EVALUATION OF ALTERNATIVES TO PHOSPHOROUS ACID CONTROL OF PHYTOPHTHORA ROOT ROT

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ABSTRACT

Avocado root rot caused by the soil fungus *Phytophthora cinnamomi* is common in New Zealand avocado orchards but can be controlled through the use of fungicides. The most common treatment is labour intensive as an injection into the trunk, via a plastic syringe, a concentrated solution of phosphorous acid. An alternative to injecting with syringes that is less labour intensive would be of benefit to avocado growers. For better delivery of phosphorous acid a high pressure injecting system has been developed where the phosphorous acid normally applied with dozens of syringes can be delivered in a single injection. This study examined injecting mature Hass avocado trees with Stemex Stemshot AV1™ compared to syringes using HiPK™. Other chemicals have been proposed for control of phytophthora root rot that may be less expensive or more effective than phosphorous acid. Stemex Stemshot AV2™, a proprietary mixture of nutrients, and soluble forms of silicon soil drenches were evaluated against phosphorous acid. Hass avocado trees located in a severely Phytophthora infected site were treated and the health of the canopy and proportion of diseased roots followed for 13 months. The untreated control trees Phytophthora symptoms got worse during the trial. Injection of HiPK™ or Stemshot AV1™ showed a consistent trend to an improved canopy health after 13 months. The Stemshot AV2™ and silicon soil drench treatments 13 months after treatment canopy rating was the same as at the six month assessment. Thirteen months after treatment feeder root decay in the HiPK™ treatment continued to be reduced compared to the control. The silicon, AV1 and AV2 treatments had similar feeder root decay to the control. The two different methods of applying phosphorous acid gave similar results, implying either method was suitable for effective Phytophthora control. The silicon soil drenches and injecting the trees with a nutrient solution (Stemshot AV2™) appeared to have little effect on the tree canopy rating. There was a positive beneficial effect on tree canopy rating and a reduction in percentage feeder root decay when mulch was applied. Using mulches and phosphorous acid treatments in combination would be a useful subject for further study.

Keywords: HiPK™, Stemshot AV1™, Stemshot AV2™, silicon, high pressure injection

INTRODUCTION

Avocado root rot caused by the soil fungus *Phytophthora cinnamomi* is common in New Zealand avocado orchards (Horner and Jensen, 2004). The symptoms of avocado trees infected with Phytophthora root rot are a gradual decline in growth where the foliage becomes sparse at the tops of the tree and branch die back can occur (Pak and Everett, 2001). The decline in tree health can also have the effect of reducing fruit size and tree yield. Very effective control of Phytophthora root rot can be achieved through the use of fungicides. The most common is injecting into the trunk a concentrated solution of phosphorous acid (Horner and Jensen, 2004). Following trunk injection phosphonate moves up the tree into the leaves before moving downwards to the roots (Pegg *et al*., 2002). Correct timing of injection is important to target feeder root flushes. The injection of phosphorous acid is by drilling holes in the trunk and inserting one plastic syringe per metre of canopy diameter (Pak and Everett, 2001). Large avocado trees may require 20 syringes or more. To insert the syringes into the trunk involves drilling

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holes low to the ground. To properly treat the trees it is necessary to crawl under the canopy to the trunk. For many avocado growers crawling around on their hand and knees under avocado trees is tedious and stressful on backs and joints and a major labour cost. An alternative to injecting with syringes as a treatment to control Phytophthora that is less labour intensive would be of benefit to avocado growers.

Phosphorous acid has good efficacy against Phytophthora root rot (Faber and Downer, 2007; Giblin *et al.*, 2007) but could be delivered by a better method than multiple syringes. To achieve better delivery a high pressure injecting system has been developed where it is claimed that all of the phosphorous acid normally applied with dozens of syringes can be delivered in a single injection. Injection of phosphorous acid using a high pressure system has not been evaluated in an independent replicated trial in New Zealand. In the study reported here injecting mature Hass avocado trees located in a site with high phytophthora pressure with Stemex Stemshot AV1™ at label rates was compared to injecting trees with syringes using HiPK™ (Aongatete coolstore) at label rates.

From time to time other chemicals are proposed to control phytophthora root rot that may also give good control but be less expensive or more effective than phosphorous acid. There is the possibility that Phytophthora could build up resistance to phosphorous acid (Duvenhage, 1994; Duvenhage and Kohne, 1997) therefore alternative chemical choices are a good idea to expose the Phytophthora fungus to different chemicals; minimising the build up of resistant populations. Stemex Stemshot AV2™ is a proprietary mixture of nutrients for application to Phytophthora affected avocado trees that has been claimed to help avocado trees recover full health. Soluble forms of silicon applied as soil drenches have been reported to suppress plant diseases in crop plants (Epstein, 1999). The effect of silicon on suppressing avocado root rot in New Zealand is not known. Most of the recent research on silicon and avocados has been conducted in South Africa where soil drenches of 5,405ppm silicon dioxide (20L solution of 20ml per L 20.7% soluble potassium silicate) suppressed Phytophthora and increased root density in nursery avocado trees (Bekker *et al.*, 2005). The 20ml per L concentration was determined from laboratory studies on fungi grown on agar (Kaiser *et al.*, 2005). Although over 5,000ppm soluble silicon was determined in these preliminary studies to be effective the cost of silicon needed for a 20 L per tree drench would be prohibitive at $20-$30 per tree for the silicon alone. To evaluate the possible effect of a silicon treatment at a more economical rate a soil drench of 100 and 200ppm elemental silicon was applied.

To determine the efficacy of Stemex Stemshot AV2™ and silicon soil drenches as alternatives to phosphorous acid 'Hass' avocado trees located in a severely Phytophthora infected site were treated and the health of the canopy and proportion of diseased roots followed for 13 months.

MATERIALS AND METHODS

Thirty-six 'Hass' on 'Zutano' seedling rootstock trees severely affected by Phytophthora root rot in an orchard located near the Bethlehem area of Tauranga were randomly assigned to one of six treatments. Individual trees were categorized into tree size (large, medium and small), if they were irrigated and if the tree had been mulched with horse manure from a stable. These categories were then accounted for in the statistical analysis. Mulch in the form of hay and horse manure was added to all the trees 2 to 3 months after treatment. Further mulch as added to selected trees 10 to 12 months after treatment.

The following treatments were applied to individual trees, a total of six trees per treatment, as per label rates and/or the manufacturer's instructions:

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1) No treatment
2) HiPK™ (20% phosphorous acid) applied using syringes
3) Sodium metasilicate 100 ppm a.i. soluble Si as a 30 L/tree soil drench
4) Sodium metasilicate 200 ppm a.i. soluble Si as a 30 L/tree soil drench
5) AV1 applied with Primaxa injector as per manufacturer's instructions
6) AV2 applied with Primaxa injector as per manufacturer's instructions

Tree health assessments

The canopy of each tree was rated for tree health according to a Ciba-Geigy scale (Darvas *et al*., 1984) where 0 was a perfectly healthy tree and 10 was a dead tree. Each individual tree was photographed and the canopy health rated three times, the day the treatments were applied (19/4/2007, the autumn root flush), six months after treatment (30/10/2007, the spring root flush) and 13 months after treatment (15/5/2008). Canopy health was rated off the photographs.

Feeder root health assessments

At each tree health assessment four feeder root samples were taken at cardinal points around each tree. The sample holes were 150mm diameter and 150mm deep. Feeder roots were collected from the soil sample and separated as either live and healthy or diseased and dead until all the feeder roots had been collected or five minutes had elapsed, whichever came sooner. In the laboratory the roots were stored at -18°C until the root tips were counted.

Data was analysed using the general linear models analysis of variance function of MINITAB version 13.31. The statistical model used allowed for the effect of the tree categories size, irrigation and mulch on canopy health rating to be accounted for separate from treatment effects. Treatment effects on tree canopy health was analysed for each assessment time separately.

RESULTS

The trees used in this trial displayed a range of symptoms usually associated with Phytophthora root rot. The trees at the start of the trial had moderate to severe defoliation that depended on the location within the planted area. There was no statistical difference between the canopy rating of treated trees and the untreated control at six months or 13 months after treatment (Table 1). The untreated control trees canopy rating tended to increase over the duration of the trial indicating that the Phytophthora symptoms were getting worse. Injection of HiPK™ or Stemshot AV1™ trees had either no or only a slight improvement in canopy health rating after six months but showed a consistent trend to a lower canopy rating after 13 months demonstrating a general improvement in tree health (Table 1). The Stemshot AV2™ and silicon soil drench treatments had an increased canopy rating six months after treatment indicating poorer tree health. However, 13 months after treatment the trees in the Stemshot AV2™ and silicon 100ppm treatment canopy rating was the same as at the six month assessment (Table 1). The canopy rating for the silicon 200ppm treatment was lower at 13 months than at six months after treatment.

The change in canopy health rating was greatest for the Stemshot AV1™ and HiPk™ treated trees (Figure 1). The canopy health of these trees continued to improve over time and by 13 months after treatment had improved by 1.6 to 1.8 points on the rating scale. The silicon 200ppm drench trees also improved from six months to 13 months (Figure 1). While there was no improvement in the canopy health rating for the Stemshot AV2™ and silicon 100ppm treatments the canopy health did not get worse. The untreated control trees canopy health rating declined over the assessment period (Figure 1).

The trees that had been mulched had a better canopy rating at the start of the trial than unmulched trees (p = 0.011) and were almost significantly different 13 months after the

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Table 1. Average canopy disease rating at treatment, six months and 13 months after treatment.

Treatment	19/4/2007	30/10/2007	15/5/2008
Control	5.7[1]	6.0	6.3
HiPK™	5.3	5.3	4.5
Stemshot AV1™	6.0	5.8	4.7
Stemshot AV2™	5.5	5.8	5.8
Silicon 100ppm	5.5	6.3	6.3
Silicon 200ppm	6.2	6.2	5.7
Average	**5.7**	**5.9**	**5.6**

[1]Trees were rated on the Giba-Geigy scale of 0 (perfectly healthy) to 10 (dead).

treatments had been applied (p = 0.07). The trees six months after treatment had all been mulched therefore it was not possible to analyse an effect of mulching on canopy tree health. Interactions between mulching and treatment were not significant. Tree size and the presence or absence of irrigation was not related to the canopy rating.

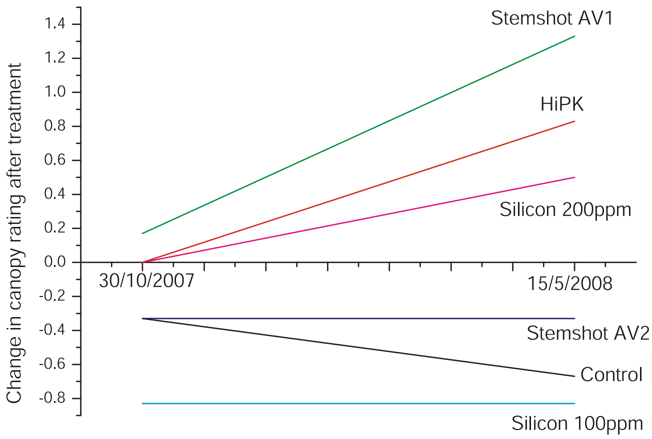

Figure 1. Change in canopy health rating at six and 13 months after treatment from the initial canopy health rating.

AV1 and AV2 treatments had similar feeder root decay to the control. The canopy health rating was correlated to the percentage feeder root decay (r^2 = 0.424, p = 0.01) (Figure 3).

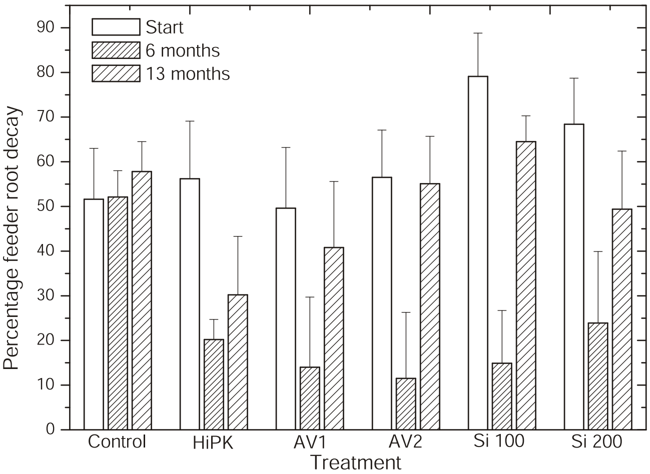

Figure 2. Average feeder root decay at each assessment of trees treated for Phytophthora root rot.

Six months after application of treatments feeder root decay, as indicated by the percentage of unhealthy roots, although not statistically significant, was reduced in all treatments compared to the control (Figure 2). Thirteen months after treatment feeder root decay, although increased compared to the six months assessment, in the HiPK™ treatment continued to be reduced compared to the control. The silicon,

DISCUSSION

Although the treatments for Phytophthora were not significantly different in their canopy rating or percentage of feeder root decay there were clear trends where the severity of Phytophthora symptoms were reduced (Figure 1). Treatments that included phosphorous acid had the greatest effect on Phytophthora symptoms with the silicon

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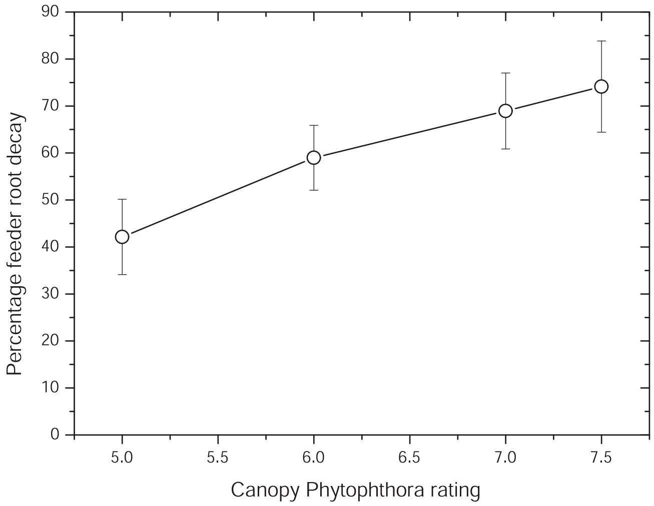

Figure 3. Relationship between the canopy health rating and percentage feeder root decay. Vertical bars represent the standard error of the mean percentage feeder root decay.

and Stemshot AV2™ treatments an intermediate effect. Compared to the control, where the Phytophthora symptoms tended to get worse, all the treatments showed trends that either maintained the tree canopy rating or improved the tree canopy rating. The benefits of treating the trees with phosphorous acid appeared to last longer than a year despite the trees receiving no further treatments. It is possible that an additional phosphorous acid treatment could have been beneficial in further improving the tree canopy rating.

The method of applying phosphorous acid, by low pressure syringes or high pressure injection, did not appreciably affect the improvement in tree canopy rating. With respect to feeder root decay the HiPK™ treatment tended to have the lowest percentage feeder root decay 13 months after treatment. Therefore, either method of applying phosphorous acid to the trees should give similar results in improving the tree canopy rating and reducing feeder root decay. The Stemshot AV2™ and silicon treatments had similar feeder root decay levels to the untreated control trees after 13 months and did not appear likely to improve the tree canopy rating or reduce feeder root decay.

Using a system of rating the canopy for Phytophthora symptoms gives a useful indication of the severity of feeder root decay. Identifying Phytophthora affected trees from their canopy health is therefore a useful method for avocado growers to assess the amount of Phytophthora affected trees in their orchard.

In this trial the treatments for Phytophthora were not ideal as they were in April near the end of the summer root flush. Timing the treatments to spring or in February may have given a greater difference between treatments (Whiley *et al.*, 1992). However, feeder root flushes have been measured in April under avocado trees in the Tauranga area suggesting that the treatments would have been useful even in April as it was likely that there were new roots coming into winter. When collecting root samples for assessment of percentage feeder root decay, new white feeder roots were found in the mulch and soil under the trees in the study.

The silicon soil drenches appeared to have little effect on the tree canopy rating. The silicon treatment evaluated was a single soil application. South African research (Bekker *et al.*, 2007) has suggested that repeated applications of silicon to the soil are needed to have a useful fungicidal effect on Phytophthora symptoms. Applying silicon multiple times may have been more effective. Injecting the trees with a nutrient solution (Stemshot AV2™) did not appear to be a useful treatment to improve the tree canopy rating but may hold the trees from getting worse. The possibility exists that the timing of treatment was wrong for Stemshot AV2™ injection and that careful consideration tree phenology when applying Stemshot AV2™ is required. There was a positive beneficial effect on tree canopy rating and percentage feeder root decay when mulch was applied. This study did not examine the combination of mulch and Phytophthora treatments for best improvement in tree health. Using mulches and phosphorous acid treatments in combination would be a useful subject for further study.

This study adds to the body of research reports that confirms the value of phosphorous acid as a fungicide treatment for Phytophthora infection in avocado trees. There is a further suggestion that mulches could further improve avocado tree root health.

CONCLUSIONS

Applying phosphorous acid either by low pressure syringes or with a high pressure injection was effective in improving tree canopy health and maintaining lower feeder root decay 13 months after treatment compared to no treatment and treatment with silicon or injecting with nutrients. Based on this study phosphorous acid treatment remains the most effective means of controlling Phytophthora infection.

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