Improving avocado fruit quality and safety: Alternatives to prochloraz for postharvest treatment

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INTRODUCTION

There are several diseases and other physiological disorders of avocado fruit impacting the quality of product and eating experience for the customer. Trees and fruit are pushed to their limits in terms of yields, productivity, biotic stress (diseases and insect pressure) and abiotic stress (floods, drought, low soil fertility etc.). On top of this, as production volumes increase and export markets expand, fruit are stored for lengthy periods after harvest and frequently transported long distances to market. No wonder fruit doesn't always arrive in the best condition! It is the responsibility of all stakeholders in the chain to supply avocado fruit and processed product which is safe with respect to foodborne contaminants, of high quality with minimal postharvest wastage.

Globally, the primary diseases (rots) affecting avocado fruit *after* harvest are anthracnose and stem end rot, however, Alternaria rot and bacterial rot also contribute to significant losses in some countries and under extenuating circumstances, for example, bacterial rot is frequently problematic in fruit affected by cyclonic weather or rain splash on low-hanging fruit. Anthracnose (Figure 1) is primarily caused by fungal *Colletotrichum* species, and while fruit may be infected at any time during their development, the fungus remains dormant for many months after penetrating the fruit cuticle without causing obvious symptoms. After harvest during the ripening process, the fungus resumes growth causing disease symptoms. Several fungal species are associated with stem end rot (Figure 2), including *Colletotrichum* spp., *Diaporthe* (*Phomopsis*) spp., *Pestalotiopsis* and species in the Botryosphaeriaceae family (*Lasiodiplodia theobromae*, *Fusicoccum* spp., and *Neofusicoccum* spp.). These fungi are frequently present as endophytes internally infecting living plant tissues without causing any visible disease for at least part of their life cycle. They may colonize the fruit peduncle and be present in the stem end of harvested fruit. During ripening the fungi recommence growth and become pathogens, causing disease emanating from the stem end, frequently tracking along the vascular strands within the pulp. Stem end rot is frequently worse in fruit from stressed trees, such as those in decline from Phytophthora root rot.

Growers should not rely solely on post-harvest fungicide treatments to manage fruit diseases such as anthracnose and stem end rot. Management of these diseases must commence on-farm with a combination of tools for high-health orchards. These include orchard hygiene and canopy management to reduce fungal infection events, strategic applications of registered fungicides, including thorough coverage of protectant fungicides, as well as post-infection chemistry; optimal irrigation and nutrition for healthy trees and robust fruit, and careful harvest and post-harvest practices.

Current research in my team has evaluated post-harvest treatments including Graduate A+, a fungicide comprised of two active ingredients, azoxystrobin and fludioxonil, as well as electrolyzed oxidizing (EO) water, a chlorine-based sanitizer, for their effect on anthracnose and stem end rot compared with the industry standard prochloraz, and some indicative results are presented briefly here.

Figure 1 a and b. Anthracnose, caused by *Colletotrichum* spp. fungi. Note the hemispherical lesions arising from initial infection of the peel, and rotting into the pulp.

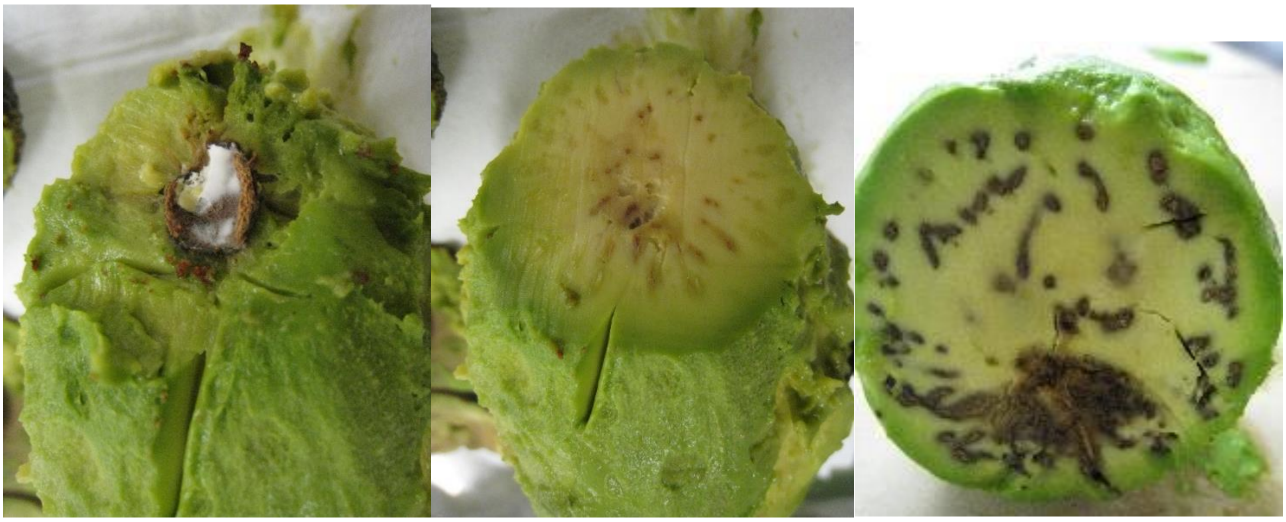

Figure 2 a b and c. Stem end rot, arising from infection at the stem or "button" and progressing along the vascular strands.

RESULTS

PART 1 Evaluation of Graduate A+ in commercial packing sheds in Queensland – demonstration trials

Three demonstration trials were undertaken in commercial packing sheds in Queensland, utilizing different post harvest fungicide application methods. Samples of fruit were collected from the line after the initial rinse (as untreated control), and after fungicide spray with label rates of prochloraz or Graduate A+ (azoxystrobin + fludioxonil). Fruit were dried, packed into trays and transported to the laboratory facilities at Ecosciences Precinct, Brisbane. Fruit were maintained in a controlled environment room 23°C and 65% relative humidity to encourage expression of disease. Fruit were checked each day and removed from the ripening room when deemed "eating soft" and assessed for severity of symptoms caused by anthracnose and stem end rot.

<u>Trial 1 Non-recirculating spray, North Queensland</u>

Graduate A+ (250mL/100L) was applied via a non-recirculating spray system for 30 seconds (Figure 3). Both anthracnose and stem end rot were reduced by Graduate A+ treatment (Figure 4).

Figure 3 a and b. Hass fruit progressing through the line. The fruit covered with tape indicated when to collect fruit prior to (untreated) and after fungicide treatment

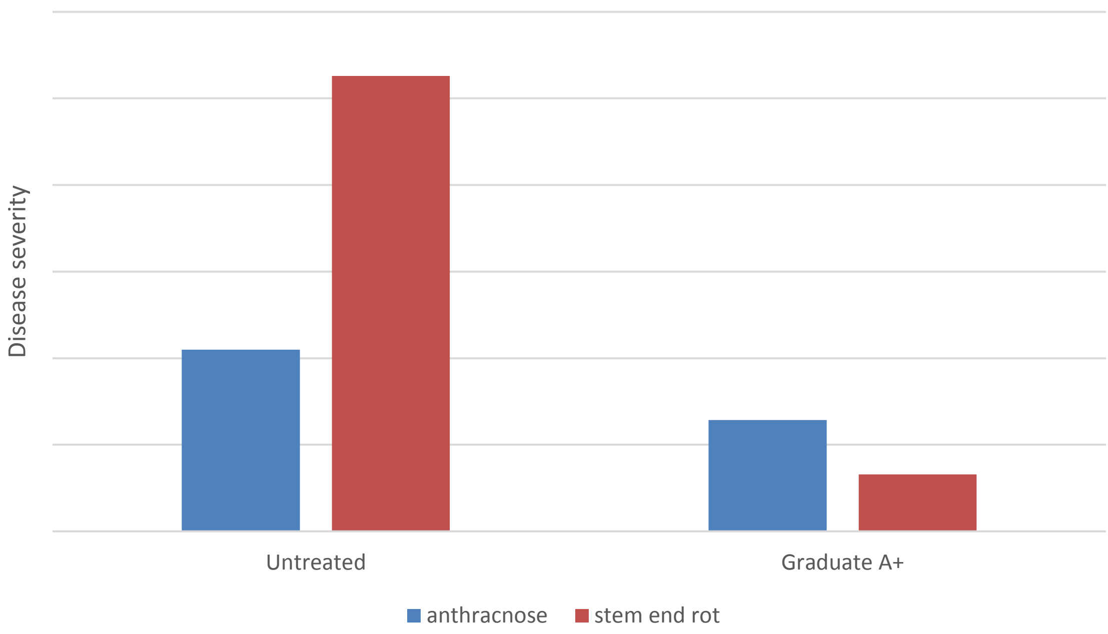

Figure 4. Effect of Graduate A+ on anthracnose and stem end rot disease in avocado cv. Hass. Graduate A+ (250mL/100L) was applied via a non-recirculating spray system for 30 sec, Trial 1

<u>Trial 2 Recirculating spray, Central Queensland</u>

Graduate A+ (250mL/100L) was applied via a recirculating spray system for 30 sec. One tank (about 650 L) of Graduate A+ was prepared in the morning of Day 1. From the first bin of the day to the last, 48 tonnes of fruit went through the line and spray solution volume dropped from 650L to approx. 375 L. In the morning of Day 2, prochloraz (Sportak, 55mL/100L) was prepared and applied for the day. Fruit from the same orchard was treated with both Graduate A+ and prochloraz.

Fruit treated with Graduate A+ in the morning or afternoon of Day 1 had less severe anthracnose and stem end rot compared with respective fruit that went through the rinse only (Figure 5). On the second day, anthracnose and stem end rot were also reduced by prochloraz treatment, although efficacy against stem end rot was not as remarkable as that achieved by Graduate A+ the previous day.

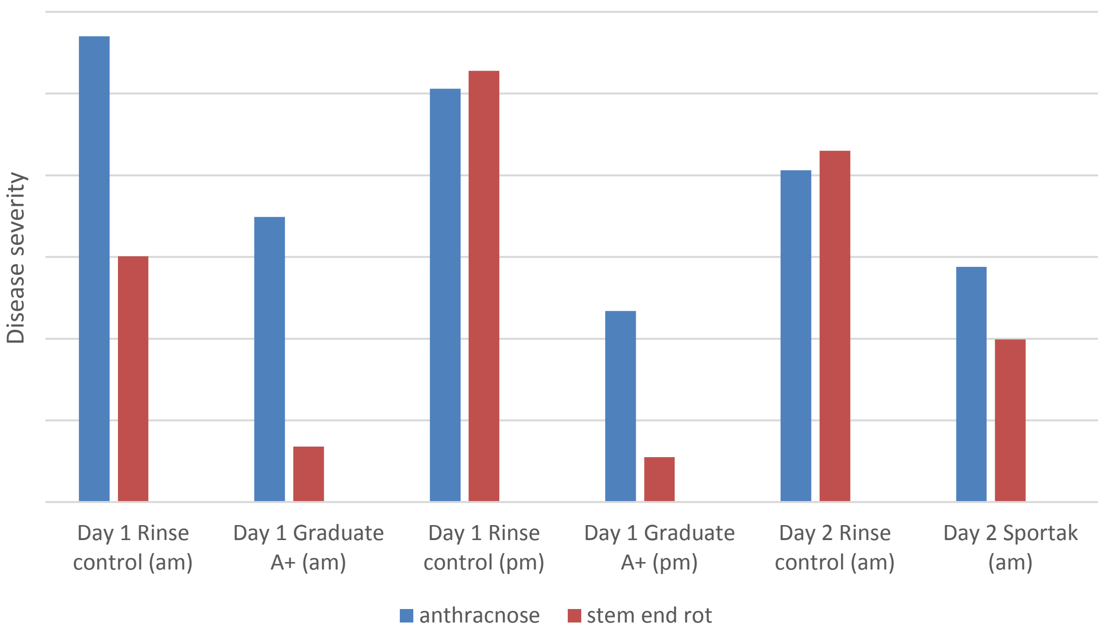

Figure 5. Effect of Graduate A+ and Sportak (prochloraz) fungicide on anthracnose and stem end rot disease in avocado cv. Hass. Fungicides were applied via a recirculating spray system for 30 sec, Trial 2

Trial 3 Non-recirculating spray, Central Queensland

This trial with cv. Wurtz incorporated a combination of final or penultimate field sprays of Amistar (azoxystrobin) or copper prior to harvest. The post-harvest treatments were applied through a non-recirculating spray tunnel for 30 seconds, which wet the fruit past the point of run off. The results show two field sprays with azoxystrobin followed by Graduate A+ post-harvest provided similar levels of anthracnose control as that when three field sprays of azoxystrobin then Graduate A+ were applied (Figure 6). Stem end rot was least severe when fruit were treated after harvest with Graduate A+.

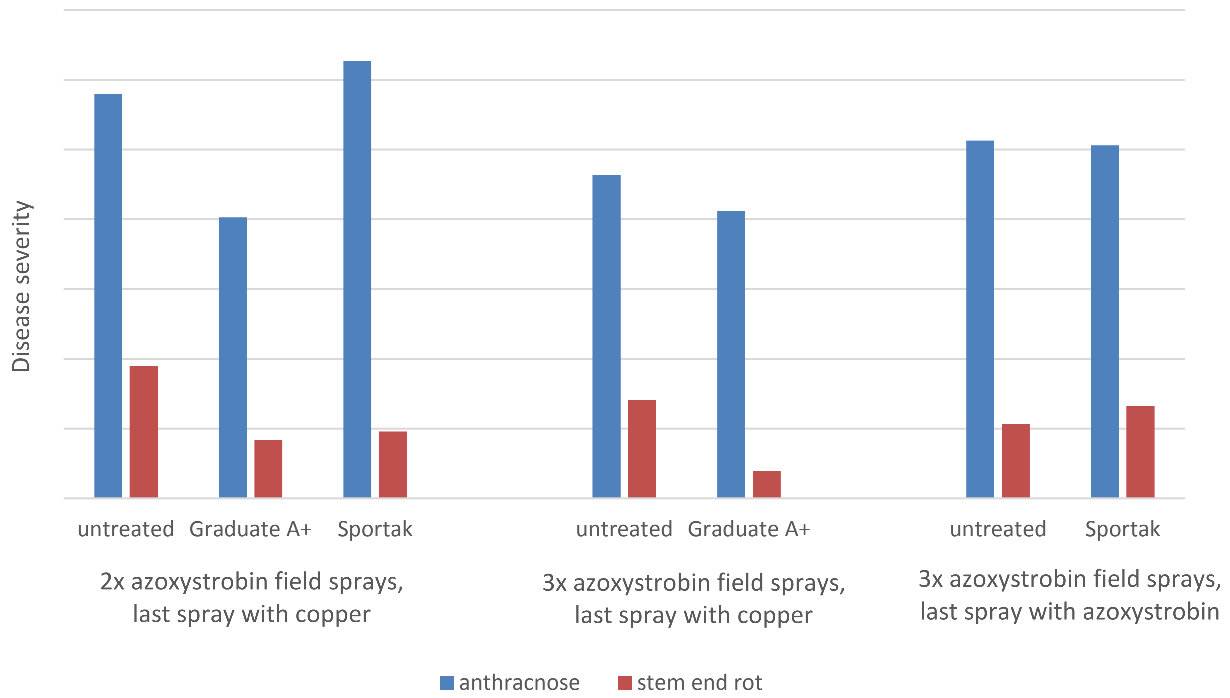

Figure 6. Effect of Graduate A+ and Sportak (prochloraz) fungicide on anthracnose and stem end rot disease in avocado cv. Wurtz. Fungicides were applied via a non-recirculating spray tunnel for 30 sec, Trial 3

PART 2 Effects of treatment with electrolyzed oxidizing water on postharvest diseases of avocado

Electrolyzed oxidizing (EO) water is generated by electrolysis of a dilute salt solution, and its microbiocidal effect is attributed to its high oxidation reduction potential and available chlorine (predominantly as hypochlorous acid). There are several benefits of EO water over other chlorine-based sanitizers, including its low corrosion potential, low toxicity and irritant levels (thus safe for operators), low chemical impacts on the environment (no residues due to decomposition back into dilute saline solution once the hypochlorous acid has been used), production on-site and approval for use in organic production systems.

Four trials with avocado cv. Hass and one trial with cv. Wurtz harvested at commercial maturity (24-34% dry matter) were undertaken to determine efficacy of EO water as a postharvest treatment on anthracnose and stem end rot diseases, compared with regular water (control) and industry standard post-harvest fungicides. A manuscript has been submitted to a scientific journal for publication, so results will not be presented in full here. Briefly, EO water treatments reduced stem end rot significantly compared with water control, and was more effective than hypochlorite (bleach) solution, but less effective than Graduate A+ fungicide. Anthracnose disease pressure was extremely high in most trials as fruit were sourced from unsprayed orchards, and under such high natural infection none of the treatments were particularly effective. However, treatments in the final trial were applied as overhead recirculating sprays in an experimental-scale packing line to simulate commercial conditions (Figure 8). Anthracnose was reduced similarly by both EO water and Graduate A+ compared with water control treatment.

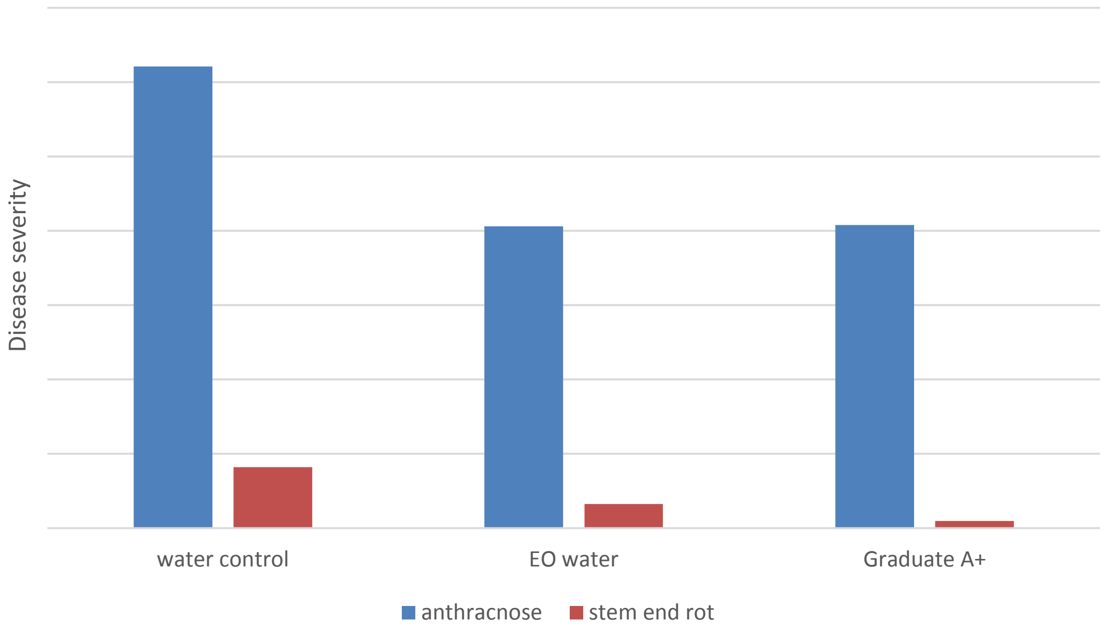

Figure 7. Effects of treatment with electrolyzed oxidizing water or Graduate A+ on postharvest diseases of avocado, cv. Hass, applied via recirculating spray for 30s

DISCUSSION

Graduate A+ was registered in Australia for postharvest use in 2018, and has been adopted by many packing sheds. It has been shown to be particularly effective against stem end rot disease. One of the limitations to adoption more widely has been the somewhat conflicting label statements. The azoxystrobin label currently states that the final field spray with azoxystrobin should be 7 days prior to harvest. Thus, azoxystrobin is typically the very last fungicide to be applied in field. However, the Graduate A+ label states that under the Crop Life Fungicide Resistance Management strategy, Graduate A+ must not be applied to avocado if Amistar (azoxystrobin, or similar Group 11 fungicide) was the final field spray. This has prompted Syngenta to apply for a label amendment to clarify that azoxystrobin does not have to be the final field spray. Further testing is required, however, our preliminary data suggests that two field sprays with azoxystrobin (with the second close to harvest) followed by Graduate A+ in the packingline, may be sufficient for very high quality fruit with minimal postharvest disease breakdown.

The research also demonstrates potential for electrolyzed oxidizing water to be incorporated into integrated management programs as an approved input for organic production of avocado, and possibly other fresh produce. As well as reducing fungal rots in fruit, it is likely to reduce foodborne (human) bacterial pathogens such as *Salmonella* spp., *Listeria monocytogenes* and *Escherichia coli*, on fruit surfaces and in processed pulp products. A recent survey by the US Food and Drug Administration reported a high incidence, 18%, of *Listeria* sp. detected on avocado skin samples, with equal numbers from domestic vs imported sources testing positive (FDA 2018). There was a lower incidence, 3.3%, of *Salmonella* spp., detected. Similar low levels, 2.3%, of *Listeria* was present in processed avocado or guacamole product, where most of the tested samples were of US origin. Another study in South Africa reported a high incidence, 14%, of *E. coli*, 2.4% of *Salmonella* sp. and no *Listeria* sp. from skin and pulp samples (Coetzee et al., 2017).

EO water-generating systems are now commonplace in many hospitals and facilities processing and packing fresh meat, fish, herbs, fruit and vegetables. In avocado, further research should investigate 1) efficacy of EO water treatment to reduce contamination by human bacterial pathogens 2) efficacy of field sprays with EO water throughout the season, compared with industry standard protectant and curative fungicides for reducing fungal diseases and 3) combinations of EO water and post-harvest fungicide to determine whether there is additive benefit. Conceivably, an initial wash with EO water followed by fungicide treatment could be easily integrated into fresh fruit packing facilities.

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REFERENCES

Coetzee, C., du Plessis, E., Duvenage, S and Korsten, L. (2017) Bacterial dynamics and the prevalence of foodborne pathogens associated with avocado fruit *Persea americana* Mill. South African Avocado Growers' Association Yearbook, 40:36-40.

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.

US Food and Drug Administration (2018) Microbiological Surveillance Sampling: FY14-16 Whole Fresh Avocados (report) Published Dec 2018. Web site accessed 14 August 2019. https://www.fda.gov/food/sampling-protect-food-supply/microbiological-surveillance-sampling-fy14-16-whole-fresh-avocados