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PHOSPHONATE TRUNK INJECTIONS AND BARK SPRAYS

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Potassium phosphonate is a cost-effective chemical for reducing the impact of *Phytophthora cinnamomi*. It can be applied as a soil drench, foliar spray, trunk spray or pressurized trunk injection. Phosphonate concentrations in roots are maintained at high levels for a longer time when applied as injections. Injections are the best way to rejuvenate severely affected trees. Timing in relation to tree phenology is crucial in obtaining maximum levels and persistence of phosphonate in roots. Current studies have shown that for maintaining tree health, single annual injections made after leaf and root flushing are complete, give a high root concentration of phosphonate that persists for 12 months. As wound damage to trunks from injections is of concern to some growers, experiments are underway where organo-silicate bark penetrants have been added to potassium phosphonate to increase absorption from trunk sprays.

Keywords: *P. cinnamomi*, root rot, avocado, feeder roots

INYECCIONES DE FOSFONATO POTÁSICO AL TRONCO Y PULVERIZACIONES A LA CORTEZA

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Fosfonato potásico es un químico rentable en cuanto a la reducción del impacto de *Phytophthora cinnamomi*. Este puede aplicarse mojando el suelo, con pulverización foliar, pulverización al tronco o inyecciones presurizadas al tronco. Las concentraciones de fosfonato en las raíces son mantenidas en altos niveles por un largo periodo de tiempo cuando se aplica en inyecciones. Las inyecciones son la mejor manera para rejuvenecer árboles con afecciones severas. Calcular el

momento oportuno en relación a la fenología del árbol es crucial para obtener máximos niveles y persistencia del fosfonato en las raíces. Actuales estudios han demostrado que para mantener el árbol sano, una sola inyección hecha después que se ha completado el flash de crecimiento de hojas y raíces, provee una alta concentración de fosfonato que persiste por 12 meses. La herida en el tronco producto del daño de las inyecciones es una preocupación para algunos agricultores, es por esto que se encuentran en proceso experimentos donde se han agregado fluidos penetrantes de corteza de silicato orgánico para que el fosfonato potásico incremente la absorción en las pulverizaciones al tronco.

1. Introduction

Phytophthora root rot (*Phytophthora cinnamomi* Rands) remains the most important and damaging disease of avocado worldwide, as it causes significant tree deaths and reduces yield (Pegg *et al.* 2002). The fungus mainly invades the white feeder roots of the tree and these roots become brownish-black (Guest *et al*. 1995). Wilting, yellowing and defoliation are the obvious symptoms, and the infected tree will eventually die. Since the introduction in the early 1980s of potassium phosphonate injections (Darvas *et al*. 1984), considerable progress has been made in understanding and reducing the impact of the pathogen, but optimum phosphonate application strategies have yet to be achieved.

Phosphonate is systemic in the avocado tree and high concentrations can occur in developing fruit, shoot and root tips. It is believed to work against Phytophthora at high concentrations by retarding fungal growth. Phosphonate may also work indirectly by stimulating plant defence mechanisms. This occurs when phosphonate levels are low within the roots and release of stress metabolites from Phytophthora trigger host defence systems. These natural plant defence systems then bring the invasion under control. In addition, low levels of phosphonate significantly reduce sporulation of *P. cinnamomi* (Guest *et al*. 1995)

The current recommendation for growers with healthy trees is to inject their trees with phosphonate twice a year following hardening of spring and summer flushes. We are testing the hypothesis that an injection once a year after summer flush maturity (when root flushing is complete, but before floral bud development has advanced) will be adequate. The hypothesis is that a single injection at the correct time of the year will provide a sufficient level of phosphonate in the roots to last for 12 months. In preliminary trials, it was found that injection of trees with phosphonate can actually inhibit feeder root growth if applied at the commencement of a root flush. Trials have, therefore, been established to monitor timing of trunk injections.

It has previously been shown for avocado that a concentration of phosphonate required to protect or rejuvenate feeder roots could not be absorbed through the bark of older trees. However, an organosilicone bark penetrating translocation aid

(Pentra-bark®) has been developed to allow phosphonate to be absorbed through the bark of oak trees in the USA at a sufficient concentration for the control of *Phytophthora ramorum*. It has been determined that a phosphonate root level between 25 to 40ppm is required to protect the roots (pers. comm. Whiley 2000, Sunshine Horticultural Services Pty Ltd). Hence, our trials are comparing trunk sprays with trunk injections for control of root rot. For the trunk sprays, phosphonate was used in combination with Pentra-bark as well as the organosilicone penetrant Pulse® (similar to Pentra-bark) and different rates are being assessed. Samples have been routinely collected for phosphonate analyses to monitor its movement and decline in leaves, roots, flowers and fruit over time.

2. Materials and Methods

Trial 1: This trial was carried out on healthy ‘Hass’ grafted to seedling ‘Duke 6’ rootstock trees at Hampton in south-east Queensland. The trees had not previously received treatment with phosphonate. Two treatments were applied to the trees in February 2005. Half the trees received trunk injections of phosphonate at industry standard rate (Pegg *et al*. 1987). The other half of the trees were trunk sprayed with a mixture of phosphonate and Pentra-bark.

Seven days after the initial treatment, root samples were taken 1m out from the base of the tree, below injection sites for injected trees and from the same location under trees which had received trunk sprays. Sixteen (four per quadrant) newly mature leaves were sampled at a uniform height from around the tree canopy. Samples were taken monthly for three months. After four months, trees were sampled prior to retreatment. Trees were again sampled monthly. Samples were analysed for phosphonate content. Root abundance was also assessed.

Trial 2: This trial was established to test the effectiveness of applying phosphonate to tree trunks using Pentra-bark as a bark penetrant. Root rot affected trees were treated by injection or by trunk spray with Pentra-bark in December 2003. A second spray treatment was applied in January 2004. Tree health was assessed for improvement over time.

Trial 3: This trial was carried out on healthy four-year-old 'Reed' grafted to 'Velvick' seedling rootstock trees, which had never been treated with phosphonate fungicides. Two treatments were applied to the trees in June 2006. Ten trees received trunk injections of phosphonate at industry standard rate (Pegg *et al*. 1987). Ten trees were trunk sprayed with a mixture of phosphonate and Pulse. The volume of chemical injected was equivalent to the volume sprayed on the trunk. In January 2007, a further application, using double the volume, was applied to the trunk sprayed trees only. In this trial, Pentra-bark was replaced with a similar product, Pulse, as Pentra-bark caused flocculation of the vegetable dye found in the phosphonate products, which led to spraying difficulties.

Root and leaf samples were harvested 1 month followed by every 3 months after the initial treatment. The most recent sample collection was in June 2007. Samples were taken as previously described. Flower and fruit samples were also taken as they became available.

3. Results and Discussion

Trial 1: In this trial, where treatments were applied at early vegetative flushing, the concentration of phosphonate in the feeder roots was significantly higher in the injected trees (Table 1) and this was also the case in the leaves. The considerably lower leaf phosphonate levels after trunk spraying indicate that phosphonate applied in this way provides a lower but more consistent supply of phosphonate transported via the phloem into the roots where it is needed, with little or none ending up in the canopy, thus reducing the potential for unwanted fruit residues. When injected, most of the phosphonate travels to the leaves via the xylem and then down to the roots (Guest *et al*. 1995). This occurs because the translocation to root tissue is affected by source/sink relationships at the time of injection.

Table 1: The mean concentration of phosphonate in leaf and root samples from trunk injection/trunk sprays at Hampton (not all data shown) (means with the same letter were not significantly different at a $p<0.05$)
Tabla 1: la concentración media de fosfonato en las muestras de hojas y raíces desde el tronco inyectado en Hampton. (no todos los datos son mostrados) (las concentraciones con la misma letra no fueron significativamente diferentes a una $p<0.05$)

	Feb 05*		Mar 05*		Jun 05*	
	Roots (mg/kg)	Leaves (mg/kg)	Roots (mg/kg)	Leaves (mg/kg)	Roots (mg/kg)	Leaves (mg/kg)
Trunk injection	30.4 a	220 a	47.1 a	228 a	47.4 a	40.6 a
Trunk spray	9.1 b	5 b	15.3 b	9 b	12.1 b	5.0 b
P	0.002	<0.001	0.019	0.002	0.024	0.003

* Some samples were at non-detectable levels (i.e. <5 mg/kg) – for statistical purposes these values were changed to 5 mg/kg

It was also found that feeder root development was inhibited under injected trees (Table 2), suggesting that high phosphonate levels in root tips in the early stage of the feeder root flush can have an adverse but temporary effect on root growth. As this reduction in root mass may be detrimental, it reinforces the recommendation to delay injections until the vegetative flushing, as well as the root flushing, is complete. It has also been found that growers achieve a higher root concentration which persists longer by delaying injections (pers. comm. Thomas 2005, G.L.T. Horticultural Services Pty Ltd).

Table 2: The effect of trunk injection or trunk spray at Hampton on feeder root mass four months after treatment (means with the same letter were not significantly different at a $p<0.05$)

Tabla 2: Efecto de el tronco inyectado y efecto de el tronco pulverizado en Hampton sobre la masa de las raices secundarias por cuatro meses después de el tratamiento (concentraciones con la misma letra no fueron significativamente a una $p<0.05$)

Application method	Mean root mass*
Trunk injection	2.14 b
Trunk spray	2.86 a
P	0.004

* 1 = roots sparse, few roots, 2 = roots present, network not developed, 3 = roots abundant, network developed

Trial 2: Tree health improvement was assessed in this trial. Even though root levels of phosphonate may be less in trees receiving trunk sprays, this treatment was as effective as trunk injection for the recovery of severely affected trees in a field trial at Duranbah (Table 3).

Table 3: Improvement in health in 'Hass' trees severely affected by Phytophthora root rot at Duranbah

Tabla 3: El mejoramiento de la salud de los paltos 'Hass' severamente afectados por fitofora en la raíz podrida después de inyectar el tronco o pulverizar el tronco en Duranbah

Treatment	Improvement in tree health (%)
Untreated	0
Trunk injection	15.8
Trunk spray	12.2

Trial 3: In this trial, where treatments were applied after vegetative and root flushing, even though injected trees generally gave higher levels of phosphonate in the roots (e.g. 65.8mg/kg in Jul 06; 48.1mg/kg in Jun 07), the trunk spray treatment using the same chemical volume per tree gave sufficient levels (e.g. 30.3mg/kg in Jul 06; 46.2mg/kg in Jun 07) to control root rot for 6 months. Re-application of trunk spray was necessary after 6 months as phosphonate levels in the roots had dropped below the optimal level for disease control. Leaf analyses show the undesirable movement of phosphonate to the tree canopy after injection (e.g. 114.8mg/kg in Jul 06). The benefit of using trunk spray treatment is that leaf levels remain consistently low (e.g. 5.7mg/kg in Jul 06).

These experiments are ongoing and it is anticipated that we will have a more cohesive disease management recommendation to deliver to avocado growers in the future. The cost implications and environmental impacts of the various application methods for phosphonates will be an important component of our analyses.

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