Bark and soil penetrants used in alternative application methods of phosphonate for the control of Phytophthora root on avocado

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ABSTRACT

Different application methods of phosphonates were evaluated, including a phosphonate/bark penetrant trunk application (spray application), soil drenching and trunk injections for the control of root rot caused by *Phytophthora cinnamomi* in avocados. The trial was conducted in an 11-year old 'Hass' avocado orchard in Politsi, naturally infected with *Phytophthora* spp.. The trial was conducted over approximately three and a half seasons and tree ratings (ratings – 0=very good health – 10=dead) were taken at specified intervals. When season one and two were compared to each other, it was found that most of the treatments showed an increase in tree ratings indicating increased tree health decline. Only two treatments showed a decrease in tree ratings. 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. The same trend was observed in the third season, until the trees were severely pruned before the mid-season evaluation. The trees slowly started to recover and at the start of the fourth season overall tree health improved drastically. This improvement continued with each monthly evaluation. When comparing the initial tree health ratings from the first to the fourth season, only two treatments showed an overall increase in tree health, the Brilliant with Anngro sprays and drenches (treatments 5 and 6). Trees injected with Avoguard showed no change in overall tree health during the four seasons.

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 root necrosis, 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 mainly 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 can remain 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, however, 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, i.e. host response, 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, 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 (2005-2006) 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."

The efficacy of soil drench applications as found by QMS Laboratories™ and the minimal labour involved, also prompted an interest in the 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 McClean, personal communication). This possibility of resistance has been investigated by Dobrowolski *et al.* (2008) in Australia, who found that prolonged use of phosphonates in orchards does select for isolates of *P. cinnamomi* less sensitive to phosphite *in planta.* This is 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 earlier work with phosphonates on avocado nursery trees in bags, QMS Laboratories™ found the ammonium phosphonate superior to potassium phosphonate products as a soil drench and was thus 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 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 without the negative effects of trunk injections. This may have huge financial benefits to the South African avocado industry.

MATERIALS AND METHODS

The trial was conducted in an avocado orchard in Politsi (Limpopo province). 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 sight. Each of the seven treatments (Table 1) were replicated eight times. The first round of applications commenced on 10 October 2012. Bark sprays and soil drenches were applied at six-week intervals (rain dependent). The trial was repeated for a second and third season, starting October 2013 continuing until June 2014 and again from October 2014 until June 2015. In the second and third season, the Brilliant + Link combination was changed to only Brilliant applications, as it was advised that Brilliant works best on its own. The other Brilliant combinations were kept, due to promising results. The same trees were used for the treatments each season.

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

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).

RESULTS AND DISCUSSION

The ratings done before applications started, ranged from 4.25 to 5.25 for all the treatments. After 18 weeks tree improvement/decline could be observed. The untreated control was the only treatment where the overall average tree rating increased (from 4.63 to 4.88), indicating a decline in tree health. 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.

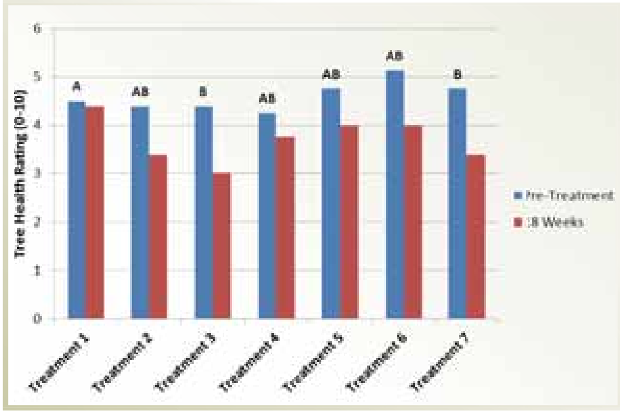

Figure 1. Comparison of tree health ratings before treatments and 18 weeks into the treatment programme.

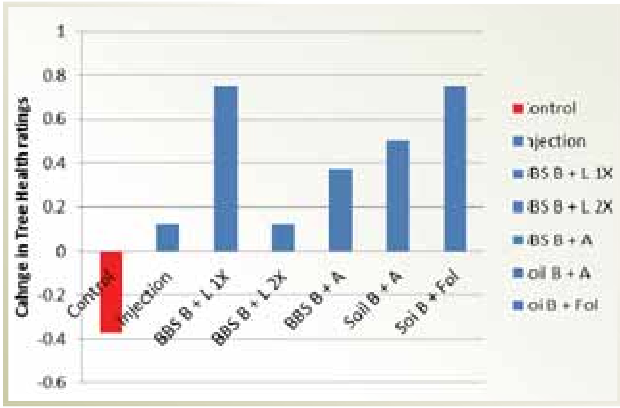

Figure 2. Change in tree health from beginning of season to 18 weeks into the phosphonate treatments.

When comparing tree ratings from the end of season one and the beginning of season two, two treatments showed 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 (health decline) in season two than in season one, with treatment 5 having the highest increase in tree rating between the two seasons (Fig. 3).

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 that increased between 0.125 and 0.5 (Fig. 4). There were statistically, however, no significant differences between ratings at the end of season one and the start of season two.

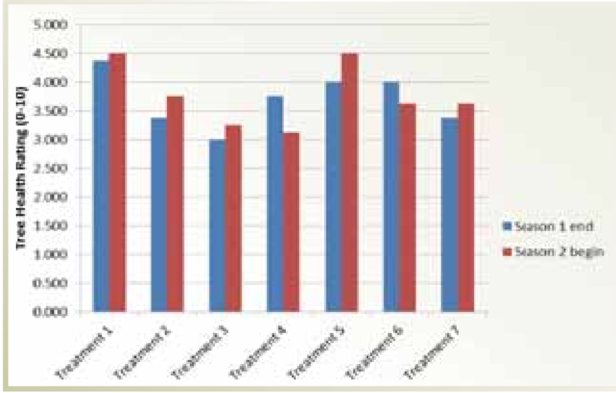

Figure 3. Comparison of tree health between the end of season one and the beginning of season two.

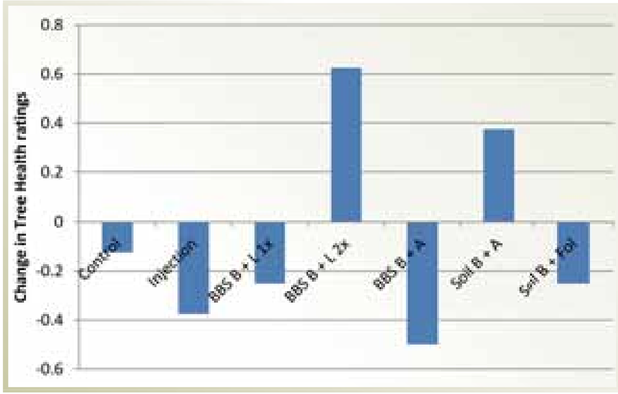

Figure 4. Change in tree health from the end of season one to the beginning of season two.

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,

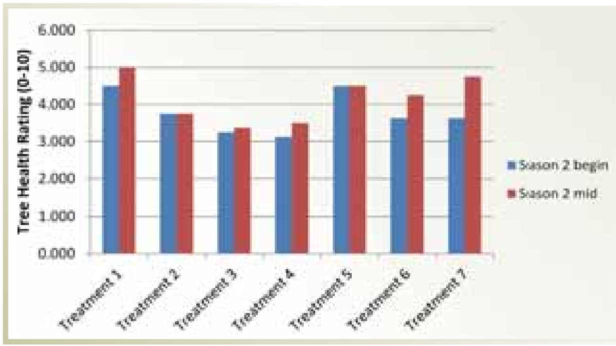

Figure 5. Comparison of tree health ratings taken at the beginning and in the middle of season two.

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.

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 of the second season. As shown in Figure 6, tree ratings of all the treatments increased. The average rating for the untreated control increased from 4.5 to 6.25. Treatment 2 had the lowest rating increase, with 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.

Ratings indicated no significant differences 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.

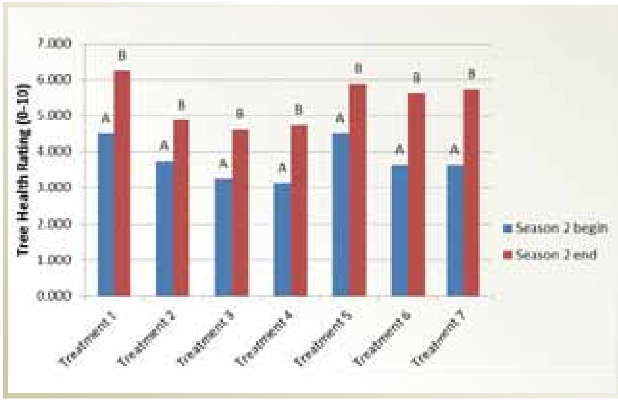

Figure 6. Comparison of tree health ratings taken at the beginning and end of season two.

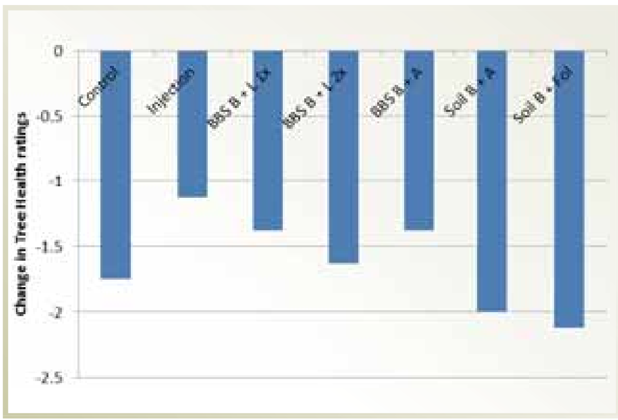

Figure 7. Change in tree health from the beginning until the end of season two.

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 all the treatments showed an increase in tree ratings, indicating that tree health declined. The ratings at the end of season two are significantly different from those made at the end of season one and the beginning of season two.

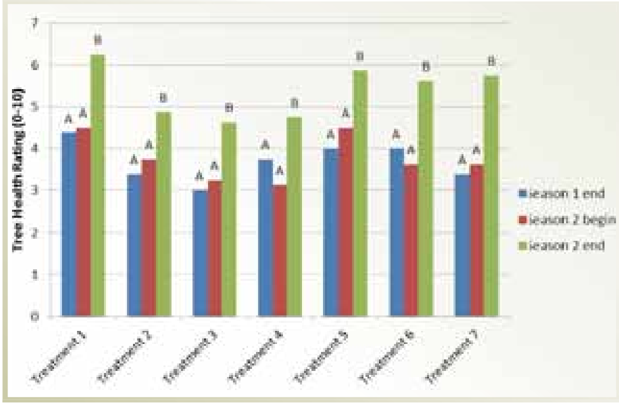

Figure 8. Comparison of tree health ratings taken at the end of season one and beginning and end of season two.

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.

At the start of the third season, the trees were evaluated again and a decrease in tree health ratings was noted for all the treatments (Fig. 9). The changes in tree ratings are indicated in Figure 10. Treatment 6 showed the highest decline in rating, indicating that these trees improved the most in health (42.9%). This difference was not significant when compared to the treatment with the lowest decline in tree rating or any of the other treatments. Treatment 5 showed the lowest decline in tree rating (24.2%). The percentage improvement in tree health for each treatment is indicated in Figure 11.

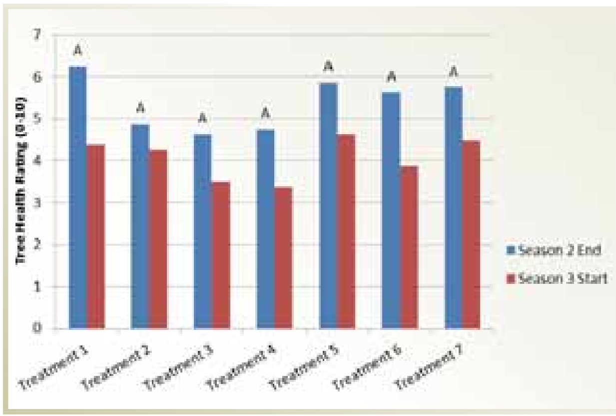

Figure 9. Comparison of tree health ratings taken at the end of season two and beginning of season three.

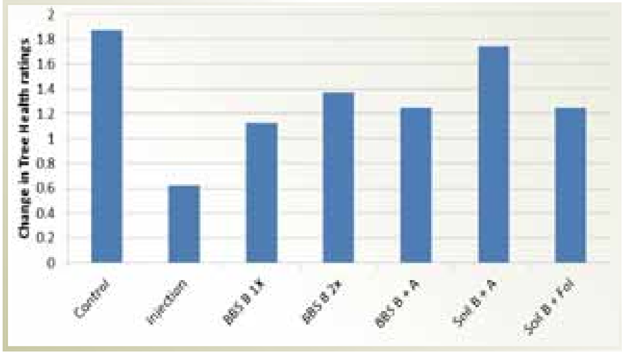

Figure 10. Change in tree health from the end of season two and beginning of season three.

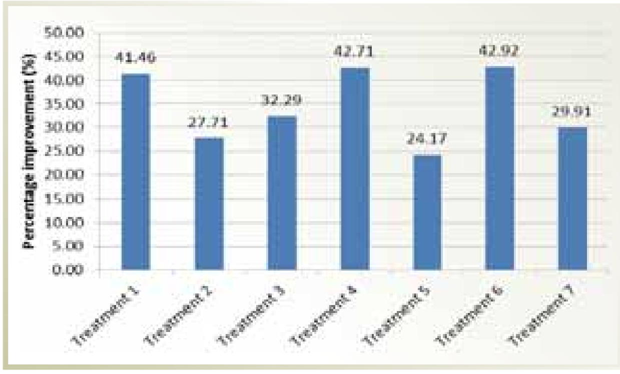

Figure 11. Percentage improvement in tree health from end of season two and beginning of season three.

From the beginning of season three to the end of the season, tree health declined severely and at the end of the season the trees were harshly pruned. The drought and extreme disease pressure appeared to be too much for the trees to handle. The data collected during this season indicated that treatment 7 showed the lowest decline in overall health compared to the other treatments. This treatment has had a lower overall tree health than most of the other treatments throughout the course of the trial. Treatment 4, however, showed the highest decline in tree health after being pruned. The tree health rating comparisons are shown in Figure 12, change in ratings in Figure 13 and the overall percentage decline in health in Figure 14.

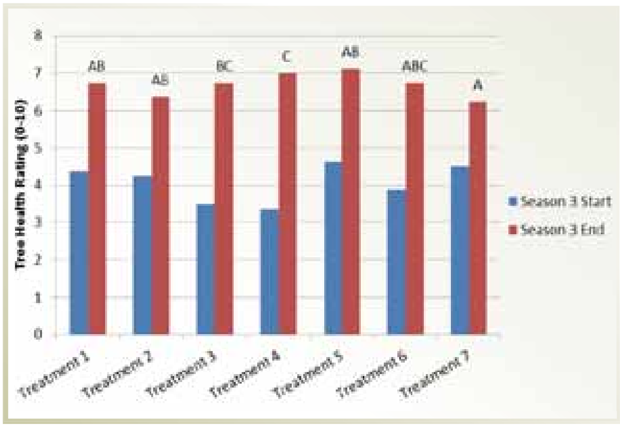

Figure 12. Comparison of tree health ratings taken at the beginning and end of season three.

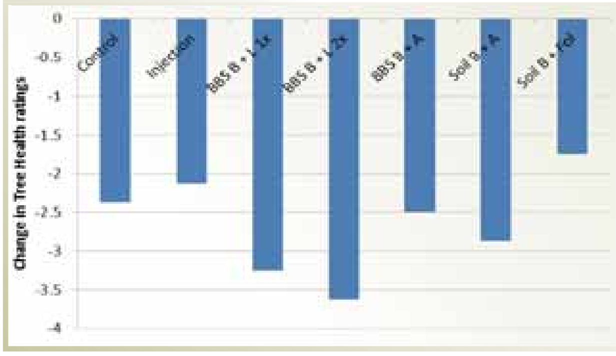

Figure 13. Change in tree health from the beginning to end of season three.

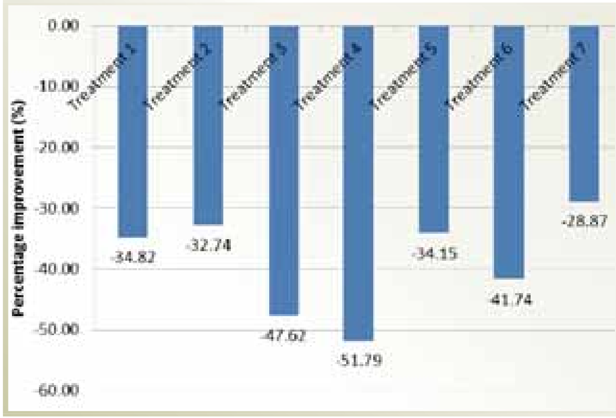

Figure 14. Percentage improvement in tree health from the beginning and end of season three.

To monitor the improvement of the trees, after pruning, evaluations were continued monthly for the first half of a fourth season. At the start of the season there was already a clear improvement in the overall condition of the trees. Treatment 3 showed the highest decrease in tree rating, thus the highest improvement of tree health. Treatments 5, 2 and 6 followed closely behind. The treatment with lowest improvement was treatment 7 followed by treatment 1 and 4. The differences between the treatments were significantly different. Figure 15 illustrates the comparison in tree ratings, while Figure 16 shows the overall change in ratings and Figure 17 the percentage improvement in tree health.

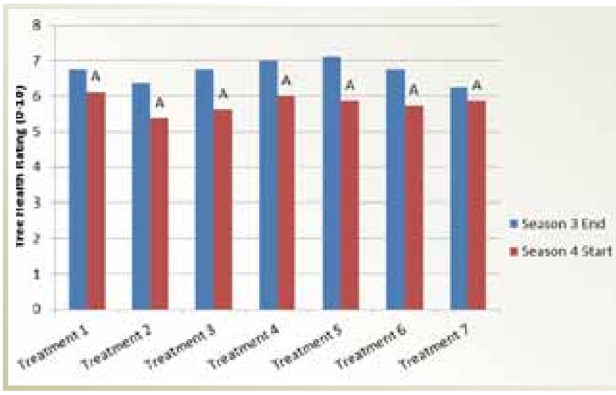

Figure 15. Comparison of tree health ratings taken at the end of season three and beginning of season four.

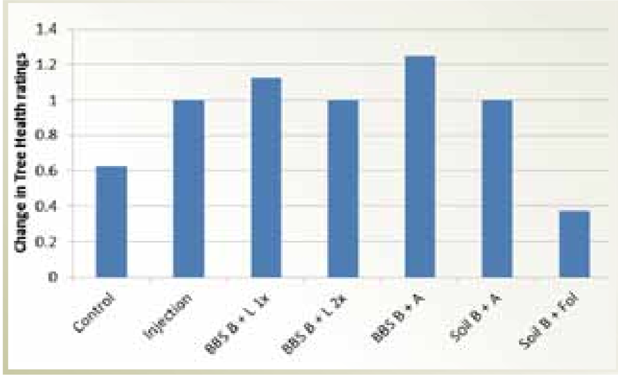

Figure 16. Change in tree health from the end of season three to the beginning of season four.

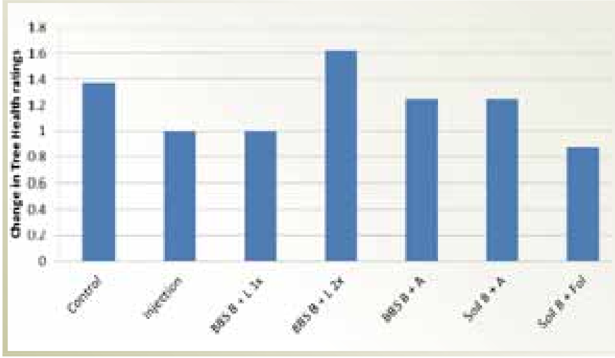

Figure 19. Change in tree health from the beginning to end of season four.

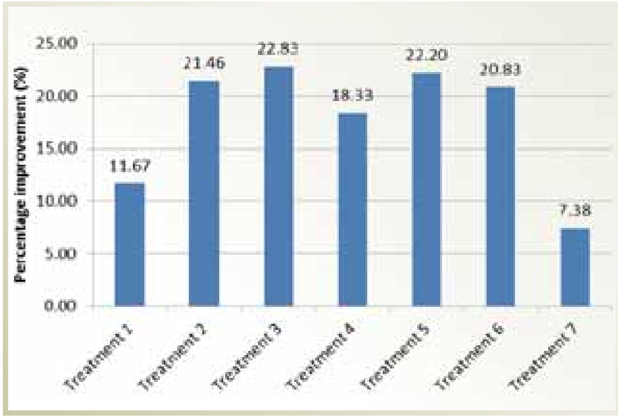

Figure 17. Percentage improvement in tree health the end of season three to the beginning of season four.

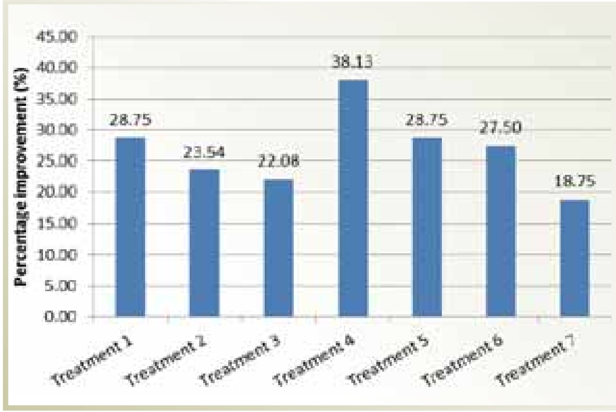

Figure 20. Percentage improvement in tree health from the beginning to end of season four.

The trend of improvement in overall condition continued and by the last evaluation it was clear that treatment 4 improved the most in tree health, as the tree ratings for this treatment was much lower than at the start of the season (Fig. 18). It differed significantly from treatments 7, 3 and 2 which were the treatments with the least improvement in tree health. The changes in these ratings are illustrated in Figure 19 and the percentage improvement in tree health per treatment in Figure 20.

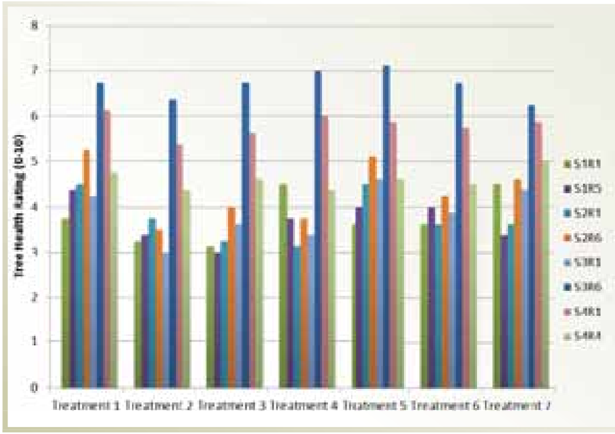

Figure 21. Gradual decline of tree health.

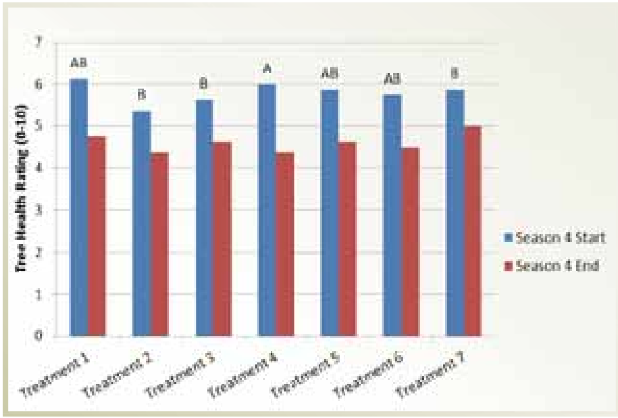

Figure 18. Comparison of tree health ratings taken at the beginning to end of season four.

Throughout the season a gradual decline was observed in all trees, until the trees were pruned. This gradual decline is illustrated in Figure 21. The decline in tree health peaked at the end of the third season and tree health steadily improved after the severe pruning.

CONCLUSION

When comparing the initial evaluations to the final evaluations it can be concluded that treatment 6, a soil drench containing Brilliant and AnnGro, was the best treatment to improve tree health and aid in recovery of heavily stressed trees (Fig. 21). From the start of the trial until the end, this treatment resulted in a 16.25% improvement in tree health over approximately four seasons. Application of treatment 5, a bark spray containing Brilliant and AnnGro, resulted in a 3.13% improvement in tree health. The rest of the treatments showed an overall decline in tree health. Treatment 2, the Avoguard stem injections, showed a very slight decrease in tree health by 0.63%, although there was no difference in the overall ratings. Treatment 4 had a slightly higher decrease in tree health. The double strength application of Brilliant as a bark spray showed a 1.25% decrease in tree health. Treatment 7, Brilliant and Foliar Complex soil drench showed a 3.75% decrease in tree health and treatment 3, single strength Brilliant bark spray, showed a 3.96% decrease in tree health. Treatment 1, the untreated control, showed the highest decrease in tree health with a decline of 5.63%.

Recommendations

When treating heavily infected orchards, especially older orchards, it is advised to start with a double strength Brilliant soil drench or stem spray. Be aware that the double strength application should not be applied near harvest time, due to the risk of exceeding acceptable MRLs. As shown in this trial, the addition of AnnGro to the soil drench can be very advantageous. Follow up applications of Brilliant as a stem spray or drench should follow every 4 to 6 weeks. If disease pressure seems to be very high, then monthly applications are advised.

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