Phytophthora root rot of avocado: the disease and how to manage it

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SUMMARY

INTRODUCTION

> **“Dealing with Pc is a never ending battle, make sure I’m the first you call when you find a cure!!!”**
>
> - an Australian avocado grower (2018)

The quote above, written in an email about *Phytophthora cinnamomi* (Pc), encompasses the desperation and frustration, endured by avocado growers, not just in Australia, but worldwide. There is no doubt that Phytophthora root rot (PRR) is the primary constraint to orchard productivity in most avocado growing regions. In Australia, PRR has been conservatively estimated to cost AUD$17 million annually (approximately US$1,200/Ha/year), based on lower production from declining trees, cost of management and replacement of blocks with new trees (Dann and Hall, unpublished). This estimate does not include losses within the nursery or price penalty in the packingshed for smaller, poorer quality fruit. A more detailed study has been completed of losses attributable predominantly to PRR (but including some other soilborne diseases), within the Colombian industry (Ramírez-Gil et al., 2017). An average estimate of nearly US$300/Ha/year over 8 years was reported. While such studies and estimates of losses cannot be directly comparable, it is sufficient to conclude that PRR accounts for severe economic impacts within avocado production.

The disease

PRR has mostly been attributed to one species, *P. cinnamomi*, however recent studies have reported isolations of *P. multivora*, *P. niederhauserii* and *Phytopythium vexans* from established avocado orchards in the Canary Islands (Rodríguez-Padrón et al., 2018), and these were also pathogenic in glasshouse seedling tests. Similar reports are likely from other producing regions around the world, aided by molecular identification techniques. A comprehensive description of *P. cinnamomi* and disease epidemiology is presented in Dann et al., (2013). *P. cinnamomi* has an extremely wide host range of close to 5,000 plant species, including 4,000 Australian natives (Hardham and Blackman, 2018). Important agricultural and forest hosts include chestnut, macadamia, pineapple and oak. It is not a true fungus, but a member of the Oomycota class, with the water moulds. It has three different spore types, important for survival, spread and disease development. Chlamydospores form in infected decaying roots and their thick walls enables long-term survival in dry soil or root debris. Oospores are also thick-walled and are long-term survival structures, but are less common than chlamydospores. Oospores are formed when strains of A1 and A2 mating types are paired, or by "selfing" within A2 populations. Zoospores are the main infective propagules, and are produced in abundance and released from structures called sporangia. Zoospores have whip-like appendages called flagella, which enable the spores to swim in free water. They are attracted by chemical root exudates to the zone of elongation the tips of new feeder roots, where they encyst (lose their flagella), and form germination tubes infecting the root. This is why initial visible symptoms include browning and necrosis at the root tip. The infection proliferates through the root causing severe necrosis and renewing the cycle of chlamydospore and zoospore production.

A recent study in South Africa showed that colonisation of roots in orchards in the major tropical/subtropical avocado growing region was greatest in May (late autumn) and August (late winter), and lowest in late spring and summer (March and November). See poster by Jolliffe et al., WAC-074. This was determined by quantitative analyses of DNA in roots (Jolliffe 2019). This is consistent with observations of optimal disease development at lower temperatures, where Pc grows better than avocado, and conversely, disease is less severe at higher temperatures where avocado root growth is strong (Dann et al., 2013). Despite consistent irrigation, it is common to see improvement in tree health (of declining trees) over extended warm, dry periods. Disease can develop in soils with a wide range of pH, so adjustments to soil pH specifically to manage PRR are pointless.

Stressful growing conditions, such as extremes of climate, eg. flooding, drought, as well as poor quality irrigation water (eg. salinity, poor fertilisation regime) etc. can predispose avocado to infection by Pc and cause severe disease. Short periods of saturated soil favour zoospore release and spread of the pathogen, however, extended waterlogging in oxygen depleted soils are damaging to avocado roots and also inhibit the pathogen. The pathogen spreads to new areas by movement of infested soil on machinery or by animals, movement of zoospores or infested debris in groundwater or in flooding surface water, and commonly by infected trees from the nursery. Alarmingly, the extremes of climate we are experiencing is likely to increase *P. cinnamomi* disease problems in agriculture, forestry and sensitive native ecosystems (Hardham and Blackman, 2018).

Knowledge of the infection patterns of Phytophthora and disease cycle are crucial for effective disease management and maintenance of healthy and productive orchards.

How to manage it

Luckily, avocado growers have an arsenal of weapons they can deploy to fight the battle against PRR. Indeed, the battle is never-ending, and growers must remain vigilant with respect to their Phytophthora management throughout the life of the orchard. Preventative management practices to maintain healthy trees from nursery stage are always preferable to curative attempts to bring declining trees back to health. An integrated approach, as recommended by Ken Pegg and Nigel Wolstenholme and their colleagues in Australia and South Africa since the 1970s, remains the current best practice strategy (Wolstenholme and Sheard, 2010). The basic components are summarized in Figure 1 “The Pegg Wheel for healthy trees”. The figure was reproduced with permission from a poster published for the Australian industry on how to manage Phytophthora root rot. The principles are broadly applicable to any pest or disease problem and orchard management more generally and a recent study has demonstrated that a multi-faceted approach to PRR management reduced disease severity and improved fruit quality more effectively than individual control methods (Ramírez-Gil et al., 2016). The key elements of integrated Phytophthora management include: 1) careful site selection and preparation, including adequate drainage to reduce the build-up of free soil water, 2) selection of rootstocks which are tolerant to *Phytophthora cinnamomi* (Pc), such as Dusa, Bounty, Velvick, and new selections such as SHSR04 in Australia (Smith et al., 2011), and R0.06 from the Westfalia and South African industry selection program (WTS team, pers. comm.), 3) planting Phytophthora-free trees sourced from accredited nurseries, 4) application of mulches and/or composts to improve soil structure, encourage root regeneration and stimulate microbial activity to reduce the survival of Pc propagules, 5) optimal irrigation management and tree nutrition, including calcium amendment to suppress Pc and 6) judicious use of chemicals, such as phosphonates and metalaxyl, applied correctly and supported by root and fruit residue analyses where available.

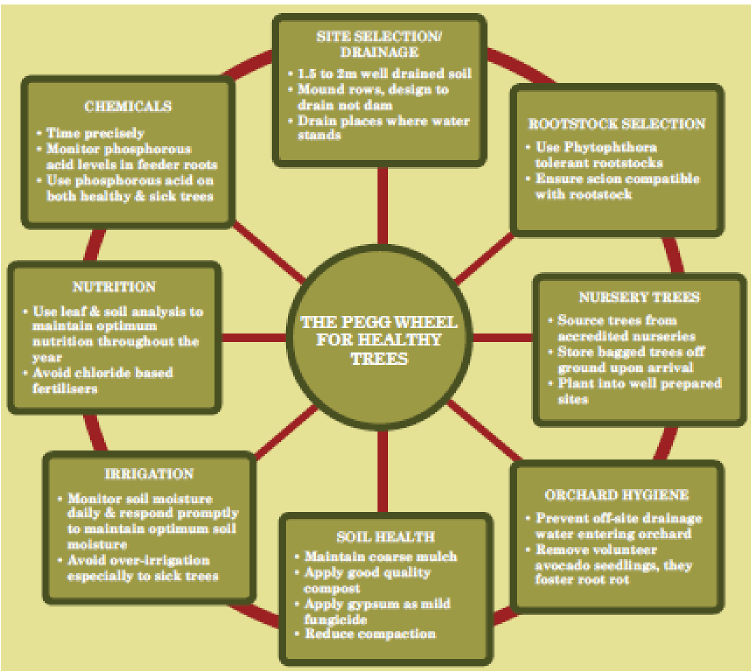

Figure 1. The Pegg wheel for healthy trees (reproduced with permission from S. Newett et al.)

Prior to the availability and widespread adoption of the two key fungicides, metalaxyl and phosphonates, PRR in subtropical growing regions in Australia was actively managed by attempts to recreate rainforest soil conditions in orchards, by additions of organic mulch, calcium and animal manure. This originated from Guy Ashburner (Figure 2), one of the first avocado growers in Australia in the 1950s and 1960s, who observed that rainforest trees adjacent to his orchard did not suffer from PRR. The Ashburner system of biological control (described in Downer et al., 2002) remains a key component to soilborne disease management. Deforestation leads to soils depleted in base cations and organic matter, and reduced pH. Thus, organic mulches with high cellulose content (Guy is sitting on bales of straw), calcium (eg. lime, dolomite or gypsum), and nitrogen (eg. from composted animal manure) are key ingredients of the Ashburner system. Nitrogen promotes growth of both avocado roots and soil microbes, and its addition is essential to prevent nitrogen "drawdown". This is where microorganisms draw N from the soil to give them energy to decompose the new organic mulch, thus reducing the N which is available to the plant.

A "healthy" soil contains an abundant and diverse population of microorganisms, contributing to suppression of Pc. Additions of organic mulches which are high in structural polysaccharides (glucans, eg. cellulose) increases the abundance and activity of microorganisms in the soil which are capable of degrading it. This occurs via the secretion by microbes of cellulytic glucanase enzymes, such as cellulase. As Phytophthora cell walls are composed of cellulose and other types of glucans, they are also targets for the microbial cell degrading enzymes. An elegant study by Downer et al. (2001) showed complementary direct effects of two of these key enzymes on Pc spore formation, growth of hyphae, zoospore encystment and infection of roots. Interestingly, thick-walled chlamydospores which formed within decaying roots were largely shielded from enzymic degradation (Downer et al., 2001). This and similar studies highlight the importance and role of the organic mulch component of the Ashburner system.

A preliminary study by my group (Figure 3) shows a trend of greater relative abundance of total microorganisms in soil collected from under "healthy" trees, compared with that under "sick" or declining trees across 6 orchards in eastern Australia under different management regimes and soil types. It is impossible to determine cause and effect, ie. whether trees became sick because microbial populations were lower, or if sick trees supported a lower relative abundance of microorganisms. This requires further investigation and is an element of current research within my group.

Figure 2. Guy Ashburner (left) Alan Jenyns (right) – Tamborine Mountain, circa late 1960s. Photo courtesy of Ken Pegg, Queensland Department of Agriculture and Forestry.

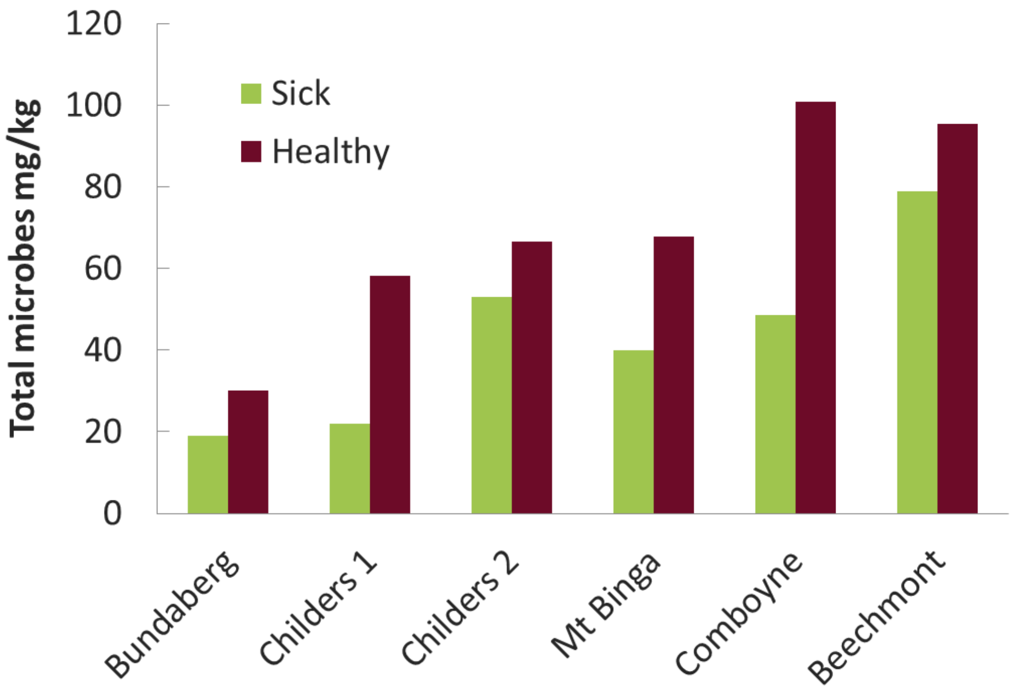

Figure 3. Total microbial biomass in soil collected from under sick or healthy avocado trees

Current Phytophthora root rot research efforts within my team are focused on evaluating: 1) alternative anti-oomycete chemistry to lower populations of Pc in soil, or reduce the infection of roots, 2) organic amendments including “biochar” and several microbial (biological) products 3) effects of soil nutrients, including plant-available silicon amendments (Dann and Le, 2017) 4) “biofumigation” with specialized Brassica crops or their derivatives, as a pre-plant and/or orchard treatment (see poster WAC-071) and 5) optimizing the delivery and timing of phosphonate applications to maximize translocation to the roots and minimize fruit residues.

CONCLUSION

> **“Dealing with Pc is a never ending battle, make sure I’m the first you call when you find a cure!!!”**

While acknowledging that management of PRR is constant, the grower author of the above quote is cheekily optimistic that research will find a “cure” for PRR. In the late 1970s and 1980s the discovery and adoption of fosetyl-Al and phosphonic acid trunk injection is credited with “rescuing” the avocado industry in Australia and South Africa. This chemical is still an important component of the management toolbox. Will such a savior come again? We should not expect it, but efforts to find additional sustainable and effective weapons to fight Pc must continue. In the meantime, the basic tools of the Pegg Wheel for maintaining optimal tree health are available now, and those growers who follow this basic philosophy are rewarded with healthy trees and high yields of good quality fruit, resulting in productive and profitable orchards.

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REFERENCES

Dann, E. K., Ploetz, R. C., Coates, L. M. and. Pegg, K. G (2013) Foliar, Fruit and Soilborne Diseases, in "The Avocado: Botany, Production and Uses, 2nd Ed", eds. B. Schaffer, N. Wolstenholme, A. Whiley, CABI Publishing, Wallingford, UK, pp. 380-422.

Dann, E. K. and Le, D. P. (2017) Effects of silicon amendment on soilborne and fruit diseases of avocado, *Plants 6*(4), 51; DOI 10.3390/plants6040051 , Special issue "Practical use of Si to influence plant production".

Downer, A. J., Menge, J. A. and Pond, E. (2001) Effects of cellulytic enzymes on *Phytophthora cinnamomi*, *Phytopathology*, 91: 839-846.

Downer, J., Faber, B. and Menge, J (2002) Factors affecting root rot control in mulched avocado orchards, *HortTechnology*,12: 601-605.

Hardham, A. R. and Blackman, L. M. (2018) Pathogen profile update: *Phytophthora cinnamomi*, *Molecular Plant Pathology*, 19:260–285.

Ramírez-Gil, J. G., Castañeda-Sánchez, D. A. & Morales-Osorio, J. G. (2016) Production of avocado trees infected with *Phytophthora cinnamomi* under different management regimes, *Plant Pathology*, 66:623-632.

Ramírez-Gil, J. G., Ramelli, E. G. and Morales-Osorio, J. G. (2017) Economic impact of the avocado (cv. Hass) wilt disease complex in Antioquia, Colombia, crops under different technological management levels, Crop Protection, 101:103-115.

Rodríguez-Padrón, C., Siverio, F., Perez-Sierra, A. and Rodríguez, A. (2018) Isolation and pathogenicity of Phytophthora species and *Phytopythium vexans* recovered from avocado orchards in the Canary Islands, including *Phytophthora niederhauserii* as a new pathogen of avocado, *Phytopathologia Mediterranea* (2018), 57, 1, 89−106.

Smith, L. A., Dann, E. K., Pegg, K. G., Whiley, A. W., Giblin, F. R., Doogan, V. & Koppitke, R. (2011). Field assessment of avocado rootstock selections for resistance to Phytophthora root rot, *Australasian Plant Pathology*, 40:39-47.

Wolstenholme, B. N. & Sheard, A. (2010) Integrated management of Phytophthora root rot: The "Pegg Wheel" updated, South African Avocado Growers' Association Avoinfo Newsletter, 175:11-15.