height were assessed. Outer rows of the block were not included in the investigation as vine spacing differed from the internal rows. The study was carried out on contiguous vines, as counts of *A. zelandica* exuviae on any one vine are positively correlated with counts on adjacent vines (D.P. Logan, unpubl. data). Cicada exuviae were identified based on Logan & Connolly (2005) and were assumed to be from nymphs that had fed on the roots of the vine on which they were found. Vine trunk circumference was measured as a correlate for vine age as older vines are more likely to show symptoms of infection by armillaria root disease (Lung-Escarmant & Guyon 2004).

The spatial pattern and the inter-relationships between the variates were explored graphically. A randomisation test, with 10,000 random samples, was undertaken to test the hypothesis that cicada exuviae and *Armillaria* infection were correlated. Randomisation tests were used both because the residual plots were not satisfactory and because the data were not from a random sample (Ludbrook & Dudley 1998). All analyses were undertaken in R 2.4.1 (R Development Core Team 2006).

RESULTS

Although there was evidence of a spatial pattern in both numbers of *A. zelandica* exuviae and *Armillaria* infection scores, the two patterns did not appear to correspond (Fig. 1). Cicada numbers declined more or less linearly between rows 2 and 12, beyond which the numbers per row were approximately even (Fig. 2). No such pattern was apparent for *Armillaria* (data not shown), but rather there was a band of infection from the start of the first rows (bottom left in Fig. 1) to the end of the later rows (toward the top right in Fig. 1).

Plants with smaller circumferences (less than about 30 cm) did not support large cicada numbers, and rarely showed symptoms of *Armillaria* (Fig. 3). Thus, the randomisation test was conducted both on all plants, and excluding plants with circumference less than 30 cm. Higher levels of *Armillaria* were associated with lower mean numbers of *A. zelandica*, irrespective of whether or not the small plants were excluded (Table 1). This is contrary to the hypothesis, and was confirmed by the randomisation test: of the 10000 tests, only two gave the slope of the relationship between *Armillaria* severity and *A. zelandica* numbers less than that actually observed (all plants; none did so when the small plants were excluded).

To investigate whether or not the spatial patterns may have obscured the real relationship between the disease and the insect numbers, loess (local polynomial regression smoothing with the default settings in R 2.4.1) was used to fit the spatial patterns of insect numbers and disease severity separately. These fits confirmed the

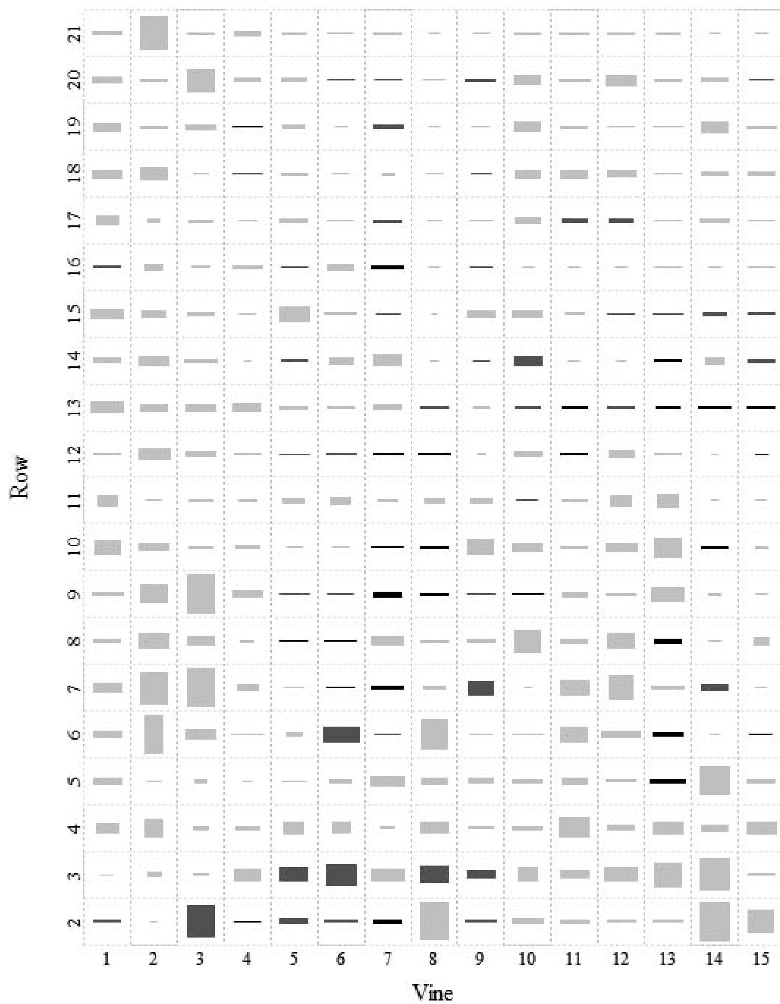

FIGURE 1: Representation of the spatial pattern of trunk circumference (box width), *Amphipsalta zelandica* numbers (box height) and *Armillaria* infection (box shading: 0 pale grey; 1 medium grey; and 2 black) for the 300 plants. A full width box represents a trunk circumference of 80 cm.

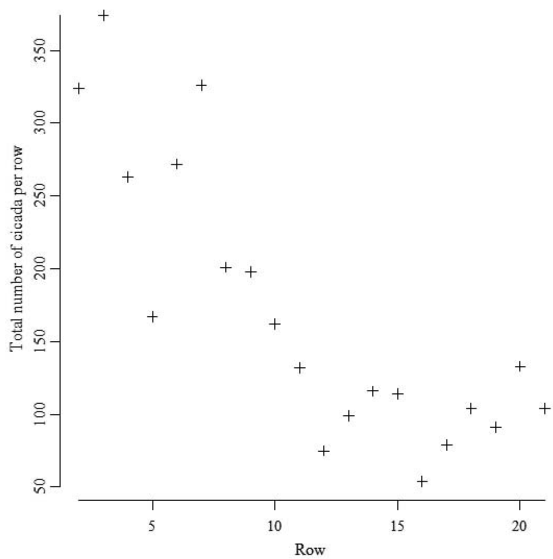

FIGURE 2: Scatter plot of the number of cicada (*A. zelandica*) per row on the row number. Note the decline between rows 2 and 12.

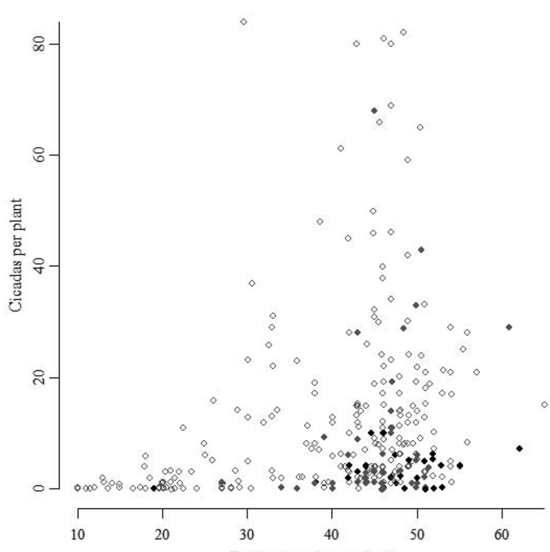

FIGURE 3: Scatter plot of the number of cicadas (*A. zelandica*) per plant on the trunk circumference (cm), coded to represent the severity of *Armillaria* infection (0 open circles; 1 filled grey circles; and 2 filled black circles).

trends noted previously. Residuals from these fits showed a similar association to that of the raw data, i.e. higher disease levels were associated with lower cicada numbers even after removing at least some aspects of the spatial patterns.

TABLE 1: Mean numbers of *Amphipsalta zelandica* exuviae per vine, and quantiles to show the skewed nature of the distributions, for each level of *Armillaria* severity. Means using all plants, and excluding smaller plants, are shown separately.

	Armillaria severity score		
	0	1	2
All plants			
Mean number of *A. zelandica*	12.8	8.3	3.3
Lower quartile	2	1	1
Median	7	3	3
Upper quartile	17	9	5
Excluding small (<30 cm) plants			
Mean number of *A. zelandica*	15.7	8.4	3.4
Lower quartile	4	1	1.3
Median	11	3	3.5
Upper quartile	21	9	5.0

DISCUSSION

The data do not support the hypothesis that healthy vines have fewer cicada nymphs than vines infected with *Armillaria*. Cicada nymphs feed on the xylem sap of roots. Any root death or reduction in root health, as occurs during advanced stages of armillaria root disease, may have a detrimental effect on cicada nymph growth and survival.

Although not the focus of the study, the data also suggest that vines with circumferences less than 30 cm do not support the development of many cicada nymphs. This may be because young vines have fewer suitable sites for egg-laying than mature vines, hence smaller initial infestations. Further, survival of nymphs to adults may be affected by the limited feeding sites of a relatively small root mass. The results of this investigation suggest that in kiwifruit orchards, highest numbers of chorus cicada nymphs are likely to occur on large vines free of root diseases. The study also supports the observation that older vines (=vines with relatively large circumferences) are more likely to show symptoms of infection by armillaria root disease (Lung-Escarmant & Guyon 2004).

This study examined a generalisation that ‘healthy plants have fewer pests’, which was found in this instance not to be true. Plant health is related to the physical, chemical and biological properties of soil. Empirical studies support the view that when plant nutrition is unbalanced, plant growth is favoured over plant defence, and herbivores benefit in enhanced development, survival and reproduction (Phelan et al. 1996; Phelan 1997; Herms & Mattson 1992). The example examined in this study was arguably a case of plant health affected by a serious disease and not by imbalances in nutrition. However, it demonstrates how a plausible generalisation can be inappropriately applied to a plant health problem as a result of a poor understanding of pest biology.

ACKNOWLEDGMENTS

Funds for this work came from HortResearch CF project 11: Landscape ecology. We thank Ian Horner for valuable comments.

REFERENCES

Air8tors 2006. Leading by innovation. www.air8tors.com (last accessed 28 May 2007).

Herms DA, Mattson WJ 1992. The dilemma of plants: to grow and defend. Quarterly Review of Biology 67: 283-335.

Hood I, Sandberg CJ 1987. Occurrence of *Armillaria* rhizomorph populations in the soil beneath indigenous forests in the Bay of Plenty, New Zealand. New Zealand Journal of Forestry Science 17: 83-99.

Horner IJ 1991. Epidemiology of Armillaria root-rot of kiwifruit. Acta Horticulturae 297: 573-578.

Horner IJ 2006. Control treatments for *Armillaria* in kiwifruit orchards: results of a four year trial. New Zealand Kiwifruit Journal, February. Pp. 5-7.

Logan D, Connolly P 2005. Cicadas from kiwifruit orchards in New Zealand and identification of their final instar exuviae (Cicadidae: Homoptera). New Zealand Entomologist 28: 37-48.

Ludbrook J, Dudley H 1998. Why permutation tests are superior to *t* and *F* tests in biomedical research. The American Statistician 53: 127-132.

Lung-Escarmant B, Guyon D 2004. Temporal and spatial dynamics of primary and secondary infection by *Armillaria ostoyae* in a *Pinus pinaster* plantation. Phytopathology 94: 125-131.

Phelan PL, Norris KH, Mason JF 1996. Soil management history and host preference by *Ostrinia nubilalis*: evidence for plant mineral balance mediating insect-plant interactions. Environmental Entomology 25: 1329-1336.

Phelan PL 1997. Soil-management history and the role of plant mineral balance as a determinant of maize susceptibility to the European corn borer. Biological Agriculture & Horticulture 15: 25-34.

R Development Core Team 2006. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-00051-07-0, URL http://www.R-project.org.

Scheuerell S, Mahaffee W 2002. Compost tea: Principles and prospects for plant disease control. Compost Science & Utilization 10: 313-338.

Sweet GB 1989. Maintaining health in plantation forests. New Zealand Journal of Forestry Science 19: 143-154.