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Timing of Phosphonate Trunk Injections for *Phytophthora* Root Rot Control in Avocado Trees

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Abstract. **Avocado trees, cv. Hass, were trunk-injected with 20% phosphonic acid, formulated as potassium phosphonate, at various stages of tree phenology and the dynamics of translocation to the roots studied. Phosphonate was detected in the leaves 24 h after trunk injection with the concentration peaking (60-80 mg/kg) within the first 10 days. However, the rate of accumulation and final concentration of phosphonate in the roots was dependent on the time of injection in relation to the sink/source status of the leafy shoots. Trunk injection at the beginning of the spring growth, when renewal shoots were strong sinks, resulted in phosphonate root concentrations of < 9 mg/kg which peaked at about 45 days after treatment. When phosphonate injections were given after the sink/source transition of the spring shoots, root concentrations increased to > 28 mg/kg at about 60 days after treat- ment. Injections of potassium phosphonate given during the period of summer shoot growth gave similar concentrations of phosphonate in the roots to the treat- ment given at spring shoot maturity.**

Phytophthora cinnamomi Rands is a devastating root disease of avocado *(Persea americana* Mill) in most countries that grow this fruit crop. The fungus invades the fine white feeder roots that grow during the spring and summer months, but rarely attacks the suberized woody tissue of the major roots or collar of the tree. Phosphonates (viz. salts or esters of phosphonic acid) are the first commercially used fungicides to have both acro- and basipetal movement in plants (Zentmyer, 1979; Luttringer, and De Cormis, 1985). Their novel development as a trunk injection has been shown to give effective control of *Phytophthora* root rot in avocados (Darvas *et al.,* 1984; Pegg *et al.,* 1985). The phosphonates, injected into the woody trunk tissue, are carried by the xylem stream directly to the leaves where they are later translocated to the roots to give protection against the invasion of the root rot pathogen. Trees rating 9 on the health scale of 0 = healthy to 10 = dead can be brought back to full health within 2 years by a trunk injection program with phosphonate fungicides (Pegg *et al.,* 1987). However, commercial management of this technology has often given variable and disappointing results. Our research investigated the translocation of phosphonate to the roots in relation to the time of trunk injection.

Materials and Method

The trees selected for the experiment were healthy twelve-year-old 'Hass' grafted to Velvick seedling rootstock, and had never been injected or sprayed with phosphonate fungicides. The trees were growing in a commercial orchard in subtropical Queensland (latitude 270 S, 350 m altitude). Three uniform trees were trunk injected with a 20% solution of potassium phosphonate at the beginning of spring shoot growth and a second group of 3 trees injected at spring flush maturity. The injection was carried out with Chemjet R tree injectors (Lavo Avocado Growers, Caboolture, Australia) at the rate of 15 mL/m of canopy diameter (Pegg *et al.,* 1987). Leaf and feeder (white unsuberized) root samples were collected at intervals for phosphonic acid analysis using an acid/diazomethane extraction and the concentration determined by gas chromatography.

The concentration flux of phosphonate in leaves for the 98 days it was monitored was fitted to the model derived by Wood (1967) where $y = ax^b e^{-cx}$. Regression analysis were used for the concentration flux in roots.

Results

After each injection the subse- quent rise in leaf phosphonate concentration was rapid, reaching a peak after 10 to 12 days of between 60 to 70 mg/kg (Fig. 1). This was followed by a decline in leaf phosphonate to $\leq$ 5 mg/kg 80 days after injection. Similarly the root phosphonate concentrations increased soon after trunk injection but at a slower rate and the maximum concentrations measured were considerably lower than in leaves (Fig. 1). Roots of those trees injected at the beginning of the renewal growth in spring, reached a maximum of ≈ 9.0 mg/kg phosphonate about 45 days after treatment. However, the roots of trees treated when all leaves on spring-grown shoots were fully expanded had a phosphonate concentration of ≈ 28 mg/kg about 60 days after injection. The experiment was repeated the following spring using another set of trees and similar results were obtained (data not presented).

Discussion

While some controversy exists in the literature on the mode of action of phosphonates in disease prevention it is clear that the organ targeted for protection must receive a minimum concentration of the fungicide for the mechanism to be effective. For efficient management of the technology, the grower should know when to inject his trees to maximize the translocation of phosphonate to the roots during the time when disease pressures are greatest. Our research has shown that trunk-injected phosphonate begins accumulating the roots of avocado trees within a few days of injection confirming previous results of Schutte *et at.* (1988). However, it is clear that the time of injection in relation to tree phenology is critical with respect to maximizing the translocation of phosphonate to the roots. In actively growing trees, the maximum concentration of phosphonate to accumulate in the roots after injection at the beginning of spring shoot growth (≈ 9.0 mg/kg), was significantly lower than the minimum of 20 mg/kg thought to

be required for protection against *Phytophthora cinnamomi* in field grown trees (Pegg and Whiley, unpublished data). However, in contrast up to≈ 28 mg/kg of phosphonate was measured in roots injected at the completion of spring shoot growth.

The efficiency of translocation of phosphonate to the roots appears directly relate to the sink/source status of the leafy canopy at the time of injection (Whiley, 1990; Pegg *et at.,* 1990). Following flowering there is a strong synchronization of shoot growth in the canopy which effectively remains a sink for 40 days after bud-break and injection should be avoided during this time. About 60 days after the terminal bud of the indeterminant panicle begins growing the shoots reach their maximum rate of photoassimilation (Whiley, 1990). During this time there is an effective translocation of photoassimilates from the leaves to the roots (Whiley and Schaffer, unpublished data). We believe that phosphonate arriving in the leaves via the xylem stream, is more effectively translocated by the greater basipetal mass-flow of photoassimilates at this stage of tree phenology.

Trunk injection during the summer when some new shoot growth was occurring gave a similar accumulation of phosphonate in roots to those of trees injected at the maturity of the spring growth (data not presented). Sporadic shoot growth without synchrony of the whole tree occurs within the canopy during summer. However, at anyone time there a sufficient 'source' leaves to enact efficient translocation of the fungicide to the roots when tree are injected during this period.

Conclusions

By strategically timing the trunk injection of phosphonates into avocado trees the efficiency of translocation of the fungicide to the roots can be increased by about 300%. This more effective use of fungicide will be off considerable economic benefit to producers requiring a root rot man- agement program. In subtropical Australia disease pressure is greatest during the summer months when soil temperatures and moisture are optimum for the growth and development of the pathogen. Injections of phosphonate fungicides at either the maturity of spring shoot growth and/or during the mid summer months will give protection to the tree during this critical period. Further research is required to more closely define the minimum concentration required to protect roots in relation to the complex pathogen/host interactions.

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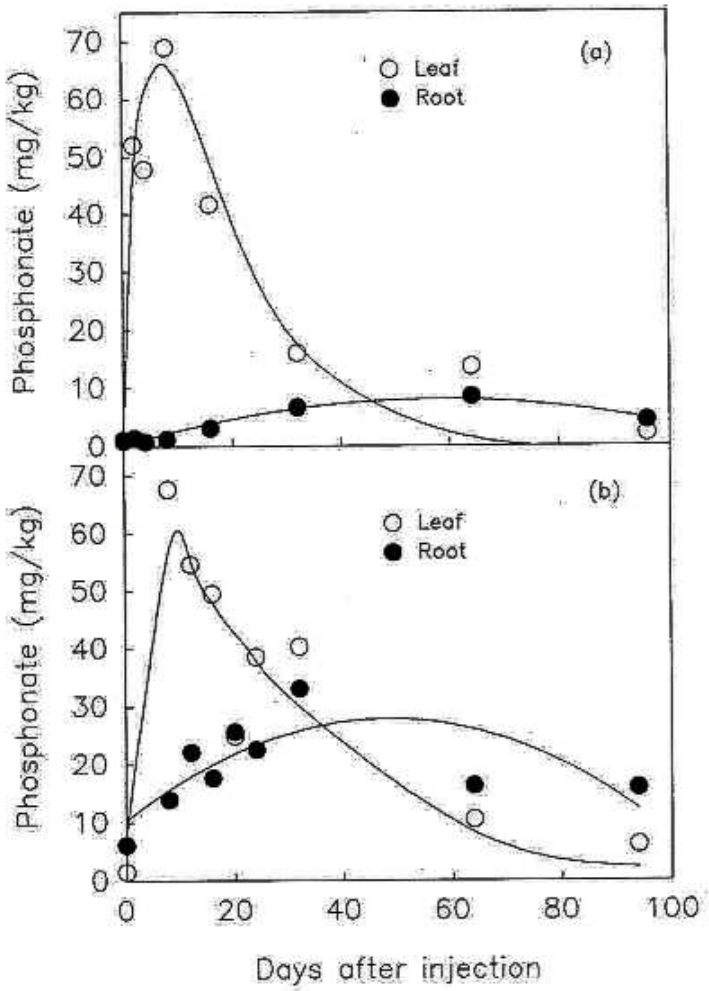

Fig. 1. The concentration flux of phosphonate in avocado tissues following trunk injection at (a) the beginning of spring shoot growth where the model for leaves is represented by $y = 36.0x^{0.649}e^{-0.093x}$, $R^2 = 0.69$; and for roots by $y = 2.94 + 0.24x - 0.0025x^2$, $R^2 = 0.87$; (b) the maturity fo the spring shoot growth where the model for leaves is represented by $y = 39.7x^{0.356}e^{-0.048x}$. $R^2 = 0.73$; and for roots by $y = 10.36 + 0.72x - 0.0074x^2$, $R^2 = 0.60$.