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EFFICACY OF WATER SOLUBLE SILICON FOR CONTROL OF *PHYTOPHTHORA CINNAMOMI* ROOT ROT OF AVOCADO

by

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DECLARATION

I hereby certify that this seminar is my own work, except where duly acknowledged. I also certify that no plagiarism was committed in writing this thesis.

Signed ____________________

Theo Frederik Bekker

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ABSTRACT

Avocado production worldwide has been under great pressure due to *Phytophthora cinnamomi* Rands. root infection, which ultimately leads to tree death. In an attempt to find a viable alternative treatment for phosphonate fungicides against Phytophthora root rot of avocado, studies have been conducted to determine the effect of potassium silicate application on *P. cinnamomi* root rot development in both avocado nursery trees and trees in the field.

The direct inhibitory effect of potassium silicate was tested *in vitro*, and results indicated it to have a dose-related inhibitory effect on *P. cinnamomi* growth at concentrations as low as $5ml.l^{-1}$. By means of greenhouse trials it was demonstrated that potassium silicate either stimulates root growth or imparts some form of protection to avocado roots if applied prior to *P. cinnamomi* inoculation, as inoculated, silicon treated trees resulted in the highest fresh and dry root mass compared to all other treatments. Potassium silicate application inhibited Phytophthora root rot in inoculated greenhouse trees effectively, and in all repetitions either resulted in similar, or better root rot ratings compared to the current control treatment potassium phosphonate. The beneficial effects of potassium silicate was however lost in treatments receiving only one silicate application, and reapplication of potassium silicate is essential. These findings are of paramount importance as this implies that potassium silicate may be proposed as a possible alternative control to inhibit the effects of *P. cinnamomi* on avocado nursery trees. Three potassium silicate soil drench applications resulted in significantly higher root densities compared to the control and potassium phosphonate (Avoguard®) treatments. These results correlated well with tree canopy ratings. All potassium silicate soil drench treatments resulted in lower disease ratings (canopy condition). Three applications (Si x 3) of soluble potassium silicate per season resulted in significantly higher phenolic root concentrations compared to the untreated control. Crude phenolic concentrations obtained in the Si x 3 treatment samples were similar to that of potassium phosphonate. These results indicate that potassium silicate application to avocado trees under *P. cinnamomi* infectious conditions increase total phenolic content of avocado root tissue, suggesting potassium silicate to have an indirect inhibitory effect on *P. cinnamomi* infection of avocado trees.

INTRODUCTION

The avocado (*Persea Americana* Mill.) is an evergreen, polymorphic tree species, originating in a broad geographic region from the eastern highland of Mexico to the pacific coast of central America (Knight, 2002). The genus *Persea* (Clus.) belongs to the family *Laureaceae* (Scora *et al.*, 2002), being amongst the families *Proteaceae* and *Magnoliaceae*, one of the oldest plant families on earth. Three distinct, ecologically separate sub-species of the avocado have been termed by Popenoe (1920) as Guatemalan, Mexican and West Indian or Antillean. Avocado production is limited to the tropical and subtropical regions of the world, and the fruit is exported worldwide (Knight, 2002). In South Africa avocado production is confined to the Limpopo and Mpumalanga provinces in the north and north-east of the country, and to a lesser extent to the frost-free lowland coastal belts and cooler midlands of KwaZulu-Natal (Lovegrove and Hooley, 2000).

Phytophthora root rot has been the main limiting factor to successful avocado production in countries such as Australia, South Africa and the USA. Phytophthora root rot, caused by the fungus *Phytophthora cinnamomi* Rands. (Hardy *et al*., 2001), is the most important and destructive disease of not only avocados worldwide, but over 1000 plant types (Zentmyer, 1980), including pineapple, macadamia, peach, pear, kiwi fruit, chestnut, eucalyptus, and many native Australian and South African plants (Pegg *et al*., 2002). In avocado, it attacks and kills trees of all ages, from nursery trees to large bearing trees through the destruction of feeder roots. Its reproduction, growth and spread are favoured by free soil-water. Movement of infected soil therefore plays an important role in the spread of this fungus (Hardy *et al.,* 2001). It has been postulated by Arentz and Simpson (1986) and Linde *et al*. (1997) that the fungus originated in Papua New Guinea, and was moved by the activities of people into other tropical and subtropical regions of the world.

Phytophthora cinnamomi causes rot of feeder roots, leading to the death of host plants (Anon, 2004). Infection is mostly limited to the feeder roots, which become black and brittle and eventually die off. Feeder roots may be difficult to find under trees with advanced root rot symptoms (Pegg *et al*., 2002), and this dieback of feeder roots may impose severe water stress on the tree, even in moist soils. Visible symptoms include wilted and chlorotic foliage and eventually defoliation and dieback of branches, depending on root rot severity.

Numerous control measures have been implemented to control root rot, but a well-managed program is necessary to ensure disease suppression. Biological control of *P. cinnamomi* has been investigated by numerous authors (McLeod *et al.*, 1995; Duvenhage and Kotze, 1993; Casale, 1990; Pegg, 1977) and shows promise for reducing root rot (Pegg *et al.*, 2002). Host resistance is an important method of reduction of Phytophthora root rot (Coffey, 1987), with some rootstocks expressing tolerance to root rot by the rapid regeneration of active feeder roots while in others the progress of infection in the root is inhibited (Phillips *et al.*, 1987). Cahill *et al.* (1993) reported increased levels of lignin and phenolics after inoculation with *P. cinnamomi*, suggesting phenolic compounds play a role in plant resistance to Phytophthora root rot. Wehner *et al.* (1982) and Brune and van Lelyveld (1982) reported on the sensitivity of pathogens to antifungal substances in avocado tissue. They concluded that some phenolics act as antioxidants during induced resistance and these phenolic antioxidants are present in plant lipophylic regions.

Chemical control however remains the most important control measure, and to this end, phosphate-based fungicides play a major role. Phosphonate fungicides, including fosetyl-Al (Aliette®) and its breakdown product phosphorous acid, are highly mobile in plants (Guest *et al.*, 1995). It is believed to control *Phytophthora* spp. by a combination of direct fungitoxic activity and stimulation of host defence mechanisms (Guest *et al.*, 1995; Hardy *et al.,* 2001). Darvas *et al.* (1983, 1984) and Darvas (1983) first reported on the use of a trunk injection method obtaining "outstanding control" of *P. cinnamomi* by fosetyl-Al. This remains to date the most effective application method of phosphonate fungicides in avocado. Subsequently, Duvenhage (1994) was the first to report on the possibility of resistance to fosetyl-Al and H_3PO_3 and found that isolates of *P. cinnamomi* obtained from trees treated with fosetyl-Al or H_3PO_3 were less affected by fosetyl-Al and H_3PO_3 *in vitro*, compared to isolates obtained from untreated trees. He concluded that the possibility of resistance does exist (Duvenhage, 1999), which would pose a serious threat to the industry.

Research on the role of silicon in plant physiology depended on the advent of the solution culture technique (Epstein, 1999). Numerous functions have been attributed to silicon including improvement of mechanical properties (soil penetration by roots, stature, resistance to lodging, exposure of leaves to light), enhancement of growth and yield, resistance to salinity, reduction of transpiration and resistance to drought stress. As discussed in more detail later, a number of studies demonstrated suppression of a range of diseases by means of silicon application. Mechanisms include induction of plant enzymes and increased resistance arising from the deposition in amorphous silica, or accumulation of phytotoxic phenolic compounds (Fauteux *et al*., 2005).

The present study was initiated to determine whether the application of potassium silicate to *P. cinnamomi* infected trees would suppress the disease. The objectives of the study were:

- To determine whether potassium silicate has a direct effect on fungal growth *in vitro*.
- To investigate the possibility of potassium silicate having an indirect effect on disease development, through the alteration of the plant's biochemical composition.
- To establish if the application of potassium silicate to avocado nursery and field grown trees suppresses root rot development and spread in avocado roots.
- To determine, if suppression is observed, the concentrations, dosage rates and timing of potassium silicate applications to avocado orchards for *P. cinnamomi* suppression.
- To investigate the biochemical composition of plants with specific reference to phenolic concentrations in avocado root tissue to ascertain if potassium silicate leads to an increase or alteration of the phenolic content of plant cell content.

The primary applied objective of these investigations was to develop an alternative control strategy for the avocado industry to alleviate the stress of resistance to phosphonate fungicides as the only chemical control method currently used.

LITERATURE CITED

ANON, 2004. *Phytophthora cinnamomi*: Diagnostic protocols for regulated pests. *OEPP/EPPO Bulletin* 34, 201-207.

ARENTZ, F. & SIMPSON, J.A., 1986. Distribution of *Phytophthora cinnamomi* in Papua New Guinea and notes on its' origin. *Trans. B. Mycol. Soc.* 87, 289-295.

BRUNE, W. & LELYVELD, L.J., 1982. Biochemical comparison of leaves of five avocado (*Persea americana* Mill.) cultivars and its possible association with susceptibility to *Phytophthora cinnamomi* root rot. *Phytopath. Z.* 104, 243-254.

CAHILL, D.M., BENNETT, I.J. & McCOMB, J.A., 1993. Mechanisms of resistance to *Phytophthora cinnamomi* in clonal, micropropagated *Eucalyptus marginata*. *Plant Pathol*. 42, 865-872.

CASALE, W.L., 1990. Analysis of suppressive soils and development of biological control methods for *Phytophthora* root rot of avocado. *California Avocado Society Yearbook* 74, 53-56.

COFFEY, M.D., 1987. *Phytophthora* root rot of avocado: An integrated approach to control in California. *Plant Dis.* 71, 1046-1052.

DARVAS, J.M., 1983. Five years of continued chemical control of *Phytophthora* root rot of avocados. *South African Avocado Growers' Association Yearbook* 6, 72-73.

DARVAS, J.M., TOERIEN, J.C. & MILNE, D.L., 1983. Injection of established avocado trees for the effective control of *Phytophthora* root rot. *South African Avocado Growers' Association Yearbook* 6, 76-77.

DARVAS, J.M., TOERIEN, J.C. & MILNE, D.L., 1984. Control of avocado root rot by trunk injection with fosetyl-Al. *Plant Dis.* 68 (8), 691-693.

DUVENHAGE, J.A., 1994. Monitoring the resistance of *Phytophthora cinnamomi* to fosetyl-Al and H_3PO_3. *South African Avocado Growers' Association Yearbook* 17, 35-37.

DUVENHAGE, J.A., 1999. Biological and chemical control of root rot. *South African Avocado Growers' Association Yearbook* 22, 115-119.

DUVENHAGE, J.A. & KOTZE, J.M., 1993. Biocontrol of root rot of avocado seedlings. *South African Avocado Growers' Association Yearbook* 16, 70-72.

EPSTEIN, E., 1999. The discovery of the essential elements. In: S.D. Kung & S.F. Yung (Eds.), Discoveries in Plant Biology, Vol 3, World Sci. Publ., Singapore, pp. 1023.

FAUTEUX, F., REMUS-BOREL, W., MENZIES, J.G. & BELANGER, R.R., 2005. Silicon and plant disease resistance against pathogenic fungi. *FEMS Microbiology Letters* 249, 1-6.

GUEST, D.I., PEGG, K.G. & WHILEY, A.W., 1995. Control of *Phytophthora* diseases of tree crops using trunk-injected phosphonates. *Hort. Rev*. 17, 299-330.

HARDY, G.E. St. J., BARRETT, S. & SHEARER, B.L., 2001. The future of phosphite as a fungicide to control the soilborne plant pathogen *Phytophthora cinnamomi* in natural ecosystems. *Austr. Plant Pathol*. 30, 133-139.

KNIGHT, R.J., 2002. History, Distribution and Uses. In: A.W. Whiley, B. Schaffer, & B.N. Wolstenholme (Eds.), Avocado: Botany, Production and Uses, CABI-Publishing, pp 1-14.

LINDE, C., DRENTH, A., KEMP, G.H.J., WINGFIELD, M.J. & VON BROEMBSEN, S.L., 1997. Population structure of *Phytophthora cinnamomi* in South Africa. *Phytopath*. 87, 822-827.

LOVEGROVE, A. & HOOLEY, R., 2000. Gibberellin and abscisic acid signalling in aleurone. *Trends Plant Sci*. 5(3), 102-110.

McLEOD, A., LABUSCHAGNE, N. & KOTZE, J.M., 1995. Evaluation of *Trichoderma* for biological control of avocado root rot in bark medium artificially infected with *Phytophthora cinnamomi*. *South African Avocado Growers' Association Yearbook* 18, 32-37.

PEGG, K.G., 1977. Soil application of elemental sulphur as a control of *Phytophthora cinnamomi* root rot of pineapple. *Aust. J. Exp. Agric. An. Husb*. 17, 859-865.

PEGG, K.G., COATES, L.M., KORSTEN, L. & HARDING, R.M., 2002. Foliage, Fruit and Soilborne Diseases. In: A.W. Whiley, B. Schaffer, & B.N. Wolstenholme (Eds.), Avocado: Botany, Production and Uses, CABI-Publishing, pp 432.

PHILLIPS, D., GRANT, B.R. & WESTE, G., 1987. Histological changes in the roots of an avocado cultivar, Duke 7, infected with *Phytophthora cinnamomi*. *Phytopathol*. 77, 691-698.

POPENOE, W., 1920. Manual of Tropical and Subtropical Fruits. Macmillan, London, pp 524.

SCORA, R.W., WOLSTENHOLME, B.N. & LAVI, U., 2002. Taxonomy and Botany. In: A.W. Whiley, B. Schaffer, & B.N. Wolstenholme (Eds.), Avocado: Botany, Production and Uses, CABI-Publishing, pp 15-37.

WEHNER, F.C., BESTER, S. & KOTZE, J.M., 1982. Sensitivity of fungal pathogens to chemical substances in avocado trees. *South African Avocado Growers' Association Yearbook* 5, 32-34.

ZENTMYER, G.A., 1980. *Phytophthora cinnamomi* and the diseases it causes. Monogr. 10, Am. Phytopathol. Soc., St Paul, Minnesota, pp 96.