Phosphonates and its use for managing Phytophthora root rot on avocado

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INTRODUCTION
Phosphonate fungicides are alkali metal salts of phosphorous acid. In plants, phosphonates dissociate into several anions, hereafter referred to as phosphite. Phosphite anions are involved in the control of Oomycete plant pathogens such as Phytophthora cinnamomi.

In South Africa, three phosphonate fungicide formulations are widely used, including ammonium phosphonate, potassium phosphonate and alkyl phosphonate. In avocado, mainly potassium phosphonates (Fighter®, Avoguard® and Rootmaster 98®) are used and are registered for application as trunk injections to manage root rot caused by P. cinnamomi. Based on tree health, two different dosages are applied; 0.3 g a.i./m² canopy diameter for the treatment of healthy looking trees (preventative treatment) or mildly diseased trees, and 0.5 g a.i./m² canopy diameter for severely diseased trees.

An alkyl phosphonate, also known as fosetyl-Al (Aliette®) is registered as a foliar spray on avocado on established trees, and on nursery trees as a root drench and foliar spray. However, Aliette foliar sprays are not used on established trees commercially, due to the high cost of the product. In South Africa, Brilliant® is the only ammonium phosphonate that is registered for use as a fungicide.

Trunk injection timing and resulting phosphite residues in fruit

Phosphonates are also used by injecting in tree trunks. Two application windows are recommended for the application of phosphonates on avocado, which coincide with the two root flushes. The two application windows consist of the periods after the summer- and spring foliar flushes have hardened off. Applications made after the summer foliar flush has hardened off (usually from February to April, depending on the cultivar and production region) is deemed the most effective for phosphate applications. This is most likely due to the fact that there are no fruit on trees that will also act as a strong sink for phosphate.

The application window following the hardening off of the spring foliar flush, usually around November/December, is a less effective application window, likely due to small fruit on trees being a strong competitive sink for phosphite in addition to roots. Products registered as trunk injections in South Africa recommend application during both application windows. The latter approach is also supported by published research from Darvas et al. (1984). However, due to the enforcement of maximum residue limits (MRL) in South Africa, most growers have started avoiding applications after the spring flush has hardened off. This is due to the fact that this application window contributes to high fruit residues that were significant higher than the untreated control (Fig. 1). Another aspect which is poorly understood regarding phosphite translocation to fruits, is whether re-mobilization of phosphite and re-mobilization of phosphite to fruit differs due to the method of application (foliar sprays versus injections).

Problems with MRLs resulting from stem injection

Information on strategies which will limit MRLs at or below the EU restriction, but still provide effective control, is limited. This is partly due to our limited understanding of the temporal nature of phosphite translocation in avocado trees.

It is known that phosphite is translocated in a source-sink nature at the time of application (Whiley et al., 1995). However, what is unknown is whether re-mobilization of phosphite can take place in trees. In apple trees, phosphite residues were still present in buds and fruits two years after phosphonate application, suggesting a remobilization of phosphite in plant storage organs to fruits (Malusa and Tosi, 2005).

Evidence for the re-mobilization of phosphite to fruits following initial application has also been evident in avocado trials conducted by Stellenbosch University and ZZ2. In trials conducted over two seasons, application of phosphonates only after harvest in fall when no fruits were present on trees, resulted in fruit residues that were significantly higher than the untreated control treatment (Fig. 1). Another aspect which is poorly understood regarding phosphite translocation to fruits, is whether translocation of phosphite and re-mobilization of phosphite to fruit differs due to the method of application (foliar sprays versus injections).

Potential of foliar sprays to reduce the risk of exceeding EU MRL limitations

There is currently no data to indicate whether application method has an influence on fruit residues. However, trials in South Africa have shown that when phosphonates are applied as 1% a.i. foliar sprays only after harvest, fruit residues can be lower than when a trunk injection (1 g a.i./m²)
Several new trials are in process of being established for the 2018/19 season in order to try and finalise the registration data for registering foliar sprays on avocado in South Africa. It is difficult to estimate the cost of foliar phosphate applications in comparison to trunk injections due to variables associated with low-density orchards (low number of trees/ha) versus the newer high-density orchards (higher number of trees/ha). For the high density orchards, four or five foliar potassium- or ammonium phosphate sprays will be slightly less expensive than two trunk injections, considering product and application costs. However, with increasing labour costs, in future, foliar sprays are likely to become even more cost-effective in comparison to trunk injections.

**Conclusion**

In conclusion, phosphonates remain an important component of managing Phytophthora root rot on avocado. The products are, however, problematic with regard to market access due to fruit residue problems. When using phosphonates in a preventative management strategy, foliar applications have the potential for avoiding exceedances of the EU MRL. However, maintaining residues below that required by certain German supermarkets (1/3 of EU MRL) will be problematic based on trials conducted thus far. For severely diseased avocado trees, registration trials have been conducted for the past two seasons (2015/16 and 2017/18) in order to register potassium phosphonate (Fighter®) and ammonium phosphate (Brilliant®) as foliar sprays. The trials conducted by Stellenbosch University and ZZ2 in the Mooketsi and Letaba regions have shown that four or five 0.5% a.i. foliar sprays applied after harvest at weekly intervals will be effective in suppressing Phytophthora root rot in a preventative management strategy.

When applying this high dosage foliar sprays, it is important to adjust the pH of the foliar sprays to a pH of 7.2, in order to avoid phytotoxicity. The volume of spray applied is also important, since it not only affects costs but also efficacy. In trials conducted in South Africa, a spray volume calculated using the following Unrath formula have been found effective:

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\text{Spray volume} = \frac{\text{tree height} \times \text{tree canopy diameter} \times 900}{\text{row width}}
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![Figure 1: Fosetyl-Al fruit residues (mg/kg) for avocado fruits obtained from avocado trees receiving different phosphonate treatments in trials conducted in the (A) 2016/17 ('Maluma Hass' on 'Duke7') and (B) 2017/18 seasons ('Maluma Hass' on 'Dusa' [Mookeetsi] and 'Carmen' on 'Dusa' [Letaba]). Phosphonate products applied as foliar sprays included a potassium phosphonate (Fighter®) and ammonium phosphate (Brilliant®). Following each treatment name, in brackets, are the number of applications that were made in fall (after harvest) and summer (after the spring foliar flush hardened off). The red dotted line indicates the European Union residue limit. Histogram bars of the same colour that have the same letters do not differ significantly from each other (P > 0.05) based on Fisher’s least significance test.](image)
trees suffering from Phytophthora root rot, trunk injections twice or three times a year remains the only option when using phosphonates. In these situations, it seems that there is as yet no solution to the balance between effective disease management and fruit residues.

It is important to use an integrated management strategy for managing root rot, which will assist in a faster and more sustained recovery of diseased trees. The most important management strategies include proper irrigation scheduling, planting on ridges, using tolerant rootstocks and the regular application of mulches and organic material to orchards.

It is also of utmost importance that, when new orchards are established, young trees should be protected against Phytophthora root rot for the first three years from planting. The application of a phenylamide soil drench at planting is important, followed by regular applications of phosphonates according to label recommendations.

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REFERENCES