



Kauri Ora: Heat treatment protocol

Best practice guide
for killing PA in soil,
plant material and
on inanimate objects
with heat



KA RAUHĪ TE TUPU O TE KAURI

GIVE KAURI SPACE TO GROW



Tiakina Kauri is an agency based within Biosecurity New Zealand that provides national direction for the achievement of the objectives of the National Plan for Kauri, through active partnership with mana whenua and collaboration with regional councils and the Department of Conservation.

For more information about protecting Kauri, visit www.kauriprotection.co.nz

About this guide

This guide provides best practice for using heat treatment for hygiene management on items that have the potential to be contaminated or infected with the pathogen *Phytophthora agathidicida* (PA) and subsequently spread through human activities.

These guidelines provide advice on how to eliminate PA in soil and soil substrates. These guidelines should form part of a layered approach to reducing risk that starts with good hygiene practices as outlined in the associated best practice guidelines.

The guide also shares what is considered best practice based on the current information and uses risk management principles to reduce the likelihood of spread of PA during operations.

For more information about protecting Kauri and about the PA pathogen, visit www.kauriprotection.co.nz

Intention of this guide

This guide is broken into two sections which focus on the following:

- *Section 1: Footwear, tools and equipment*
- *Section 2: Soil and plant material (treatment of low volumes of soil)*

The guide is **not intended** for the following:

- Treating potentially contaminated soil after the soil analysis process has been completed. The best practice method for this is autoclaving.
- Treating PA in composts, soil conditioners and mulch to standard as this is covered under NZ Standard 4454.
- Treating large volumes of dirt associated with earthworks.

The National Pest Management Plan for Kauri

In August 2022, a National Plan was launched to help protect Kauri from the *Phytophthora agathidicida* (PA) pathogen. The National Plan includes 10 rules that apply to anyone who grows Kauri, goes into Kauri forests, or lives or works around Kauri.

By following this guide and the rules of the National Plan, we can all help protect Kauri for generations to come.

How do the National Plan rules for Kauri work?

The Tiakina Kauri | Kauri Protection programme helps people understand and comply with the National Plan rules through education and awareness programmes.

In cases of clear and substantial or continued non-compliance with the rules, prosecution or infringement fees could be applied.

For more information about the National Plan, visit www.kauriprotection.co.nz/national-plan

Biosecurity Act 1993

Under the Biosecurity Act, PA is an unwanted organism. This means it is an offence to release PA, cause PA to be released, spread, propagate, or act in a manner likely to encourage the propagation of PA. For more information about unwanted organisms, visit: www.mpi.govt.nz/biosecurity or email info@mpi.govt.nz

Obligation to clean items

Before entering a Kauri forest, you must clean all dirt and organic matter off all items that touch the ground. Clean them again before you leave. This includes cleaning tools, cars, bikes, hiking poles, footwear, gloves, etc. **(Rule 8)**

Heat treatment is a useful method for eliminating the risk of PA spread in contaminated soil and water of the appropriate volume.



About the PA pathogen

The PA pathogen infects Kauri through their roots and restricts the trees' ability to transport water and nutrients between the roots and the leaves. This causes the fatal condition known as kauri dieback disease, which eventually starves the Kauri.

There is no proven way to cure an infected Kauri, and there are limited treatment options.

The survival of Kauri depends on all of us taking action to stop PA from spreading, like following correct hygiene protocols when moving and working around Kauri.

The PA pathogen can be spread by:

- vehicles and machinery
- footwear, clothing or equipment that touches the soil
- animals, including wild pigs and stock



PA pathogen infection can cause bleeding gum



View of Kauri canopy with dead branches

Recognition of Kauri

Identifying Kauri from other trees is the key first step to protecting Kauri. Kauri has identifiable features, including three main stages of their life, that are important to know if they are to be accurately identified in the field. See the Tiakina Kauri website for more information on how to recognise Kauri.

Kauri Hygiene Zone

The best way to protect Kauri and avoid introducing or spreading PA through the movement of soil or dirt is to avoid operations around Kauri Hygiene Zones and Kauri forests whenever possible.

To protect Kauri, it is also important not to damage or disturb their roots. Kauri roots are shallow and fragile and extend outwards about 3x the radius of the canopy of the tree; this is known as the Kauri Hygiene Zone.

Figure 1: The illustration shows the Kauri Hygiene Zone for a single Kauri

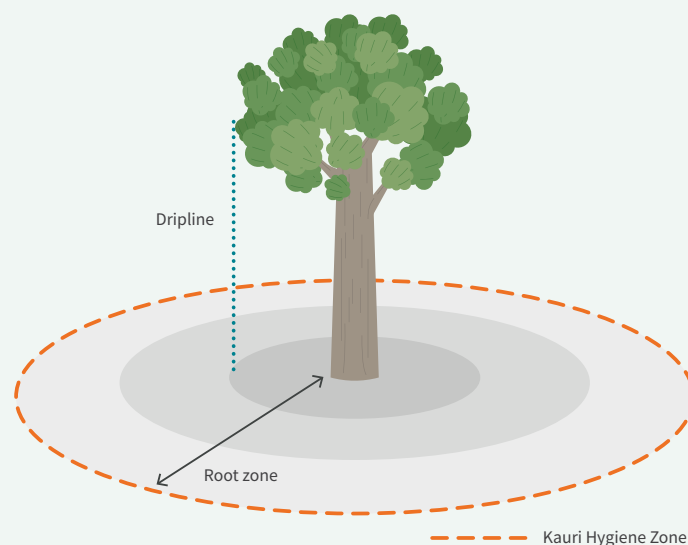
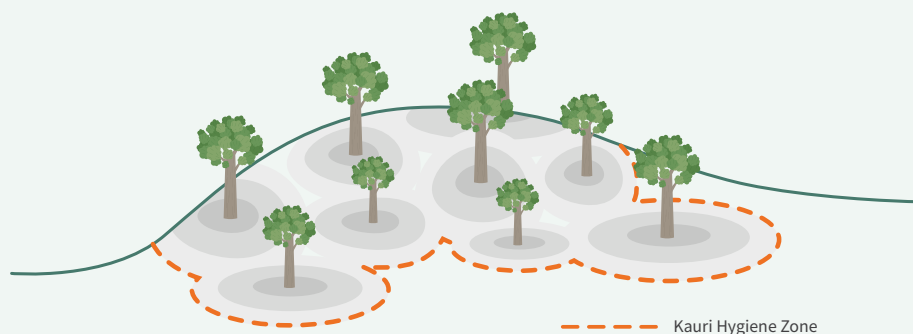


Figure 2: Interconnected stand of Kauri Hygiene Zones



Background

Heat can be used to kill *Phytophthora* species by exposing them to high temperatures for a sufficient length of time. However, certain life stages are more difficult to kill than others.

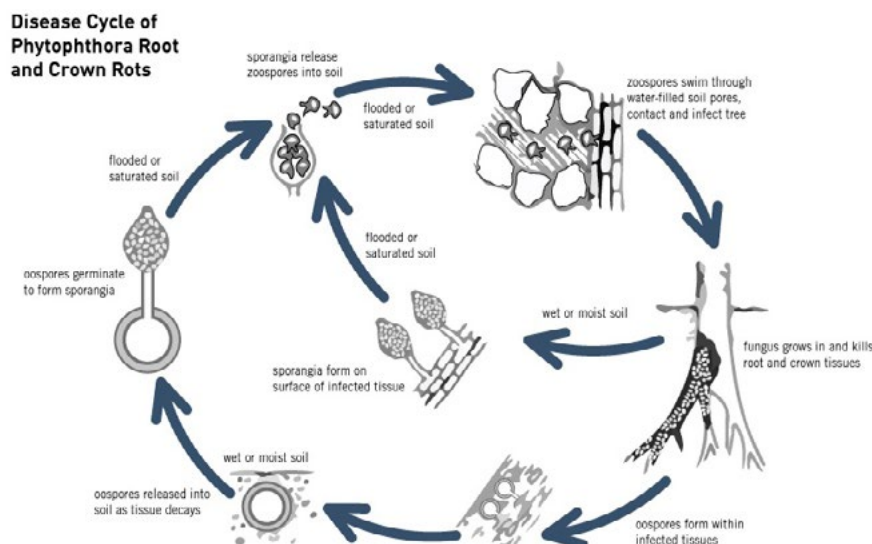
Phytophthora species don't thrive when exposed to the relatively high temperatures of between 41°C and 122°C. PA mycelia grow readily between 5-25°C with optimal growth at 22°C and no growth occurring at more than 30°C. This means exposing soil and dirt to higher temperatures will deactivate PA spores.

Oospores and/or mycelia which are located within root and fine organic fragments are the main part that survives for many species of *Phytophthora* including PA. Oospores are characterised by a thick wall, resistance to drying out and the ability to enter a dormant phase which makes it more resistant to degradation under conditions of increased heat and external stressors. Research has found that when oospores of PA are exposed to temperatures above their thermal limit, they are deactivated or killed.

From an operational perspective, the desired temperature and time combination can be achieved for either footwear, tools and equipment or soil and plant material in a number of different ways.

These are:

- Boiling water.
- Direct heat (drying ovens, containers heated by electricity, natural gas or fire).
- Soil solarisation (to a standard with the required controls, avoiding cross contamination).
- Composting (specifications under NZS 4454 2005, compost, soil conditioners and mulches).



Assumptions and constraints

These guidelines are based on current research into the efficacy of temperature against PA in non-composting and non-solarisation systems as well as overseas research into the efficacy of using heat treatment against other *Phytophthora* species using solarisation and composting. Specific research on PA has not been undertaken to determine the efficacy of heat treatment using solarisation and composting.

A safety margin has been built into the temperature provided in the document below. These are time protocols to further reduce the likelihood of any surviving parts of PA post-treatment.

The success of composting in killing pathogens is not solely a result of the heating process, but also depends on the many complex microbial interactions that may occur, as well as other factors such as moisture content. The reliability of data will depend on the accuracy and calibration of the temperature monitoring equipment.



Section 1: Footwear, tools and equipment

The removal of dirt and then spraying with a disinfectant of either methylated spirits or sterigene is the preferred hygiene method for footwear, tools and equipment. If this cannot be achieved with confidence, then equipment should be cleaned as much as practicable and then bagged or stored in a container for later heat treatment. For more information, read the Principles of Hygiene Guide on the Tiakina Kauri website.

The following minimum temperature-time protocols are appropriate for killing PA on footwear, tools and equipment.

- Boiling on a rolling boil for three minutes, or
- Keep in a moist oven at 55°C for 12 hours

The minimum treatment period must be continuously at or above the required temperature. Moistened incubation aids in ensuring the heat penetrates through the entire sample. If the equipment being treated is not already wet, add a cup of water to the drying oven.



Close up image of an oospore

Section 2: Soil and plant material

Small amounts of soil for propagating can be treated with heat using the following methods. It is not recommended to use these methods for treating soil after the sample analysis process or large volumes of soil from earthworks. Autoclaving is the preferred method for dealing with material post sample analysis.

Commercial operators are recommended to follow the New Zealand Standard (NZS) 4454 2005 for pasteurisation of material and composting. For non-commercial operators please follow this guide.

Composting

Background

Composting is when organic waste is biologically degraded by microorganisms to a humus-like material. Composting plant waste infected with *Phytophthora* species has been found to be an effective management option if well managed to ensure the temperature and time requirements are met.

Time and temperature need to be directly controlled and measured to ensure that all of the plant material being composted achieves the target temperature during the minimum time period recommended. Failures in the treatment operating process or inadequate methods of treatment can result in the survival of *Phytophthora* species. For these reasons, composting should only be used to reduce the risk of already low-risk materials sourced away from Kauri forests rather than a decontamination method for high-risk materials sourced from or near Kauri forests.

Please note: This guideline is not to be used for backyard or small-scale composting, as the treatment requirements stipulated in this guideline are unlikely to be met. Use of in vessel and static composting systems are not advised due to the lack of turning and the cooler zones which occur in the compost below the recommended temperatures.

Minimum composting requirements

Temperature	Exposure Time	Water content (Min)	Turnings (Min)
≥55°C	≥15 days	25%	Five

Operational guidelines

- To ensure that the whole compost mass is exposed to the desired temperature and time, turning of the compost should be a minimum of five turnings and designed to turn the oldest composted materials prior to the newest (raw) compost. If the compost is not turned regularly then the entire compost profile (particularly the edges) will not reach the desired temperatures.
- **The minimum temperature and time should be continuous and not averaged over a long period.**
- All treated material should be stored in such a way as to avoid any contact with untreated materials e.g. direct contact or via water, wind, machinery, tools or storage containers etc.
- The outer surface of the compost should be insulated to ensure surface cooling is sufficiently reduced.

- Composting facilities should be managed in such a way to ensure a high temperature range and a high level of biological activity.
- Carbon: nitrogen ratio should be between 15:1 to 30:1.
- Continuous monitoring and control of moisture content is necessary for optimal operations.
- The compost should be well mixed, have optimal structure and optimum air space for circulation.
- Avoid excess compaction in the centre as this reduces air and promotes lower temperatures.
- All material must be exposed to the time and temperature conditions, as described above, including corners and surface areas where it is generally cooler.
- Monitoring should be done in a way that is representative, with temperature loggers having the ability to record temperature continuously and automatically for each treatment period.
- Each facility should record the quantity, description, date of treatment and batch or reference number for tracing. In addition, record assurances that the requirements are satisfied (e.g. treatment certificate).

Contact your local regional council, unitary authority or the Department of Conservation if there are local policy or regulatory constraints. Commercial scale composting operations generally require approval to operate from regional councils, and in some cases, territorial authorities (city or district councils).

Solarisation

Solarisation is when the heat from the sun is trapped under clear plastic or glass to increase the temperature. This process produces lethal temperatures for PA on items such footwear, equipment and small volumes of soil and material. Solarisation is useful in remote field situations where other mitigation measures may not be available.

Please note: *This method is less reliable than composting and heat treatment unless carried out with good measurement and control. Solarisation requires a standard operating procedure to be written and proper management of the site to avoid cross contamination. Solarisation does not include in ground solarisation as this does not achieve required temperature targets.*

The following **cannot** be treated successfully using this process:

- Large volumes of soil.
- In situ application of ground soil.
- Vegetation (refer to composting guidelines).
- Large and complex machinery items such as bulldozers, vehicles etc.

Minimum requirements

Temperature*	Time	Water content
≥50°C	≥24 hours (accumulated)	• Soil (<10kg): Soil is moist to touch • Small equipment: >10mls free water
≥40°C	≥14 days	

Operational guidelines

- Solarisation is an alternative treatment where other mitigation measures cannot occur (e.g. removal of soil and spraying with sterigene for small soil contaminated equipment). Solarisation can also be used as a secondary treatment if a precautionary approach is required.
- Small amounts of soil and small items can be solarised in bags, pots, or plastic buckets.
- Solarisation will be most effective during the hottest weeks of the year when ambient temperatures are optimal and there are long periods of direct sunlight (non-cloudy, shade free) and little to no wind.
- Little to no wind is important, as wind moving across the plastic will rapidly dissipate the trapped heat. Strong winds may also lift or tear the plastic.
- The temperature increases more easily if there is no slope or if the slope is north facing (Elmore et. al, 1997).
- Identifying locations where the average monthly maximum air temperatures and the average number of days that are close to the lethal temperature threshold for PA will increase the likelihood of suitable temperatures and for solarisation to be successful. Refer to the following climate maps to determine whether your site could be suitable niwa.co.nz/climate-and-weather/daily-climate-maps.
- Where cooler temperatures are experienced, consideration should be given to undertake solarisation in greenhouse and nursery containerised solarisation units. These are likely to be more effective in cooler climates than field solarisation (Elmore, et. al, 1997).
- Care must be taken to avoid contamination of potting media after heat treatment. Heat treated material should only be transferred into sanitized containers using sanitized tools by workers with clean gloves who are following phytosanitary working practices.

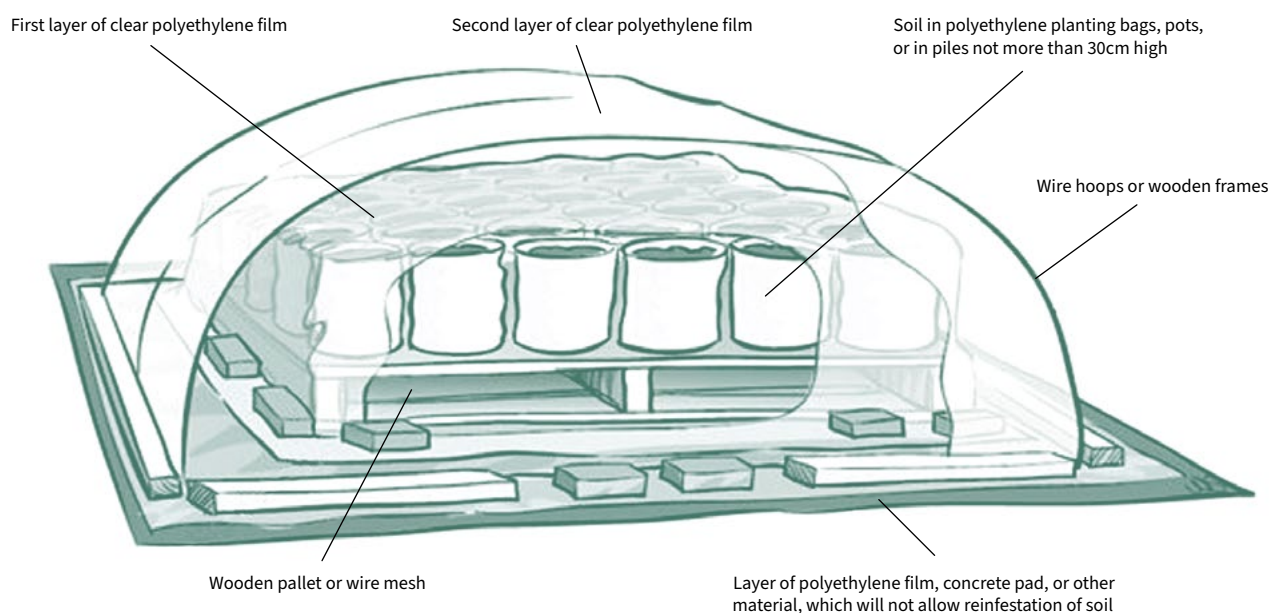
Solar ovens

Solar ovens are recommended as the mechanism to use for solarisation due to:

- their cost effectiveness to purchase or to build and operate.
- their portability and ability to be used in remote areas.
- the ability for the oven to increase temperature to sufficient levels without the use of electricity, gas or fire.

Some solar ovens used for cooking have reflective sheets to direct solar energy to the area being heat treated. Some of these ovens can reach temperatures >100°C.

Figure 1: Solar oven can easily be constructed to produce heat. Source: Stapleton, et. al, 1997.



Solar oven design considerations

1. A solid base is covered with a layer of insulation (e.g. a foam insulation panel or polystyrene base) to reduce heat loss.
2. Heating will be more efficient and uniform if hot air can circulate beneath and around the item being treated. Therefore, it is recommended that the item to be heat treated is placed on a structure like a wooden pallet or mesh stand that allows circulation from all sides.
3. A double layer of plastic film separated by an air gap between layers is placed over the item.
 - The double layer of plastic helps to reduce heat loss and acts as added insulation which can increase temperatures by up to 10°C compared to single layer (Elmore et. al, 1997, Stapleton, et. al, 1997).
 - Clear plastic bottles or PVC pipes can be used to create an air space between the layers (Stapleton, et. al, 1997). A 15 cm air space between the two layers is recommended (Duff, 2003).
 - Metal frames can be used to support the internal and external layers of plastic.
4. Use transparent clear thin plastic.
 - Use clear polyethylene plastic. The heating rays of the sun can pass through clear plastic, which makes it more effective than black plastic which absorbs and deflects heat rather than trapping it (Stapleton et. al, 2019).
 - Use thin plastic. Thinner plastics (~1 to 2 mil) are more effective than thicker plastics (> 2 mil) in generating more heat. Note: 1 mil = 0.025mm. However, if wind is an issue use a thicker plastic (for the outer layer) as it is sturdier (Stapleton, J.J & DeVay, 1986, Elmore et.al, 1997, Stapleton et. al, 2019).
 - The use of clear thermal anticondensation greenhouse film for solarisation of potting media should be considered (Anon, 2016).
 - Plastic that is UV absorbent should last indefinitely while plastics that are not may become brittle over time (Duff, 2003).

5. If holes or tears do occur in the plastic, patch with clear patching tape.
6. Reflective panels should be considered to direct solar heat towards the area being heat treated. These panels should be positioned and angled in such a way to optimise solar radiation.

Temperature and time monitoring

For small volumes (<10kg) of soil or potting mix:

- The time duration should start when the coolest part of the media reaches the target temperature and minimum temperatures should at least be maintained during the recommended period. The coolest part may be at the centre or near the edges. You may need to place several temperature probes in the media to determine this.
- The use of temperature data loggers is preferred, as they are portable and capable of autonomously recording temperature over a defined period. The digital data can then be retrieved, viewed and evaluated in the field in real-time after it has been recorded.
- The media should be moist prior to heating.
- Soil should be piled no more than 15-25 cm deep and in containers that are no more than this in diameter to facilitate heating (Anon, 2016).

For small items with soil residue:

- Temperatures should be monitored where the items are being heat treated (i.e. inside the area covered by the first layer of plastic). The use of temperature data loggers is preferred, as they are portable and capable of autonomously recording temperature over a defined period. The digital data can then be retrieved, viewed and evaluated in the field in real-time after it has been recorded.
- >10 ml of separate water should be included in a container with the equipment.

Further reading

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Glossary

Carbon to Nitrogen (C:N) Ratio	The ratio of the weight of organic carbon (C) to that of total nitrogen (N) in an organic material.
Core Temperature	The temperature at the core of the target of the heat treatment, or an acceptable substitute.
Disinfectant	Sterigene at 2%
Exposure Period	The amount of time, in one continuous block, that the item to be heat treated must be exposed to targeted temperature over the exposure period specified.
Kauri dieback	Name of the disease caused by the pathogen <i>Phytophthora agathidicida</i> .
Moisture Content	The area of ground below the canopy of an individual tree.
Epicormic shoots	The fraction or percentage of a substrate comprised of water. Moisture content equals the weight of the water portion divided by the total weight (water plus dry matter portion).
Oospore	The 'resting' or 'hibernation' spore of <i>Phytophthora agathidicida</i> .
<i>Phytophthora agathidicida</i> (PA)	Microscopic fungus-like organism that causes kauri dieback disease in Kauri.
Propagule	Microscopic life stage (like seeds) whose role is to progress the propagation of an organism to the next stage in their life cycle.
Turning	A composting operation which mixes and agitates material in a windrow pile or vessel.

Heat treatment protocols

Vector Risk	Treatment Tool	Minimum Temp. (°C)	Minimum Time	Moisture Content	Operational Considerations
Soil or potting mix (any volume)	Kiln, oven or heat chamber	≥50°C	≥24 h	20-30% before treatment - If this cannot be measured, then soil must be moist to touch before treatment.	- Add temperature probe. - Target treatment must be reached throughout the entire profile. The temperature should be measured in the coldest spot e.g. at the core of the media. - A closed system (heat tolerant bag/ sealed container) is advised so moisture is not lost during heat treatment. Note: this process is not recommended for infected soils.
Soil or potting mix (less than 10kg)	Solarisation	≥50°C	≥24 h (accumulated)	Soil must be moist to touch before treatment.	- Add temperature probe. - Use of a solar oven is advised and constructed in accordance with Section 6. - Small amounts of soil can be solarized in bags, pots, or plastic buckets. - Target treatment must be reached throughout the entire profile. The temperature should be measured in the coldest spot e.g. at the core of the soil/potting mix. - Ensure the solar oven is closed where possible to prevent moisture loss.
		≥40°C	≥14 days		
Equipment (incl. hand tools, footwear, containers, misc. equipment).	Kiln, oven or heat chamber	≥55°C Or 55C	≥12 h 24 hours	Place a litre of free water (in an open heat proof container) before treatment.	- Add temperature probe. - Only heat treat, if removal of soil cannot be undertaken. Soil contaminates to be removed for destruction by incineration or deep burial at an appropriate landfill - Not suitable for vehicles and complex machinery.
	Solarisation	≥50°C ≥40°C	≥24 h ≥14 days	Place a litre of free water (in an open heat proof container) should be included with the equipment before treatment.	- Add temperature probe. - Only solarise if removal of soil cannot be undertaken. Soil contaminates to be removed for destruction by incineration or deep burial at an appropriate landfill. - Use of a solar oven is advised and constructed in accordance with Section 6. - Target treatment must be reached throughout the entire profile. The temperature should be measured in the coldest spot e.g. at the core of the soil/potting mix. - Ensure the solar oven is enclosed where possible to prevent moisture lost.
	Boiling	100°C	3 minutes	Submerge target material in water.	Heat until at a rolling boil for at least 3 minutes while ensuring all target material is submerged during his boiling period.
Note: The assumption is that the above recommendation works based on research with other Phytophthoras					

Vector Risk	Treatment Tool	Minimum Temp. (°C)	Minimum Time	Moisture Content	Operational Considerations
Plant material	Composting*	≥55°C	≥15 days	• 25% (minimum)	1. Add temperature probe. 2. Minimum five turnings. 3. Target treatment must be reached throughout the entire profile. The temperature should be measured in the coldest spot e.g. at the edge.
	Note: Commercial operators must follow NZS 4454 2005 in order to decontaminate material to the lowest risk possible. For other operators the process above must be done thoroughly in order to achieve these targets.				
	Kiln, oven or heat chamber	≥50°C	≥24 h	• 20-30% before treatment. • If this cannot be measured, then >10 ml of free water (in an open heat proof container).	1. Target treatment must be reached throughout the entire profile. The temperature should be measured in the coldest spot e.g. at the core.



This guide was updated in 2025 by Tiakina Kauri with the help and advice of:

- Gavin Clapperton (Kauriology) – Chair of review group
- Ashley Davenport (Te Roroa)
- Stuart Leighton (Auckland Council)
- Mihi McMahon (Te Kawerau ā Maki)
- Tracy Mezger (Department of Conservation)
- Roanne Sutherland (Department of Conservation)
- Nari Williams (Plant and Food Research)

The original version of this guide was prepared by Tony Beauchamp (Dept of Conservation) and Travis Ashcroft (MPI), and endorsed by the Planning and Intelligence and Operations work streams:

- C. Green (Department of Conservation)
- G. Clapperton (Northland Regional Council)
- T. Shortland (Tangata Whenua Roopu)
- K. Froud (Biosecurity Research Ltd)
- K. Parker (Waikato Regional Council)
- N. Fowler (Auckland Council)

For more information about protecting Kauri, visit www.kauriprotection.co.nz