Phosphite treatments as part of early preventative control of Phytophthora root rot, pre- and post-planting

M Grobler, J Meyer and J Liebenberg

QMS Laboratories, PO Box 416, Letsitele 0885, SOUTH AFRICA
www.qmslab.com
E-mail: melissag@qmslab.com

ABSTRACT

Strategic timing of phosphite applications to control *Phytophthora cinnamomi*, causing root rot, is crucial for effective disease control. The aim was to determine the efficacy of pre-plant ammonium phosphonate drenches to prevent *Phytophthora* root rot. Individual trees were drenched one day prior to planting with the various treatments. Follow up treatments of foliar and drench applications of phosphites were applied at approximately six-week intervals. Evaluations, consisting of stems' circumference and height improvement, were done every four months for the first season. During the second season, treatments were applied once a month and evaluated during the same time. The trial ran for approximately two and a half seasons and throughout the seasons. With each evaluation date, various treatments performed very well with regards to the improvement of stem circumferences. Overall from the start of the trial (season 1) to the start of season 3, treatment 2 (a single strength foliar application of ammonium phosphonate at 4 to 6 week intervals without a pre-plant drench) and treatment 7 (a double strength drench application with a pre-plant drench), performed the best. This was closely followed by treatment 4, single strength ammonium phosphonate foliar applications with a pre-plant drench and treatment 6, single strength ammonium phosphonate drenches with a pre-plant drench. From 21 January 2015 until 20 November 2015 tree health ratings indicated that overall improvement of tree health was highest with treatment 4 at 78.67%, while the least improvement in tree health was observed with treatment 2 at 64.67%. It is important to note that trees treated with treatment 2 had a higher tree health and little improvement was needed. Recommendations regarding pre- and post-planting practices are discussed.

OBJECTIVES

To develop a practice that focuses on the prevention of Phytophthora root rot in newly planted orchard blocks. Determine the efficacy of a pre-plant drench application of ammonium phosphonate followed by 6-weekly foliar sprays as a preventative procedure against Phytophthora root rot in newly planted orchard blocks.

INTRODUCTION

Phytophthora cinnamomi Rands. is a plant pathogen of global importance as it affects wild and cultivated plants (Bekker *et al*., 2007; Perez-Jimenez, 2008). This aggressive pathogen causes extensive root rot in avocados (*Persea Americana* Mill.) and on average affects 20% of South African avocado orchards (Perez-Jimenez, 2008).

Several strategies have been implemented for the management of Phytophthora root rot. These include planting resistant rootstocks (Smith *et al*., 2011), biological control (Duvenhage & Kotze, 1993) and chemical control. However, chemical control such as with phosphite (H_3PO3), a neutralised solution of the phosphonate anion (Fenn & Coffey, 1984), is still the main control method used for effective inhibition of Phytophthora root rot. Phosphonate fungicides control *Phytophthora cinnamomi* by a combination of direct fungistatic activity and stimulation of host defence mechanisms (Guest & Grant, 1991).

Phosphite is highly mobile in plants as they are translocated in both the xylem and phloem (Ouimette & Coffey, 1989; Guest & Grant, 1991; Whiley *et al*., 1995). This property, therefore, permits its use as either stem injections or foliar sprays during periods of high disease pressure. Disease pressure in avocado orchards is highest during the summer and autumn months when soil temperatures and moisture promote growth and development of the pathogen (Whiley *et al*., 1995). Thus, strategic timing of phosphite applications at the beginning of spring shoot growth and maturity through to the mid to late summer months, will protect the roots of susceptible trees from colonisation by *Phytophthora cinnamomi* during this critical period.

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 & Fairman (2007) found 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 has also indicated prolonged effective levels of up to eight weeks (Ouimette & Coffey, 1989).

A pre-plant application of phosphite in pineapples has been described as 'highly effective' in controlling Phytophthora root rot (Anderson *et al*., 2012). Anderson *et al*. (2012) investigated two pre-plant applications, high volume sprays and pre-plant dip. Pre-plant dips were found to be the most effective application method, as the efficacy persisted until flowering. Pre-plant applications of potassium phosphonate, followed by monthly post-plant applications, were used by Smith *et al*. (2011) as a standard procedure for avocado rootstock selections for new avocado production blocks already infested with *Phytophthora cinnamomi*.

Previous work done at QMS with phosphites on avocado nursery trees in bags, found the ammonium phosphonate formulation to be more effective than potassium phosphonate products and that a nursery drench application gave more superior results than foliar applications.

MATERIALS AND METHODS

One day before the trees were planted, certain plots were treated with an ammonium phosphite (Brilliant SL) drench. For the first season, the various treatments (Table 1) were applied approximately every six weeks. Evaluations regarding stem circumference and height improvement were done every four months.

Table 1. Treatments applied during the experiment.

Treatments	Pre-plant drench (ml/200 ml water/tree)*	Foliar spray (%a.i/tree) (1st year)	Foliar spray (%a.i/tree) (2nd year)	
1. Untreated control	0	0	0	
2. Ammonium phosphite (X1)	0	1	1	
3. Ammonium phosphite (0.5X)	1.33	0.5	0.5	
4. Ammonium phosphite (1X + drench)	2.67	1	1	
5. Ammonium phosphite (2X)	5.33	2	2	
		Soil drench (g a.i/m²/tree) (1st year)	**Soil drench (g a.i/m²/tree) (2nd year)**	
6. Ammonium phosphite (1X drench)	2.67	0.8	0.8	
7. Ammonium phosphite (2X drench)	5.33	1.6	1.6	
		Commercial company protocol (g a.i/m²/tree) APPLY BI-WEEKLY	**Stimu-Guard (ml/tree)**	**Stimu-Root (ml/tree)**
8. Commercial programme	0	0.8	8	2

* Previous work done at QMS found soil drenching to be superior to foliar applications on avocado nursery trees

Second season treatments (Table 1) were applied once a month, on the same respective treatments trees of the previous season, until March 2015. The trees were also evaluated for overall tree health, stem girth and height once a month to determine whether the applications had any effect in preventing the onset of Phytophthora root rot. Evaluations continued until November 2015.

The results were subjected to ANOVA and Fischer (LSD) t-test at a 95% confidence interval using XLSTAT 2015.6.01.23953.

RESULTS AND DISCUSSION

During the first season, it was found that the disease pressure in the newly planted block was extremely high and some of the trees needed to be replaced. Only with treatment 2 (Brilliant (1X) without pre-plant drench) no trees were killed due to disease, followed by treatment 4 (Brilliant (1X) with pre-plant drench) where one tree out of fifteen (6.7% loss) were killed. In treatments 6 (Brilliant (1X) drench) and 7 (Brilliant (2X) drench), two trees (13.3% loss) were killed. For the untreated control, treatment 3 (Brilliant 0.5X), treatment 5 (Brilliant 2X) and treatment 8 (commercial company protocol), five trees were killed during the run of this project (33.3% loss). These results are shown in Figure 1.

Some phytotoxicity was observed on trees treated with double strength dosages.

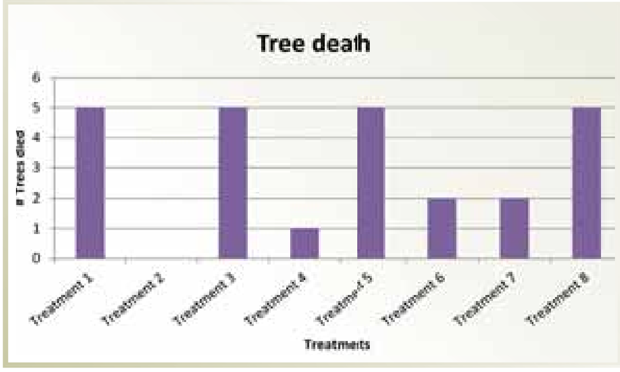

Figure 1. Number of trees per treatment that died due to Phytophthora root rot.

Average increase in stem circumference

The initial evaluations taken at planting were compared to evaluations taken during (mid) the first season (2013-2014) (Fig. 2). This comparison indicated that treatment 8 had the highest stem circumference increase from the start of the season with a significant improvement percentage of 35.4%, compared to the untreated control which had the lowest improvement percentage (28.8%). No significant differences were found between the remaining treatments. Treatment 6 was the second best performing treatment, with an improvement percentage of 34.3%. It was closely followed by treatment 4 (33.5%), treatment 7 (33.3%), treatment 5 (32.81%), treatment 2 (32.76%) and treatment 3 (32.68%).

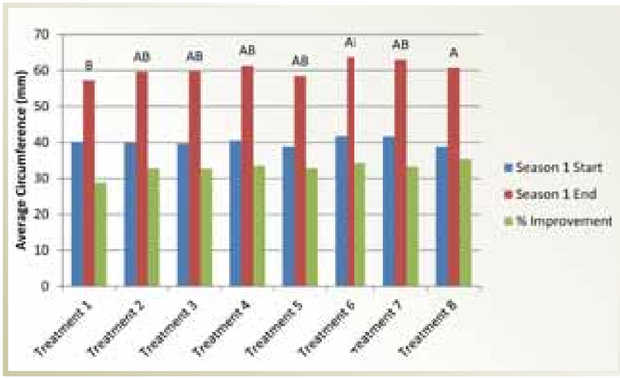

Figure 2. Stem circumference improvement from the beginning to mid-season 1.

The mid-season results were then compared to the results obtained at the end of season 1 (Fig. 3). Negative values for improvement percentage clearly shows which treatments performed very poorly, as dead trees were replaced with new, younger trees. Here it is clear again that treatment 2 performed very well, where no trees were lost to Phytophthora root rot. Improvement percentage for treatment 2 reached 21.2% from mid-season to the end of the season. Treatment 4 came in second, with an improvement percentage of 17.7%, followed by treatment 6 (15.8%) and treatment 7 (11.7%). The untreated control, where five trees were killed during the season, had an improvement percentage of -0.89%, followed by treatment 5 (-1.5%), treatment 3 (-3.1%) and treatment 8 (-5.2%). Treatments 2 and 4 were significantly different from treatment 8. No significant differences were found between the other treatments.

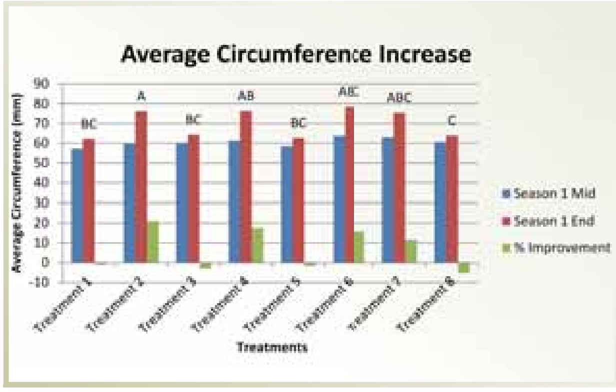

Figure 3. Stem circumference improvement from mid to end season 1.

Studies between the beginning and middle of season 2 showed no significant differences. Treatment 2 did, however, had the highest percentage of improvement in stem girth (30.52%) followed closely by treatment 3 (29.27%) and treatment 4 (26.42%). The untreated control improved by 23.7%, treatment 6 by 22.7% and treatment 5 by 18.4%. There were no significant differences between any of the treatments.

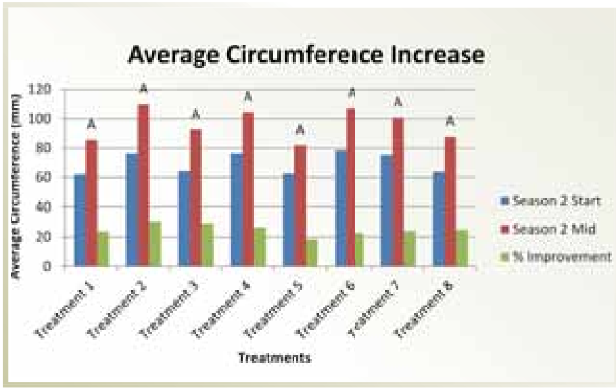

Figure 4. Stem circumference improvement from beginning to mid of season 2.

From the middle to end of season 2, treatment 5 stem girth improved with 31.83%. This differed significantly from treatment 2, treatment 4 and treatment 6, which improved only 22.2%, 21.63% and 21.28% respectively. Treatment 1 (27.52%), treatment 3 (26.29%), treatment 7 (27.81%) and treatment 8 (27.19%) did not differ significantly from each other or the rest of the treatments.

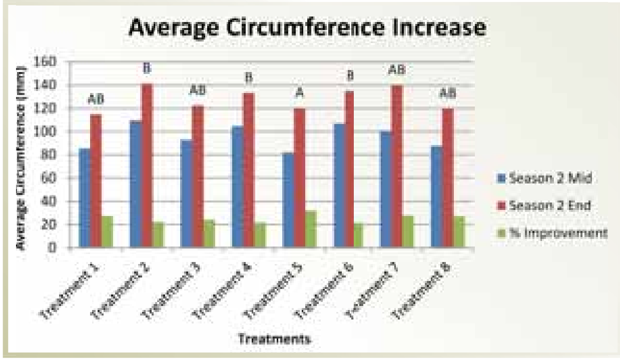

Figure 5. Stem circumference improvement from mid to end of season 2.

Stem circumference improvements were very small from the end of season 2 to the beginning of season 3. Treatment 6 showed the highest percentage improvement (6.2%) and treatment 2 the lowest (1.6%). These treatments differed significantly from each other. None of the other treatments differed significantly from each other and improvements ranged from 4.8% (treatment 3) to 2.6% (treatment 4) (Fig. 6).

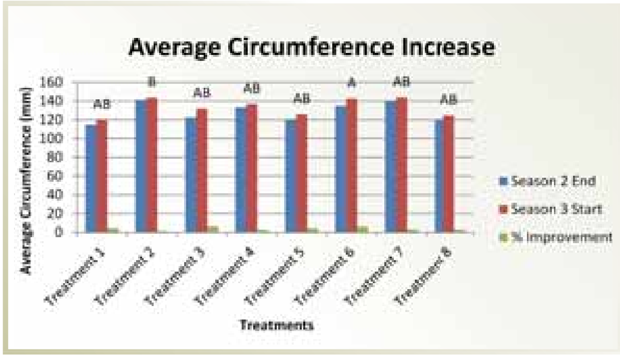

Figure 6. Stem circumference improvement from end season 2 to beginning season 3.

The overall stem circumference improvement is shown in Figure 7. Treatment 2, the Brilliant foliar spray without a pre-plant treatment, performed the best with a stem circumference improvement of 72.12%. Treatment 4 (69.48%), treatment 6 (69.78%) and treatment 7 (70.64%) did not differ significantly from treatment 2.

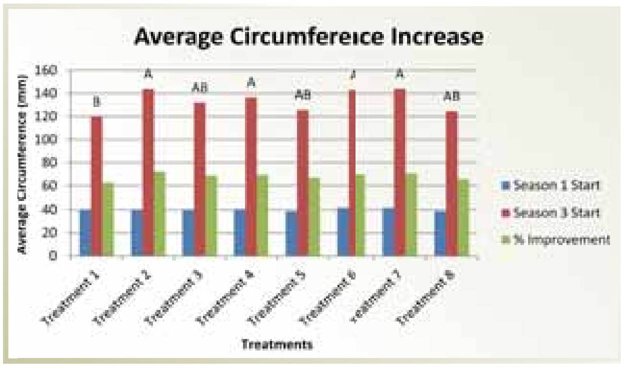

Figure 7. Stem circumference improvement from beginning season 1 to beginning season 3.

Average increase in height

Initial evaluations compared to evaluations taken during (mid) the season (Fig. 8) showed that treatment 8 started off strong with a height improvement of 17.1%, followed by treatment 7 (15.9%), untreated control (13.5%), treatment 4 (13.1%), treatment 5 (12.5%), treatment 6 (11.6%), treatment 2 (11.5%) and treatment 3 (10.99%). There were no significant differences between these treatments regarding height improvement.

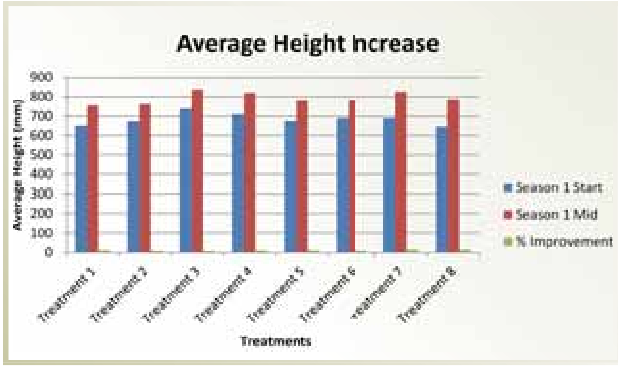

Figure 8. Height improvement from the beginning to mid-season 1.

From mid-season to the end of season 1, no significant differences were found (Fig. 9). The treatment that performed the best during this time period was treatment 6 with an improvement percentage of 21.3%. The untreated control improved with 20.2% followed by treatment 7 (17.2%), treatment 3 (16.6%), treatment 5 (15.7%), treatment 8 (15.3%), treatment 2 (14.6%) and treatment 4 (14.5%).

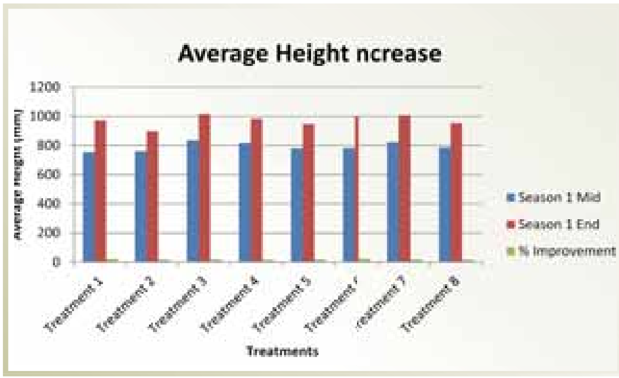

Figure 9. Height improvement from mid to end season 1.

Comparing evaluations taken at the end of season 1 and the start of season 2 (Fig. 10) found that treatment 2 performed the best with an improvement percentage of 17.5%. It was followed by treatment 4 (13.9%), treatment 7 (12.1%), treatment 6 (11.8%), untreated control (10.6%), treatment 5 (10.2%) and treatment 8 (10.1%). Treatment 3 improved only by 8.2%, which was significantly different from treatment 2.

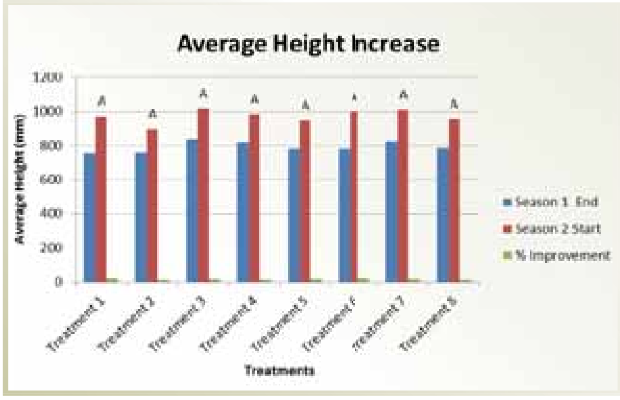

Figure 10. Height improvement from end season 1 to the beginning of season 2.

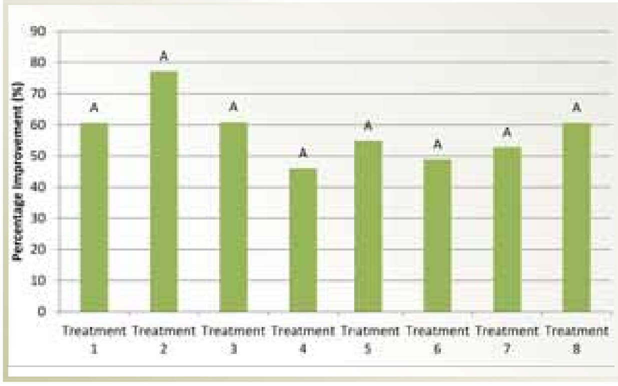

Figure 12. Percentage improvement in tree health from January 2015 to November 2015.

Wind and mechanical damage resulted in many trees losing the main branches being measured at each evaluation, making height evaluations irrelevant from the start of the second season for this trial.

Average increase in tree health (ratings)

By January 2015, the trees were big enough to be rated according to the tree canopy rating scale (0 = Healthy – 10 = Dead). The overall differences observed from January 2015 until November 2015, with the percentage improvement in tree health per treatment (the lower the rating, the healthier the tree), are shown in Figure 11 and Figure 12. After subjecting the data to Friedman's test and a multiple pairwise comparison, it was determined that the differences between the tree health improvements of the treatments were not statistically significant. Treatment 2 did, however, tend to have the greatest improvement in tree health from January until November 2015, with a 77.22% improvement. Treatment 3 performed the second best, with an improvement of 60.89%. Treatment 1 (untreated control) and treatment 8 showed improvement of 60.67%, while treatment 5 improved with 54.89%. Treatment 7 improved with 52.78%, treatment 6 with 48.89% and treatment 4 with 46.11%. These values may have been slightly different if main branches were not damaged by wind.

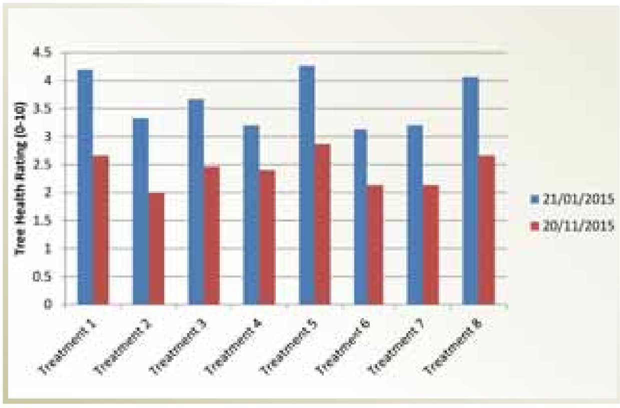

Figure 11. Change in tree health rating from January 2015 to November 2015.

Damage to main branches increased experimental error which could have contributed to not detecting significant differences, although strong trends were observed.

Recommendations when planting

From these results it can be concluded that drenching nursery trees with ammonium phosphonate (2.67 mL/200 mL water/tree) the day before planting may help limit the loss of trees after planting. The following combination treatment after planting can also aid in the establishment of the new orchard and help protect the stressed trees from being infected by *Phytophthora*, especially if the soil has a known history of harbouring the pathogen: Treat each tree with StimuGuard (8 mL active ingredient/tree) as a drench after planting followed by StimuRoot drench (2 mL a.i./tree) 7 days after the StimuGuard drench.

Follow up treatments with either the StimuGuard-StimuRoot combination or ammonium phosphonate foliar sprays (1 mL a.i./tree) or ammonium phosphonate drench (0.8 mL a.i./tree) every 6 weeks until the trees have been established in their new environment. If one treatment does not give the desired effect, a combination of treatments can be used. The results will depend on the soil type, irrigation practices, disease pressure and environmental conditions. Once the orchard has been established, ammonium phosphonate foliar sprays can be applied every 6 weeks until the start of the winter season. It is not recommended to apply these applications less than 6 weeks apart, due to a strong possibility of phytotoxic burn.

At the start of the next spring, the ammonium phosphonate foliar sprays can be continued with 6-week intervals. If disease pressure is very high, the use of a double strength ammonium phosphonate foliar spray or drench can be considered, but should not be used too often as it may cause phytotoxic burn.

It is important to note that each farm and its conditions vary and that the recommendations given should be used as a guideline only, to help in the never ending battle against Phytophthora root rot.

REFERENCES

ANDERSON, J.M., PEGG, K.G., SCOTT, C. & DRENTH, A. 2012. Phosphonate applied as a pre-plant dip controls *Phytophthora cinnamomi* root and heart rot in susceptible pineapple hybrids. *Australian Plant Pathology* 41: 59-68.

BEKKER, T.K., LABUSCHAGNE, N., AVELING, T. & KAISER, C. 2007. The inhabitation of Phytophthora root rot of avocado with potassium silicate application under greenhouse conditions. *South African Avocado Growers' Association Yearbook* 30: 49-56.

DUVENHAGE, J.A. & KOTZE, J.M. 1993. Biocontrol of root rot of avocado seedlings. *South African Avocado Growers' Association Yearbook* 17: 70-2.

FENN, M.E. & COFFEY, M.D. 1984. Studies on the in vitro antifungal activity of fosetyl-Al and phosphorous acid. *The American Phytopathological Society* 74: 606-11.

GUEST, D. & GRANT, B. 1991. The complex action of phosphonates as antifungal agents. *Biological Reviews* 66: 159-87.

OUIMETTE, D.G. & COFFEY, M.D. 1989. Phosphonate levels in avocado (*Persea americana*) seedlings and soil following treatment with fosetyl-Al or potassium phosphonate. *Plant Disease* 73: 212-5.

PEREZ-JIMENEZ, R.M. 2008. Significant avocado diseases caused by fungi and oomycetes. *The European Journal of Plant Science and Biotechnology* 2(1): 1-24.

SHEARER, B.L. & FAIRMAN, R.G. 2007. Application of phosphite in a high-volume foliar spray delays and reduces the rate of mortality of four *Baksia* species infected with *Phytophthora cinnamomi. Australian Plant Pathology* 36: 358-68.

SMITH, L.A., DANN, E.K., PEGG, K.G., WHILEY, A.W., GIBLIN, F.R., DOOGAN, V. & KOPITTKE, R. 2011. Field assessment of avocado rootstock selections for resistance to Phytophthora root rot. *Australian Plant Pathology* 40: 39-47.

TYNAN, K.M., WILKINSON, C.J., HOLMES, J.M., DELL, B., COLQUHOUN, I.J., MCCOMB, J.A. & HARDY, G.E.J. 2001. The long-term ability of phosphite to control *Phytophthora cinnamomi* in two native plant communities of Western Australia. *Australian Journal of Botany* 49: 761-70.

WHILEY, A.W., HARGREAVES, P.A., PEGG, K.G., DOOGAN, V.J., RUDDLE, L.J., SARANAH, J.B. & LANGDON, P.W. 1995. Changind sink strengths influence translocation of phosphonate in avocado (*Persea americana* Mill.) trees. *Australian Journal of Agricultural Research* 46: 1079-90.

WICKS, T.J. & HALL, B. 1988. Preliminary evaluation of phosphorous acid, fosetyl-Al and metalaxyl for controlling *Phytophthora cambivora* on almond and cherry. *Crop Protection* 7: 314-8.