Evaluation of alternative methods to stem injections to apply phosphonate to avocado trees for *Phytophthora* control, i.e. bark and soil penetrants to enhance phosphonate uptake

Final report

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ABSTRACT

Phytophthora cinnamomi causes necrosis of roots and necrotic lesions in the trunk and stem, leading to shoot-dieback or crown-death on a wide range of hosts. Chemical control of root rot with phosphite is achieved by the direct fungistatic action and/or an indirect mechanism of action. In this study the efficacy of phosphonate/bark penetrant trunk application (spray application), as well as soil drench to that of trunk injections for the control of avocado root rot on an 11-year old 'Hass' avocado orchard in Politsi, South Africa, was evaluated over a 2-year period (October 2012 – April 2014). Soil samples collected from the trial block tested positive for *Phytophthora* spp. Trees were rated before the commencement of treatments and again 18 weeks later in the first season. Trees were rated from October 2012 until June 2013 and again from December 2013 until April 2014 (rating scale 0 – 10, where 0 = very good health and 10 = dead tree. Initial tree health ratings ranged from 4.25 to 5.25 (0 being optimum tree health and 10 being tree death) and after 18 weeks and the untreated control was the only treatment where tree ratings increased, whereas all trees treated with the different phosphonate treatments showed decreasing ratings, with values between 0.125 and 0.875 indicating that there was improved tree health. In the second season all the treatments showed an increase in tree ratings, except for two treatments which remained constant. When season one and two were compared to each other, it was found that most of the treatments showed an increase in tree ratings. Only two treatments showed a decrease in tree ratings. The rest of the phosphonate treatments and the untreated control showed a decrease in tree health with rating values that increased between 0.125 and 0.5. At the end of season two, all treatments showed a significant increase in tree ratings, indicating that the overall health of all the treatment trees decreased. According to statistical analyses, ratings at the end of season one and start of season two did not differ significantly, but ratings at the end of season two did differ significantly from the previous ratings. It might be necessary to test the use of phosphonates for another season to obtain more conclusive results. It is important to also take into account the state of the trees, disease pressure and changing environmental conditions, as these factors play a role in how effectively the phosphonate applications will work.

OBJECTIVES

To compare the efficacy of phosphonate/bark penetrant trunk application (spray application), as well as soil drench, to that of trunk injections for the control of avocado root rot under South African conditions.

INTRODUCTION

Phytophthora cinnamomi is a soil- and water-borne plant pathogen with a wide host range throughout the world. *Phytophthora cinnamomi* invades the roots and/or collars of its hosts, causing symptoms such as necrosis of roots, cankers and necrotic lesions in the trunk and stem, which often leads to shoot-dieback or crown-death (Zentmyer, 1980).

Management of this disease relies heavily on chemical control, namely with phosphite (H_3PO_3), a neutralised solution of the phosphonate anion (Fenn & Coffey, 1984). H_3PO_3 is not metabolised and so remains in the plant tissue for a considerable time, months to years depending on the plant species (Guest & Grant, 1991). Invading *P. cinnamomi* mycelium may be inhibited by the direct fungistatic action of H_3PO_3, yet, H_3PO_3 concentrations found in plant tissues are often well below concentrations found to be fungistatic *in vitro*, thus an indirect mechanism of action must also be invoked (Guest & Grant, 1991).

A study done by Tynan *et al.* (2001) indicated that foliar applications of phosphite remained effective for five to 24 months in native Australian plant spp. and Shearer & Fairman (2007) showed that when *Banksia* spp. were treated with phosphite, by stem injections or foliar sprays, phosphite effectiveness persisted two years for foliar applications and four years for stem injections. Similar observations with cherry trees by Wicks & Hall (1988) indicated that the foliar sprays were not as persistent as stem injections, yet they concluded that foliar sprays were less phytotoxic and were the most economical means for phosphites applications. Fosetyl-Al and potassium phosphonate applied to avocado trees as foliar sprays, have also indicated prolonged effective levels up to eight weeks (Ouimette & Coffey, 1989).

The use of bark penetrants in combination with phosphonates increases the uptake of the chemical significantly in woody plant species (McComb *et al.*, 2008). Garbelotto *et al.* (2007) also showed that the bark applications on coastal oak to control sudden oak death were effective only when a bark penetrant was added. The effect of silicon on *Phytophthora* root rot varies and it is not recommended in Australia for this purpose (Australian Avocado Industry Report, 2005 – 2006), whereas Bekker *et al.* (2007) found potassium silicate to have a positive effect on *Phytophthora* root rot control during dryer periods.

The following was written in the Australian Industry report regarding the application method: *"After the discovery that injection of trees with phosphorous acid can inhibit feeder root growth if applied at the commencement of root flush, we compared injections with trunk sprays for control of root rot. When injected, most of the phosphorous acid travels down to the roots. The concentration in the roots is relatively high and, therefore, inhibitory. When sprayed onto the trunks, a lower, but more consistent supply to the roots, with little or none was ending up in the canopy. Levels in the roots are sufficient to see recovery in severely affected trees."* – Australian Avocado Industry Report, 2005 – 2006.

The efficacy of soil drench applications, as found by QMS and the minimal labour involved, also prompted an interest in registration of phosphonates as soil drench via irrigation. As mentioned, this practice is already in place in some production areas and has been done for many years with success by some citrus producers. A fear exists that *Phytophthora* will become resistant against phosphonates if applied as a soil drench (Lucas McClain, personal communication), either directly or indirectly by less induced resistance. This possibility has been investigated by Dobrowolski *et al.* (2008) in Australia. Their results indicated that prolonged use of phosphonates in orchards does select isolates of *P. cinnamomi* less sensitive to phosphite *in planta* as indicated by more extensive colonisation of phosphite treated plant tissue by isolates from orchards than from strains where phosphonates had never been used. However, the isolates used came from orchards where either stem injections or foliar applications have been done. The decrease in sensitivity was minor and *P. cinnamomi* has a low evolutionary potential. Whether soil application will enhance this potential is not known and has been discussed as early as 1997 (Weinert *et al*., 1997).

In our earlier work with phosphonates on avocado nursery trees in bags, we found the Ammonium Phosphonate superior to Potassium Phosphonate products as a soil drench and it was also suggested by the suppliers as a soil drench (Dr Steve Engelbrecht, personal communication). Soil application rates will be based on those used in citrus where the dosage and number of applications per annum is based on canopy size. The maximum application rate for a 200 g a.i. per L will not exceed 62 g/tree (old big trees), unlike the rate of 2640 g/m^2 as suggested by Kaiser & Whiley (1998).

Literature shows that phosphonates can be applied to avocado trees effectively as a surface trunk spray or soil drench to control *Phytophthora* root rot when mixed with an appropriate penetrant, thus without the negative effects of trunk injections. This may have huge financial benefits to the South African avocado industry.

Table 1. Treatments and dosage rates applied throughout the trial block.

Treatment number	Treatment description	Product	Application method	Active ingredient (ml/tree)
1	Untreated control	-	-	-
2	Trunk injections	Avoguard	Injections	3 x 5 ml
3	Brilliant (1X) + Link (1X)	Brilliant 300SL + Link	Bark spray	17 + 0.3 in 300 ml water
4	Brilliant (2X) + Link (2X)	Brilliant 300SL + Link	Bark spray	34 + 0.6 in 300 ml water
5	Brilliant (1X) + AnnGro (1X)	Brilliant 300SL + AnnGro	Bark spray	17 + 0.7 in 300 ml water
6	Brilliant (1X) + AnnGro (1X)	Brilliant 300SL + AnnGro	Soil drench	24 + 1 in 10 L water
7	Brilliant (1X) + FoliarComplex	Brilliant 300SL + FoliarComplex	Soil drench	24 + 4.8 in 10 L water

MATERIALS AND METHODS

The trial was conducted in an avocado orchard in Politsi. The orchard consisted of 11-year old 'Hass' trees that showed signs of decline. Soil samples were collected from the trial block and were tested for the presence of *Phytophthora* spp. by using the soil bait test. Trees were rated before the commencement of treatments and again prior to the second trunk injection (18 weeks later). Single tree plots were randomized throughout the trial sight. Each of the 7 treatments (Table 1) was replicated 8 times. The first round of applications commenced the 10th of October 2012. Bark sprays and soil drenched were applied at six week intervals (rain dependent). The trial was repeated for a second season, starting October 2013 and would continue until June 2014.

RESULTS AND DISCUSSION

Soil collected from the trial block tested positive for the presence of *Phytophthora* spp. Trees were initially rated on 8 October 2012, before treatments began. Ratings range from 0 – 10, with 0 being optimum tree health and 10 being tree death. Trees were rated 18 weeks later (Fig. 1). The ratings ranged from 4.25 to 5.25. After 18 weeks tree improvement/decline could be observed. The untreated control was the only treatment where tree rating increased (from 4.63 to 4.88). All other treatments showed that phosphonate applications (injections, bark sprays and soil drenches) improved tree health, with rating values decreasing between 0.125 and 0.875 (Fig. 2). Treatments that differ significantly from each other are indicated by different letters. Treatment 1 differs significantly from treatments 3 and 7, although none of the other treatments differ significantly from each other.

When comparing tree ratings from the end of season one and the beginning of season two, two treatments show a decline in ratings. Treatments 4 and 6 show slightly lower tree ratings in season two than in season one. Treatments 1, 2, 3 and 7 showed higher ratings in season two than in season one, with treatment 5 having the highest increase in tree rating between the two seasons (Fig. 3).

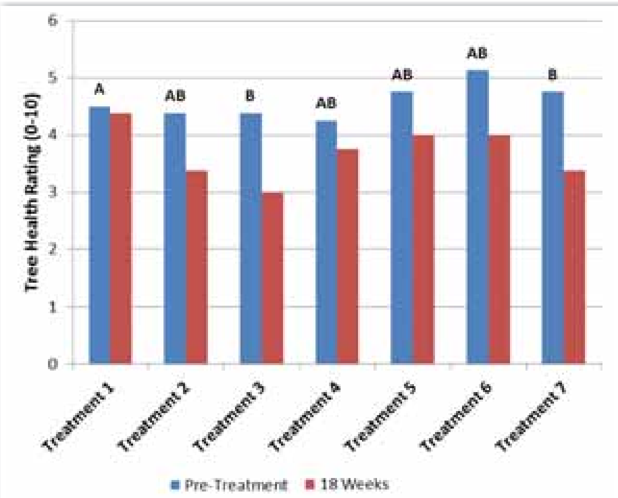

Figure 1. Comparison of tree health ratings before treatments and 18 weeks into the treatment programme.

Only treatments 4 and 6 showed a decrease in tree ratings. Treatment 4 decreased from 3.750 to 3.125 and treatment 6 decreased from 4.0 to 3.625. The rest of the phosphonate treatments and the untreated control showed a decrease in tree health, with rating values increasing between 0.125 and 0.5 (Fig. 4). There were statistically, however, no signifi-

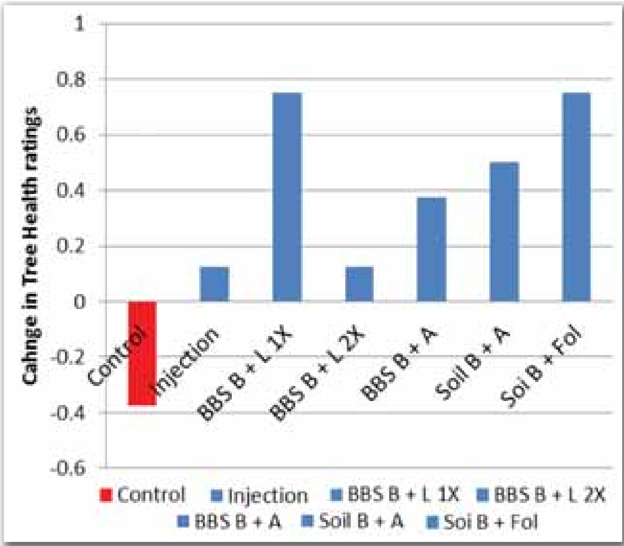

Figure 2. Change in tree health from beginning of season to 18 weeks into the phosphonite treatments.

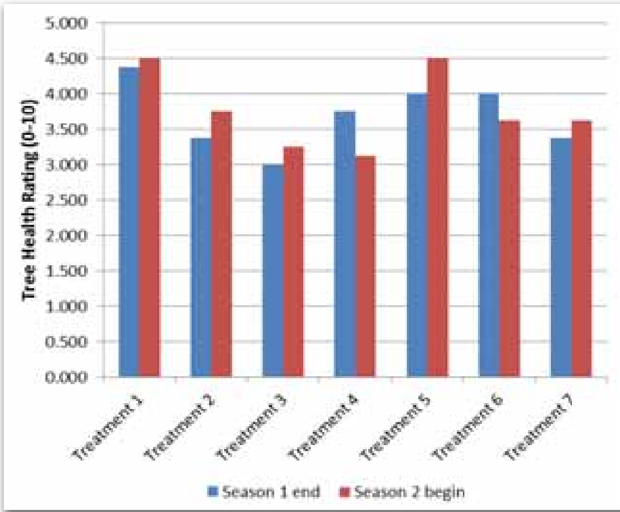

Figure 3. Comparison of tree health between the end of season one and the beginning of season two.

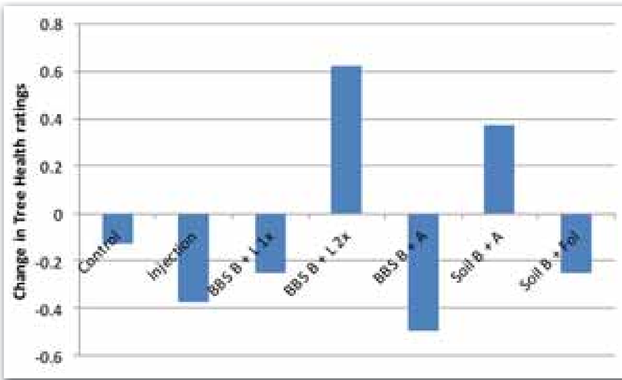

Figure 4. Change in tree health from the end of season one to the beginning of season two.

cant differences between ratings at the end of season one and the start of season two.

In season two all the treatments, except treatments 2 and 5 which remained constant, showed an increase in tree ratings. This indicates that the overall tree health for most of the treatments declined. The decline in tree health could be a due to increased environmental stress experienced during the season, such as extended wet periods (Fig. 5). No significant differences were found between the rating at the start and in the middle of the second season.

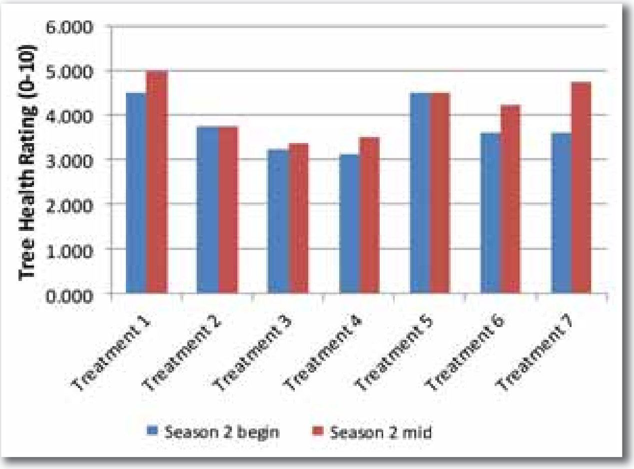

Figure 5. Comparison of tree health ratings taken at the beginning and in the middle of season two.

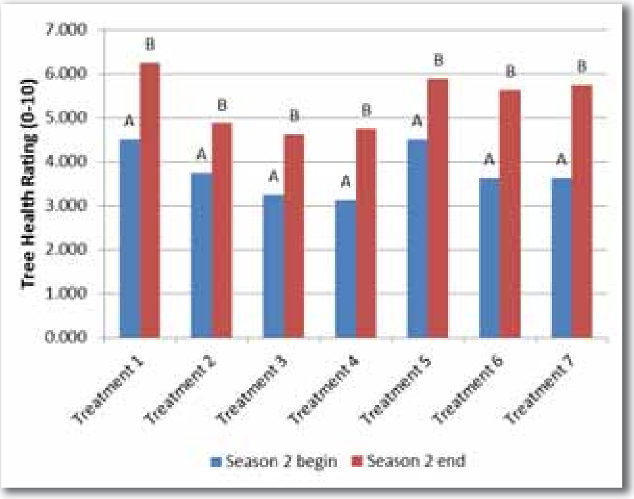

Figure 6. Comparison of tree health ratings taken at the beginning and end of season two.

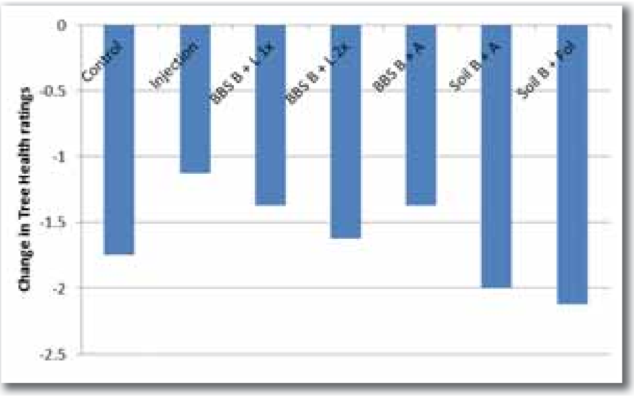

Figure 7. Change in tree health from the beginning until the end of season two.

A month after the final phosphonate treatments were applied, the trees were evaluated and rated for the last time in the second season. Ratings from the beginning of the second season were compared to those from the end second season. As shown in Figure 6, all treatments' tree ratings increased. The untreated control average tree rating increased from 4.5 to 6.25. Treatment 2 had the lowest increase in average tree rating from 3.75 to 4.875, thus increasing by only 1.125. Treatment 3 increased from 3.25 to 4.625, treatment 4 increased from 3.125 to 4.75 and treatment 5 increased from 4.5 to 5.875. Treatments 6 and 7 showed the second highest and highest increase in average tree rating, respectively. Treatment 6 increased from 3.625 to 5.625 and treatment 7 increased from 3.625 to 5.75. At the beginning of the second season, no significant differences exist between treatments. This was again seen at the end of season two. There was a significant difference between the average tree ratings at the start and the end of the season. The decline in tree health continued from the start of the second season gradually until in the middle of the season, after which overall tree health of all the treatments declined drastically. The change in tree ratings is shown in Figure 7.

Comparisons between the average tree ratings at different stages of the two seasons were summarised in Figure 8. Ratings at the end of season one and the beginning of season two were not significantly different, although treatments four and six show a decline in tree ratings, indicating that the health of these trees did improve. The ratings at the end of season two is significantly different from those made at the end of season one and the beginning of season two.

The final rating evaluation was made near the end of harvest (a very dry period), a month after the last phosphonate treatments were applied. These factors most likely play a role in the sudden decline in tree health. According to Dr McLeod (Stellenbosch University), phosphonate levels in the roots underwent a drastic decline as well during this time. Whether or not a third season of phosphonate applications

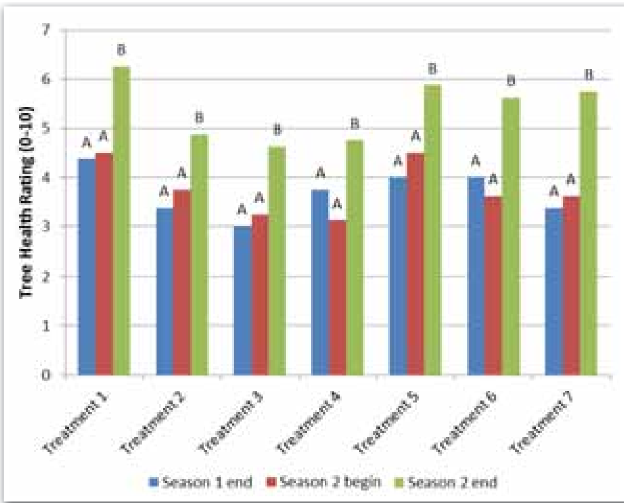

Figure 8. Comparison of tree health ratings taken at the end of season one and beginning and end of season two.

will yield more conclusive results, is uncertain. It is important to also take into account the state of the trees, disease pressure and changing environmental conditions, as these factors play a role in how effectively the phosphonate applications will work.

ACKNOWLEDGEMENTS

We thank the South African Avocado Growers' Association for financially supporting this project, as well as Tony and Graeme Lunt for allowing us to conduct the trial on Boschoek Farm.

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