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

Preliminary report

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ABSTRACT
Phytophthora cinnamomi causes necrosis of roots and necrotic lesions in the trunk and stem, leading to shoot die-back 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. Stem injections have been shown to be effective application of phosphite, yet literature indicates that bark sprays and soil drenches with the addition of penetrants can also be effective against root rot. The aim of this study was 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. The trial was conducted in an 11 year-old 'Hass' avocado orchard in Politsi, Limpopo Province. 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. The first two ratings for the second season have also been completed. Seven treatments, replicated eight times, were applied at six week intervals for the first season. The trial continued into the second season with the same treatments being applied in the same manner as for the first season, replicated six times. Initial tree ratings ranged from 4.25 to 5.25. After 18 weeks the untreated control was the only treatment where tree ratings increased, whereas all other 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 increasing to between 0.125 and 0.5. These are only preliminary data for season two. The trial will run until June 2014.

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. *P. 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 die-back 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 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.. Shearer and 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 and 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 has 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 exist 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. 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./L will not exceed 62 g/tree (old big trees), unlike the rate of 2640 g/m^2 as suggested by Kaiser and 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 randomised throughout the trial site. Each of the seven treatments (Table 1) was replicated eight times. The first round of applications commenced the 10th of October 2012. Bark sprays and soil drench were applied at six week intervals (rain dependent). The trial was repeated for a second season, starting October 2013, and will 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 the 8th of October 2012, before treatments began. Trees were rated 18 weeks later (Fig. 1). These ratings ranged from 4.25 to 5.25 (all statistics to be done on completion of the trial). 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).

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 due to increased environmental stress experienced during the season, such as extended wet periods (Fig. 3).

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. 4).

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

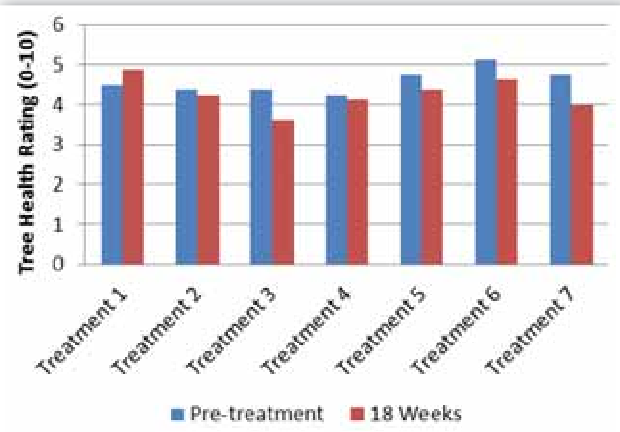

Figure 1. Comparison of tree health ratings before treatments and 18 weeks into the treatment programme.

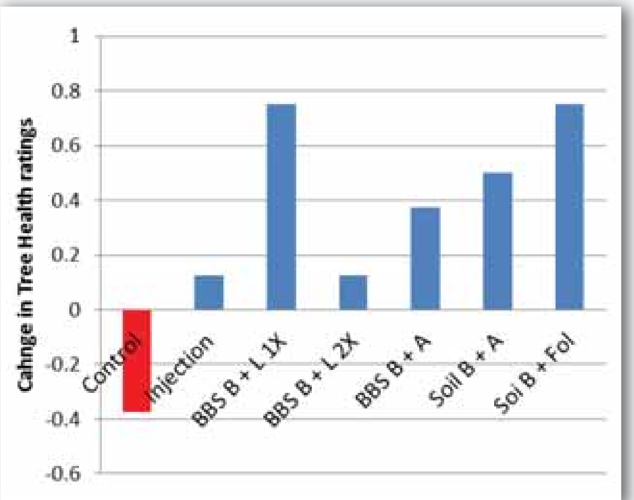

Figure 2. Change in tree health from beginning of season to 18 weeks into the phosphonite treatments.

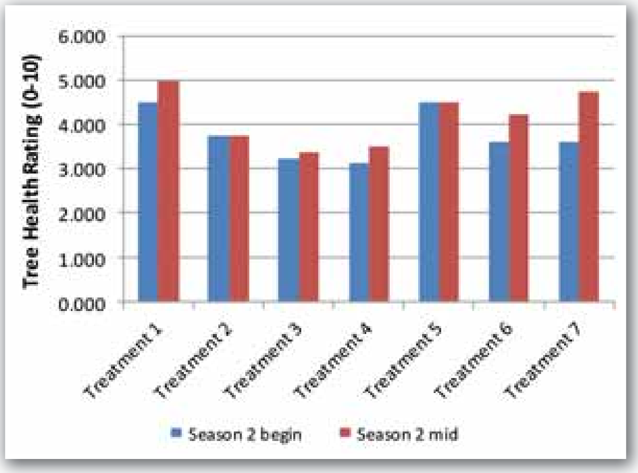

Figure 3. Comparison of tree health ratings taken at the beginning and in the middle of season two.

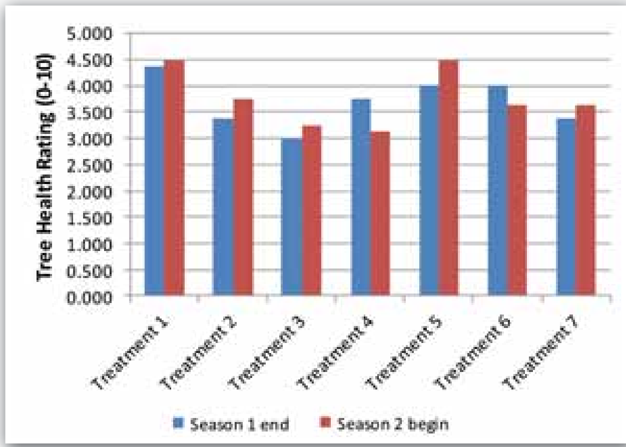

Figure 4. Comparison of tree health between the end of season one and the beginning of season 2.

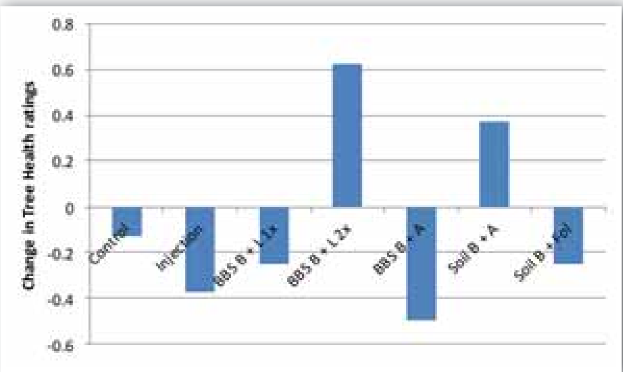

Figure 5. Change in tree health from the end of season one to the beginning of season two.

control showed a decrease in tree health, with rating values increasing between 0.125 and 0.5 (Fig. 5).

The treatments for the second season will run until June 2014 and the data discussed in this report is only preliminary for the second season. Final results will be obtained at the end of the season. Continuation of the trial will be discussed and decided at the end of the second season after final data analysis.

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