PFR SPTS No. 25848

Best practices guide for phosphite injection of kauri

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June 2024

1 Introduction

Phytophthora agathidicida is a serious problem, killing kauri trees of all ages throughout northern New Zealand forests, and threatening the unique kauri ecosystem. Treatment with phosphite (phosphorous acid, phosphonate) is one of the few options for treating infected or threatened trees.

This document is intended to provide practical guidelines for phosphite treatment of kauri trees threatened by kauri dieback, to suppress disease, slow tree decline and ultimately improve kauri tree health. The recommendations are based on research trials carried out in the glasshouse and many diseased forests from 2009 to 2024, summarised in Horner et al. (2024), where evidence provides confidence about the efficacy and safety of phosphite trunk injection for kauri dieback control. The recommendations in this guide are based on the best available experimental data, predominantly from Kauri Dieback Programme-sponsored research, but also with some reference to Kauri Rescue trials and commercial applications. This document should be updated as more information comes to hand.

These guidelines are intended for Kauri Dieback Programme partners only and not for the general public. Currently, the Kauri Rescue™ Trust (www.kaurirescue.org.nz) is an effective platform for the general public roll-out of phosphite.

2 Conclusions from trials

In trials from 2011 to 2024, injection with phosphite into kauri trees infected by *P. agathidicida* was proven to effectively suppress lesion development, aid healing, and lead in the long-term to an improvement in tree health. Trials with ricker trees demonstrated that rates from 4% to 7.5%, with 20 ml injected every 20 to 40 cm effectively healed lesions. To date only very low doses have been trialled on large trees, and these were partially, but not fully effective at healing lesions. Evidence suggests doses equivalent or higher than those used on ricker trees will be required for effective treatment of large trees, but this is yet to be determined experimentally. In ricker trees, concentrations of 20% phosphite caused phytotoxicity symptoms – concentrations above 7.5% are not recommended for kauri.

The New Zealand Institute for Plant and Food Research Limited (2024)

3 Decision framework

3.1 Basic Premise

Phosphite has the potential to prevent *P. agathidicida* infections establishing and spreading within kauri trees.

Phosphite doses must be sufficient to suppress the pathogen and/or stimulate tree defence responses.

If phosphite doses are too high, phytotoxicity may occur.

If the phosphite dose is too low, it may be insufficient to suppress lesion spread, or may provide only short-lived control.

A balance must be struck to find doses suppressive to disease development, yet safe for the tree.

Trees with advanced infections are likely to be more sensitive to phosphite, and thus more likely to decline rapidly or show phytotoxicity symptoms following treatment.

3.2 Site and tree selection

Only trees on sites with confirmed *P. agathidicida* infection should be treated.

Appropriate consultation with landowners, land managers and mana whenua should precede any applications, with all applicable approvals in place before commencing any treatment.

When deciding whether or not to treat, consider the potential benefits (e.g. lesion healing and tree survival) versus the potential risks (e.g. phytotoxicity or accelerated decline of trees with very advanced infections). Within sites, only infected/symptomatic trees and near-neighbouring trees should be treated.

In **confirmed infected sites**, consider treatment of:

- trees with canopy symptoms consistent with kauri dieback (canopy thinning, yellowing, branch dieback)
- trees with basal trunk lesions consistent with kauri dieback (lesions/resin bleeds contiguous, or almost contiguous, with the ground)
- non-symptomatic trees immediately adjacent to symptomatic trees (assessment of ‘at risk’ non-symptomatic trees to treat should consider site factors including proximity to symptomatic trees, slope, water drainage, vector pathways etc., and will vary from site to site). Decisions on distance will be subjective, until more information on local spread, disease latency, local vectors etc. is available.

Do not inject:

- trees less than 7-cm diameter
- healthy trees remote from any obvious threat of infection (taking into consideration site factors including proximity to symptomatic trees, slope, water drainage, vector pathways etc., which will vary from site to site).

3.3 Deployment

Timing: There is no evidence that any particular season is better or worse than any other for injecting trees, but this aspect has not been formally investigated. Weather and soil conditions (i.e. risk of spread) should be taken into account when planning treatment.

Pattern of treatment: There have been no studies of the optimal treatment pattern across sites, i.e. whether all trees should be treated, or whether just a percentage of trees is sufficient. The deployment strategy, concentration and dose, criteria for treating/not treating a given tree etc. should be determined in advance of commencing treatment at a site.

Frequency: No more than once every 3 years (for rickers), unless very low doses are used. For large trees, if lesion healing is insufficient in reassessments after 2 years, retreatment may be required.

Barrier treatment: Deployment of phosphite as a barrier treatment, effectively isolating the pathogen within a non-susceptible barrier, could potentially reduce spread and contain the pathogen on some sites. However, many unknowns remain, and multiple factors need to be considered (e.g. kauri tree size and density, alternative hosts, slope, vectors etc. - discussed more fully in Horner (2016)).

3.4 Phosphite concentration and dose

Phosphite is likely to be effective across a range of concentrations (% active ingredient) and doses (number of injectors per cm of trunk circumference). Trees with advanced canopy symptoms are more likely to show phytotoxicity, so doses should be reduced.

For rickers/advanced rickers, up to approx. 70 cm diameter at breast height (DBH)

Phosphite concentration: Phosphite at 4 – 6% active ingredient, potentially up to 7.5%, is recommended.

Application rate: (i.e. injector spacing) One 20-mL injector every 20 - 40 cm of trunk circumference. For trees with substantial canopy thinning (3 or 4 on the canopy scale), injectors should be spaced at 30–40 cm.

Higher phosphite concentrations and lower injector spacings (within the recommended range), are likely to provide the best control and longevity of effect.

For large trees (>70 cm DBH)

There is still no good empirical data on effective doses for treatment of large trees. Injection of 20 mL of 4% phosphite every 40 or 80 cm is too low for effective and lasting control, but higher concentrations and doses have not yet been tested on big trees. However, evidence suggests that the range of rates listed above for rickers should be safe, and if anything may be less than what is required for complete lesion healing on the very big trees. Until more empirical data is available for very large trees, close follow-up monitoring should be carried out wherever higher concentrations and doses are used.

4 Operational specifications – injection process

4.1 Equipment and preparation

- Battery-operated drill with 5–6 mm diameter drill-bit
- Spring-loaded 20-ml injectors (e.g. Chemjet®)
- Phosphite (e.g. Agrifos®600 or Phosgard/Phos400™)
- Measuring cylinders and containers for mixing phosphite and loading syringes
- Tape measure for tree girth
- Tags for labelling trees
- Protective equipment (gloves, goggles)
- Water for mixing phosphite solutions and for rinsing hands etc.
- Hard brush for cleaning syringe tip
- Hygiene equipment for working around kauri trees (nylon booties, 80% ethanol, brush)

4.2 Mixing of phosphite solution

Ideally, the phosphite should be diluted fresh from the concentrate each day, using clean water. Once diluted, efficacy is likely to decline after 48 h. ‘Hard’ or alkaline water will reduce product longevity and should be avoided if possible. Most town water supplies should be suitable (even if chlorinated), or rainwater could be used.

Table 1. Dilution of phosphite concentrate to desired concentration for injection.

Product used and concentration	Desired phosphite concentration			
	4%	5%	6%	7.5%
60% phosphite (e.g. Agrifos600)	1 part phosphite, 14 parts water	1 part phosphite, 11 parts water	1 part phosphite, 9 parts water	1 part phosphite, 7 parts water
40% phosphite	1 part phosphite, 9 parts water	1 part phosphite, 7 parts water	1 part phosphite, 5.7 parts water	1 part phosphite, 4.3 parts water

4.3 Injection procedures

- Measure tree girth (at chest height) by placing a measuring tape around the trunk, and calculate the number of injectors required, dependant on the dose chosen (e.g. one injector per 20 or 40 cm circumference). Note that a hand-span width is roughly 20 cm. Do not inject trees less than 20 cm girth.
- Load the injector by firmly holding the barrel, immersing the tip in the phosphite solution and pulling the plunger out fully. Twist the plunger slightly to lock in place. Load all injectors for a tree before starting to drill.
- Drill holes to 4.5–5 cm depth on a slight downward angle, and immediately screw in the loaded injector. Hold the barrel, not the plunger. Screw in until there is a tight fit. Release the lock, to allow the spring to slowly force the solution into the tree. Do not push the plunger in, the spring will force the phosphite into the tree automatically.

- Remove the injector as soon as possible after the injector is completely empty. This usually takes from 3 to 10 minutes. If injectors are left in too long, kauri resin can enter the injector tip or chamber, reducing its longevity.
- Post injection, leave the holes open – in most cases the tree's own resin will plug the hole.

Notes and tips:

- The injection height up the trunk is not critical, but between knee and chest height is usually most convenient and comfortable.
- The injection angle should be slightly downward, to aid complete emptying of the syringe.
- Injectors should be evenly spaced around the tree. An exception would be where dead areas or large lesions need to be avoided.
- Avoid dead areas. Do not drill directly into lesions, dead areas of wood, cracks or immediately above such areas. Sap flow in such areas will be impeded or non-existent, and there will be inadequate uptake. Preferably move injectors to healthy wood to the side of lesions, rather than above. If forced to inject above lesions, go as far away as possible (preferably >50 cm).
- Use each hole only once.
- If syringes completely stop, or do not empty within about 20 minutes, remove carefully and re-inject a fresh point at least 8–10 cm away. Estimate the total volume not taken up by a given tree and re-inject 20-ml doses accordingly, to avoid over-dosing.
- If trees are being reinjected, e.g. a few years after initial treatment, the injection points should be laterally well away from the initial points, and not immediately above or below those initial

points. Where possible, re-injection points should be mid-way between the initial points (which are usually visible for a few years).

4.4 Clean-up

Syringes should be cleaned in warm soapy water, at least daily. This will prolong their life. Soaking the syringe tip in methylated spirits for a few minutes will help unclog blocked tips, or remove persistent gum residues. Immerse the tip only, not the whole syringe, then rinse in clean water.

There is no need to clean or sterilise syringes between trees, but debris (if present) should be brushed off.

4.5 Safety

Working in *P. agathidicida*-infected forests risks spreading the pathogen, so appropriate and rigorous hygiene practices should always be followed https://www.kauriprotection.co.nz/resources/best-practice-guides/protecting-kauri-principles-of-hygiene/.

Regional Councils, the Department of Conservation (DOC), the Ministry for Primary Industries (MPI) and other agencies have existing protocols for working safely in the bush, handling chemicals, working alone etc., and these should be followed.

All operators should read and follow label instructions and refer to the Safety Data Sheet (SDS) for whatever product they are using. For example, the Agri-fos 600 SDS can be obtained here.

Gloves and eye protection should be worn during phosphite mixing and injection operations.

5 References

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Confidential report for:

MPI/Tiakina Kauri
CO036375

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PUBLICATION DATA

Horner I, Arnet M. June 2024. Best practices guide for phosphite injection of kauri. A Plant & Food Research report prepared for: MPI/Tiakina Kauri. Milestone No. 98630. Contract No. 41623. Job code: P/383003/01. PFR SPTS No. 25848.

KEYWORDS: *Phytophthora agathidicida*, kauri dieback, trunk injection, phosphorous acid, phosphonate.

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