DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

Phytophthora cinnamomi
and disease caused by it

Volume III – Phosphite Operations Guidelines

Spraying phosphite at Mondurup Peak, Stirling Ranges, April 1998

Guidelines and procedures for the use of the fungicide Phosphite in Departmental operations

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DRAFT ONLY

CONTENTS

SECTION 1 – INTRODUCTION

1.1 MANAGEMENT OF *PHYTOPHTHORA CINNAMOMI* IN WESTERN AUSTRALIA

Phytophthora cinnnamomi is an introduced pathogen, with a widespread but discontinuous distribution in areas of the south west of Western Australia with an annual rainfall above 400 mm. It kills a wide range of plant species by attacking their root system. It is estimated that 2000 of the more than 8000 native vascular plant species in the South West may be susceptible to the pathogen (Wills, 1993). Many of these species, some of which have very restricted natural distributions, have been brought to the verge of extinction by *P. cinnamomi* (Wills and Keighery, 1994). Other species of *Phytophthora*, particularly *P. megasperma,* while not as vigorous or destructive as *P. cinnamomi*, also threaten rare flora (Carstairs and Newcombe, 1997).

As well as reducing the species richness and often significantly altering the structure of a range of plant communities, *Phytophthora* root rot disease may have major impacts on fauna species. This can occur because of changes in the structure of a plant community (eg. where protection from predators is reduced) or because of the loss of a particular plant species that was formerly an important source of food to fauna. Pollinators that rely on susceptible plant species as key sources of nectar (eg. *Banksia, Grevillea*) may become rare or locally extinct along with these plants.

Strategies for management of the impacts of *Phytophthora* in native ecosystems are divided into two broad but distinct approaches. The simplest approach and one that has been used in Western Australia for over 20 years directs effort at containing the human-vectored spread of the pathogen. This approach is dealt with elsewhere (*Phytophthora* Root Rot Volume I; Management Guidelines). The second involves using various techniques to reduce the destructive interaction between the pathogen and its hosts. Most of these theoretically available techniques for modifying the host-pathogen interaction are prospective only, are too expensive or unsuitable for use in native communities (Podger, 1997).

Knowledge of phosphite application methods to either single plants or whole plant communities to give a degree of protection against *Phytophthora* infection has reached the stage where operational guidelines can be given. Since the first trials of phosphite (then called phosphonate) by stem injection into jarrah and *Banksia grandis* in 1989 by researchers at CALM's Dwellingup office, a great deal has been learnt about the methodology of its use in treating native vegetation. The chemical has been used extensively in horticulture to protect against *Phytopthora* root rot disease in avocado, pineapple and citrus for over twenty years, but its use on natural vegetation has been restricted to Western Australia.

The methodology is summarised in this manual and references are given in Section 9 to various research and management reports give much more background information. It must be emphasised at this stage however that there is still a lot to learn about the conditions required for good protection for the target plants and minimisation of the risk of chemical damage by over-dosing.

Most of the research has been done on the following species and vegetation types. Caution must be used and advice sought for treatments other than to these species and vegetation types (Table 1).

Table 1. Species and vegetation types on which experimental applications of phosphite have been carried out.

Species	**Method of treatment**
Eucalyptus marginata (Dwellingup)	stem injection
Banksia grandis (Dwellingup)	stem injection
Banksia attenuata (Swan coastal plain)	stem injection
Banksia brownii (Albany)	stem injection/knapsack spray
Banksia coccinea (Albany)	stem injection/knapsack spray
Banksia baxteri (Albany)	stem injection/knapsack spray
Banksia telmatiaea (Eneabba)	ULV applicator
Banksia menziesii (Eneabba)	ULV applicator
Lambertia multiflora (Eneabba)	ULV applicator
Vegetation type	
Banksia attenuata – B. menziesii – B. illicifolia woodland (North Dandalup)	aircraft
Banksia brownii – Eucalyptus staeri woodland (Albany)	aircraft
Banksia coccinea-B. baxteri tall shrubland (Albany)	aircraft

Operational applications of phosphite have been made to a number of other vegetation types, including *Banksia* shrublands on deep sands near Albany, *Eucalyptus marginata* mallee on the plains and lower slopes of the Stirling Range National Park, the Eastern Stirling Range Montane Community and various communities on ironstone soils near Busselton.

At present (1998) phosphite is only permitted by the National Registration Authority for Agricultural and Veterinary Chemicals to be used (as the 20% formulation) on jarrah and *Banksia* species. However, CALM has been granted a trial permit for use of phosphite in eucalypt forests and *Banksia* heath until 31 May 1999.

1.2 STRATEGIC USE OF PHOSPHITE

There are two main strategies whereby phosphite can be used to protect native flora against *Phytophthora cinnamomi* root rot disease. Firstly, a swath of phosphite can be applied in front of an advancing *Phytophthora cinnamomi* infestation to form a protective barrier. Secondly, phosphite can be applied in an already infested area to protect susceptible plants that have not yet been infected. Early results indicate that longer protection is given to plants in an area where the pathogen is not yet present. For effective protection ahead of an advancing "front" of *Phytophthora cinnamomi* the protective swath should be at least 30 to 40 metres wide to prevent root to root transfer of the pathogen across the barrier. If the infested area is upslope of the area to be protected the protective swath would need to be wider than if it is downslope. This is because of the possibility of overland or subsurface transport of *Phytophthora cinnamomi* zoospores for considerable distances downslope following rainfall. In contrast, movement of an infestation upslope is generally slower, being mainly caused by root-root contact between plants.

NOTE: This manual will be updated from time to time as ongoing research provides more data that can be translated into operational guidelines.

SECTION 2 - PHOSPHITE: CHEMISTRY, SAFETY,TOXICOLOGY, AND MODE OF ACTION

2.1 CHEMISTRY

Phosphite is an aqueous solution of mono- and di-potassium phosphite. It is made by neutralising phosphonic acid with potassium hydroxide to a pH in the range of 5.7 to 6.0. The active component of the chemical is the phosphite ion (HPO_3^-). The fungicide is sold under various brand-names at strengths of 20% and 40%.

Several companies, including UIM and Craig Mostyn, manufacture the chemical. Although the UIM product was used in CALM's trials, others can be used that meet appropriate specifications. Commercial preparations are sold as FOS-JECT 200, FOLI-R-FOS 400, FOS-ACID 200, FOS-4-PINE and AGRIFOS 400.

In the literature and various publications the fungicide phosphite is sometimes referred to as "phosphonate", "phosphorous acid" or "phosphonic acid". All these names have been used to describe mono-/di-potassium phosphite.

2.2 INSTRUCTIONS FOR SAFE USE

The following instructions should be used in conjunction with the Chemical Users Manual, CALM 1984. Accidents involving swallowing, splashing in eyes or gross skin contact should be reported to a medical officer.

TRADE NAME	FOS-JECT 200, FOLI-R-FOS 400, FOS-ACID 200, FOS-ACID, FOS-4-PINE, AGRIFOS 400.
ACTIVE INGREDIENT	200 or 400 g/l phosphonic acid
APPEARANCE	Water clear liquid
CLASSIFICATION	Fungicide exempt poison schedule
STABILITY	Non-flammable, non-corrosive, non-explosive, stable under all normal environmental conditions. Stable in original containers for at least two years.
USE	Control of *Phytophthora*
PROTECTIVE CLOTHING	
Mixing	L/S combination overalls or L/S white cotton shirt and trousers, PVC gloves and goggles.

Application	L/S combination overalls or L/S white cotton shirt and trousers, PVC gloves and goggles.
Personal precautions	Avoid contact with skin and eyes. wash skin with soap and water immediately after use and also before eating, drinking or smoking. Wash clothing regularly or when known to be contaminated.
Heath hazard	Stored in body? – No Degree of toxicity: Swallowing: Low Skin absorption: Low Inhalation: Low Not carcinogenic nor mutagenic

FIRST AID

Swallowing	Wash mouth out with clean water but do not induce vomiting, give water to drink and seek medical attention
Splashing in eyes	Flush eyes with clean water for at least 20 minutes, then see a doctor
Spillage over person	Remove contaminated clothing, flush skin with water, consult a doctor if condition persists
STORAGE	Store in manufacturer's containers in locked chemical store
SPILLAGE	Absorb excess with suitable absorbent and rinse area with water
CONTAINER DISPOSAL	Triple rinse and add liquid to mix, crush container and bury at recognised chemical disposal site.

2.3 SYNOPSIS OF TOXICOLOGY

The oral median lethal dose (LD_{50}) for 10% phosphonic acid in water is 1.5 grams of pure acid/kg body weight. This places the Technical Active Ingredient in Class III of the World Health Organisation classification. Class III is the "slightly hazardous" class and phosphonic acid is at the very low end of the scale within this class. Twenty percent and 40% products have been formulated to eliminate the very slight poisonous and corrosive properties of the Technical Active Ingredient.

Furthermore, the formulated products are safer than the Technical Active Ingredient because they are neutralised. Phosphite has a pH of 5.7-6.0 which is comparable with that of the skin and therefore will not cause dermal irritation and is not corrosive to the skin or eyes. Contact with the skin is likely to cause only mild irritation to cuts or mucous membranes. In addition, the slightly acid pH lowers the likelihood of phytotoxicity in plants.

The LD_{50} for FOS-JECT 200 is of the order of 23.6 grams/kg bodyweight and is classified as "not poisonous" by Australia's National Health and Medical Research Council. Estimated LD_{50} to fish is approximately 1.5 g/l. The chemical is not broken down in animals and is excreted in the normal way. In the soil phosphite is slowly broken down to phosphate by microflora.

Application of phosphite to native plant species generally does not cause chemical leaf-burning when the fungicide is applied at recommended rates. Higher rates or treatments applied under unfavourable environmental conditions, or at flowering, are likely to result in chemical burning of foliage and can affect the reproductive capabilities of sprayed plants. Species vary in their susceptibility to chemical burning, with certain eucalypt species being amongst those most likely to suffer leaf-burning. At the rates of phosphite recommended in this manual no long-term damage will occur to plants that incur leaf-burning.

2.4 MODE OF ACTION

The action of phosphite in the protection of plants from *Phytophthora* infection has been described as mixed (Smillie *et al*., 1989). At high enough concentrations phosphite will act directly on the pathogen itself as a fungicide or fungistat to either kill it or halt its growth. This direct effect appears to occur within the *Phytophthora* organism. In addition phosphite, or the chemicals produced by *Phytophthora* as a result of phosphite's direct action on the pathogen, may mobilise the plant's dynamic natural defence mechanism to ward off the invasion of its root system.

SECTION 3 - TRUNK INJECTION OF PHOSPHITE

3.1 INTRODUCTION

The success of trunk injections against *Phytopthora* root rot disease in avocados and other horticultural plants first prompted similar studies in native plants. Experimental trials established by CALM in 1989 clearly demonstrated that trunk injections of the fungicide are very effective in the protection of a number of native plant species infected by the pathogen. As in avocado, the chemical is readily translocated in both xylem and phloem. However, injected phosphite gives protection to native species of *Banksia* as well as jarrah for a least four years, compared to two years or less for orchard crops (Shearer and Fairman, 1997).

The technique costs between $0.70 and $2.00 per tree (1997 figures) depending on size. Trunk injections can be used to treat small infections and are particularly useful for the protection of trees of special interest at picnic spots, schools and tourist attractions, or where only a limited number of plants need to protected (eg. rare flora).

Injection can be done at any time of year, but the best period appears to be early spring to autumn.

3.2 EQUIPMENT

3.2.1 Syringe injection

Syringes
Disposable 50 ml catheter-tip syringes are recommended, and are available through medical suppliers. New syringes need a small hole drilled on both sides of the end of the plunger handle, opposite each other, so that a locking pin can be inserted to maintain air pressure.

Drill
A good quality high-speed cordless electric drill is required. Auger or dowelling bits drill the cleanest holes, but they break easily and cost more than high speed steel bits.

Springs and retention plates
Springs are used to maintain pressure on the syringe once it is inserted into the tree. Use a small wire-loop spring approximately 60 mm long, 6 mm outside diameter, 0.7 mm galvanised wire with a loop on each end. A spring retention plate needs to be made. Use a metal strip about 60 mm wide and 2 mm thick cut into 100 mm lengths. Drill a small hole in each end and a 10 mm hole in the middle.

3.2.2 Hydraulic injectors

Various hydraulic and non-hydraulic injectors are available, but some may not be suitable for jarrah or other Western Australian hardwood trees. Amongst the commercially available injectors are the "Rawlins Hydaulic Injector", the "F1-11 Trunk Injector" and the "Sidewinder Tree Injector". The Rawlins Tree Injector consists of a 5 litre backpack reservoir, a hydraulic cylinder and lever, and a tapered nozzle with a non-return valve.

It is important that the injector be equipped with a high quality drill, good quality rechargeable battery and be of robust construction.

One of the problems that may be encountered with hydraulic injectors being used on eucalypts are poor sealing between the injector and tree and consequent loss of chemical down the outside of the trunk. This problem is largely overcome in the "Sidewinder" model which has a threaded nozzle that is screwed into the trunk by the drill that comes with this injector.

3.3 APPLICATION RATE

For most plants (eg. *Banksia coccinea* and *B. brownii*) a solution of 5% phosphite (v/v) is the highest recommended rate. Some species, such as thick-barked banksias, including *Banksia attenuata* and *B. grandis*, a 10% solution can be used.

Caution must be used when selecting the concentration to inject. An inappropriately high rate may disrupt the tree's natural defence mechanism and result in the acceleration of infection and increased deaths compared to untreated trees.

3.4 METHOD OF APPLICATION: SYRINGES

1. Make up the solution. To obtain a 5% mixture dilute 1 part of 20% phosphite product (eg. FOS-JECT 200) with 3 parts of water.

2. Measure the circumference of the tree at about waist height and inject 1 ml of the solution per cm of circumference. Use a maximum of 20 ml per syringe or injection. A tree with a circumference of 68 cm would require 60 ml applied in four syringes containing 17 ml each spaced equidistant around the tree. Injections are made at several places around the trunk because there is a minimal radial movement of the phosphite solution.

3. Drill holes at about waist height on a slight downward angle and about 25 mm deep. Drill into the sapwood but not through it. Some eucalypts have very thick bark so scrape off some of the outer bark around each injection site before drilling.

4. Syringes: suck up the required volume into the syringe, hold it with the nozzle up and push the plunger up to expel air from the syringe. Place a spring plate over the nozzle.

5. Insert the nozzle into the hole by pushing while turning to give a snug, airtight fit. Pull back the plunger with one hand while holding the syringe with the other hand. If there is no back-pressure, air is being sucked in (you should hear it) and it will leak, screw the syringe in tighter and recheck. If there is back-pressure and small bubbles appear the fluid should be taken in without leaking.

6. Attach springs to the plunger – this will ensure constant pressure.

7. The time required for the fluid to be taken in varies greatly depending on the health and type of tree. A healthy *Banksia grandis* will take-up in from 2-10 minutes, while a sick jarrah may take 24 hours.

8. If no fluid has gone in after about 1 hour then consider drilling a new hole and trying again. A good seal between the nozzle and the tree must be obtained.

9. When the fluid has gone remove syringes, or the injector nozzle. The holes will callus over within 12 months.

3.5 METHOD OF APPLICATION: TRUNK INJECTORS

The first three steps of trunk injection using commercially available injectors are the same as for the use of syringes. The principle of injection is the same but instead of plungers and springs the liquid is forced into the tree by the use of a lever and hydraulic cylinder or an air pump. For details of application methods see manufacturer's instructions.

Fig. 1. Trunk injection of *Banksia littoralis* trees.

SECTION 4 - SPRAYERS AND POWER MISTERS

4.1 INTRODUCTION

Ground-based treatment with knapsack sprayers, power misters or ‘reel-hose’ type sprayers can be combined with trunk injection, or used alone. Reel-hose sprayers attached to motor-driven pumps, and knapsack sprayers use relatively large volumes of water and produce large spray droplets, whereas backpack power misters require lower volumes of water and with the appropriate attachments can produce ultra-low volume spray. In general trees larger that 2 metres cannot be treated effectively using knapsack sprayers. Power misters have a much larger swath and may be used on trees up to 10 metres high.

Knapsack spraying is labour intensive as it requires large amounts of water and frequent refilling. It is generally most suitable for the treatment of small infections where good access is available. The daily upper limit for treatment by knapsack sprayer if only one unit is available is about a quarter hectare. At 25 l /100m^2 this would require 625 litres of water and over 30 refills of a 20 l capacity sprayer. If the area to be treated is accessible by vehicle and within reach of a reel-hose this technique would be much faster than a knapsack sprayer. Backpack misters, depending on the application rate chosen and site conditions, could do a hectare or more in a day. Vehicle mounted misters can do much more than this but obviously can only be used where an infection is easily accessible.

4.2 EQUIPMENT

Knapsack sprayers (Hardie RY2 with flat spray nozzles) were used for the experimental treatments carried out by CALM. There are two types of knapsack sprayer: those that have a separate pressurised chamber that enables constant output pressure, and those that must have the spray reservoir pressurised during use. Swath widths are about 2 metres. Vehicle-mounted spray equipment with reel-hoses, such as that used for blackberry spraying, has been successfully used for phosphite application.

Power misters give a much larger swath than knapsack sprayers. Depending on the type of machine and wind conditions swaths of 15 metres or more and vertical ranges of 10 metres may be obtained with backpack misters. Backpack misters consist essentially of a 10 – 15 litre reservoir, a petrol motor, pump, fan blower and a flexible nozzle. The fan draws air in a expels it at high speed through the nozzle with the chemical entering the airstream just before it enters the nozzle.

4.3 WETTING AGENT

The addition of wetting agents to the fungicide solution improves foliar coverage and reduces losses by evaporation. Water alone does not wet leaf surfaces efficiently because of hydrophobic molecules in leaf cell-wall membranes. Various products are available, but Synertrol Oil has been chosen for phosphite application to native vegetation because it is a natural plant extract and is readily biodegradeable. It is derived from food-grade canola oil (832 g/l) and as such is not subject to Poison Scheduling, Hazchem Code or a dangerous Goods Class. The other ingredients include surfactants and emulsifiers. The inclusion of Synertrol improves coverage and effective adhesion to the waxy leaf surface and allows more time for penetration. **It is important that Synertrol is pre-mixed with the fungicide prior to adding it to the spray tank, or adding water to the mixture**. If this is not done the effectiveness of the wetting agent will be greatly reduced. Pre-mixing enhances the distribution of the oil through the fungicide and ensures a coating of oil over the spray droplets. When using "Synertrol" the mixture must be agitated continuously during the spraying operation. (knap-sack sprayers agitation). The recommended rate for Synertrol Oil is 20 – 30 ml per 10 litres of phosphite solution.

4.4 PHOSPHITE APPLICATION RATES

A phosphite concentration of between 0.3% and 0.5% is recommended for knapsack sprayers and power misters. Higher concentrations may cause chemical leaf burning. Plants are sprayed to run-off point, that is until the fungicide solution first starts to drip from the plants.

The amount of chemical required per unit area to achieve effective protection from *Phytphthora* will vary widely with amount of leaf area to be sprayed. In CALM trials in *Banksia* tall shrubland on the South Coast an application rate of 24 l /100 m^2 was applied. This is only a guide, however, and further work needs to be done to establish the optimum rate for different vegetation types. At a concentration of 0.4% phosphite, 24 l /100 m^2 translates to about 10 kg/ha of phosphite active ingredient.

4.5 APPLICATION METHOD

- The chemical should be applied by walking through the area at a steady pace that allows an even amount of the fungicide to be applied. As mentioned above, enough spray should be applied to just achieve run-off.

- Some method of marking the areas already sprayed should be used. This can be done by marking out swaths with lines of coloured tape. It is important that areas should not be over-sprayed because leaf burning may result.

- It is also recommended that a width of about 10-30 metres ahead of the infection be sprayed to help prevent spread. If the infection is on a slope a wider 'buffer' downslope should be sprayed.

- Application should not be carried out under windy conditions or while it is raining. A rain free period of at least 15 hours is required after spraying.

- For optimal protection from *Phytophthora* the area should be sprayed in two applications, half the chemical in each of two doses spaced 4 to 6 weeks apart.

SECTION 5 - AERIAL APPLICATION OF PHOSPHITE

5.1 INTRODUCTION

Aircraft must be used to apply phosphite cost effectively over areas greater than about 2-3 hectares. In addition aerial application is the only method for the treatment of very rugged areas, such as on the peaks of the Stirling Range.

Aerial spraying of over 100 ha a day are possible if the air strip is close to the targets and the weather is suitable, however more usual rates are in the range 20-30 ha per day.

The spray trajectory and deposition of aerially applied phosphite is not as predictable as ground spraying. Spray droplets generated by aircraft nozzles move at speeds in excess of 160 km/h and are subject to violent air movements.

There are several factors that influence spray effectiveness, including various controllable and non-controllable parameters. Time of application and environmental conditions, application volume, canopy structure and amount and type of surfactant may all influence the effectiveness of a spraying operation.

5.2 TIMING OF APPLICATION

5.2.1 Environmental factors

Wind speed and direction, air temperature and relative humidity, and rainfall can all influence spray efficiency.

Wind direction and speed
The distance spray droplets travel depends on their size, downward velocity, aircraft height and speed and direction. For aerial spraying some lateral movement is necessary and treatments have performed better when applied in wind speeds exceeding 10 km/h. The upper speed should not exceed 25 km/h. On the peaks of the Stirling Ranges, however, because of the danger of up-drafts and swirling winds, spraying should only take place when wind speeds are below 10 km/h and preferably below 5 km/h.

Air temperature and relative humidity
Temperature significantly affects foliar spray efficiency where water is used as the spray carrier, as is the case with phosphite formulations. High temperature combined with low relative humidity rapidly reduces the size of drops by evaporation. Also, atmospheric turbulence increases as temperature rises, so spraying should not be done in summer or during periods of high temperature. Low temperatures are known to significantly reduce the rate of plant physiological activity and leaf membrane fluidity which in turn affect ion uptake and translocation. Therefore spraying should not be carried out on frosty mornings or periods of

particularly cold weather. On the other hand, a long period of hot, dry weather may place plants under stress and reduce the rate of phosphite uptake.

Rainfall
Rainfall shortly before or after phosphite application can have an effect on the effectiveness of the treatment. If rain falls just before application losses of phosphite can occur by washing from the leaves before uptake by the plant. Therefore it is best to allow foliage to dry before treatment takes place. Rainfall soon after phosphite application can also lead to losses. In a trial using simulated rainfall CALM researchers found that rainfall 7 hours after application could lead to a reduction in phosphite uptake by 50% when compared to control plants. Using this trial as a guide it is recommended that spraying should be delayed if significant rainfall is predicted within 15 hours of spraying. Surfactants have been found in some cases to increase the 'rainfastness' of pesticides, but in the CALM trial doubling the rate of Synertrol made no difference to the loss through rainfall (Komorek and Shearer, 1997).

5.2.2 Phenological events

As mentioned above, external environmental conditions can affect the rate of phosphite uptake, and plant internal metabolic activity determines the rate of translocation, accumulation and concentration of the fungicide. Experiments involving avocado crops have demonstrated seasonal effects on the relative concentration of phosphite in roots and foliage. Plants under stress, for whatever reason, will take up and translocate phosphite more slowly. On the other hand, rapidly growing plants will dilute the concentration of phosphite in their tissues more rapidly and thus will require reapplication of phosphite sooner.

Phosphite is preferentially stored in the roots where concentrations may be 5 or 6 times higher than in the foliage. Research on avocados has show that the best time to apply phosphite is late summer when the roots are the main metabolic sink of the plant (Whiley *et al*, 1986). This corresponds reasonably well with the preferred time for aerial application of phosphite to native vegetation in Western Australia (autumn) when calm weather conditions prevail.

5.3 DROPLET SIZE

The effectiveness of a fungicide is determined not only by application rate but by the quantity that adheres to plants and is available for uptake. Spray droplet size is the most important factor influencing the efficiency of the spray application process. This is because the amount of chemical which reaches the target is closely related to droplet size. Excessive droplet size results in a decrease in droplet density coupled with uneven deposition of the fungicide, large droplets (> 500 μm) also have a tendency to 'bounce' off the leaf. Conversely, droplets that are too small are prone to excessive drift away from the target area . As mentioned above, phosphite is a water based product and thus is liable to evaporation before it reaches the target. Smaller droplets evaporate faster.

Droplets produced by Micronair equipment fitted to an aircraft used in CALM's phosphite trials ranged from 100 μm to 500 μm, with 70% being between 200 μm and 500 μm. It is generally recommended that droplets be in the range 300-500 μm to optimise target coverage.

In windy conditions spray droplet size should be increased (200-800 µm, to average about 500µm) to reduce drift. Droplet density in the CALM trials was 50-60 /cm^2.

5.4 APPLICATION RATES

CALM trials in Swan Coastal Plain banksia woodland and South Coast mallee-banksia shrubland have found that aerial applications of 30-60 l/ha of 40% phosphite can give effective protection for up to 3 years. Post-fire regeneration or areas where plants are present only as a single shrub layer (no overstorey) should be treated with lower amounts of 15 l/ha. Montane shrub communities in the Stirling Ranges, where plant growth is slow, have been sprayed with 15 l/ha or less. At present no prescriptions are not available for forest areas.

It is strongly recommended that a second application take place 4-6 weeks after the initial treatment. This has the effect of substantially boosting plant tissue concentrations of the fungicide. In CALM trials a second application increased plant concentrations by 4 to 6 times. The length of protection afforded by phosphite is closely related to the concentration of the fungicide in plant tissue at the completion of spraying. In banksia woodland two applications of 40% phosphite at 60 l/ha induced 2½ times higher tissue concentrations than did two treatments of 20% phosphite at 60 l/ha.

Table 2. The recommended rates for aerial application of 40% phosphite in different vegetation structural types.

Vegetation structural type	L/ha of 40% phosphite	Total phosphite applied (l/ha)
banksia woodland /mallee-shrubland	30-60	60-120
post-fire regeneration	15-20	30-40
low shrubland/montane shrubland	15-30	30-60

However the concentrations and rates of phosphite we can apply is limited by the susceptibility of the vegetation to chemical leaf burning. Treatment with 40% phosphite can result in chemical burning of the leaves of some species, particularly eucalypts. The trials conducted by CALM demonstrated that 10-15% of the leaf area of some non-target species was burned by the application of 40% phosphite at 60 l/ha. A list of species which have shown some degree of chemical burning by phosphite is shown in Table 3.

Table 3. Species showing some leaf burning after the application of 40% phosphite at 60 l/ha or 30 l/ha (*).

Species	Family
Agonis hypericifolia	Myrtaceae
*Agonis aff. marginata**	Myrtaceae
*Andersonia axilliflora**	Myrtaceae
Eucalyptus marginata (mallee form)*	Myrtaceae
Eucalyptus staeri	Myrtaceae
Isopogon cuneatus	Proteaeceae
Petrophile diversifolia	Proteaceae
Xanthorrhoea preissii	Xanthorrhoeaceae

5.5 WETTING AGENT

Synertrol Oil, which is derived from food-grade canola oil, is the recommended wetting agent or adjuvant for phosphite application. It is preferred because, being made from a naturally occurring plant extract, it is less objectionable for use in conservation reserves than mineral-based oils would be. Further details on Synertrol Oil are given in section 5.3. Research is being carried out into more efficient adjuvants that will increase the uptake of phosphite into the plant.

5.6 EQUIPMENT

5.6.1 Aircraft

Both fixed-wing aircraft and helicopters can be used to apply phosphite, but owing to the lack of suitably equipped helicopters in Western Australia only Cessna A-188B and Airtractor AT-502 fixed-wing aircraft have been used so far by CALM. Airtractors are more expensive to hire, but this is offset by greater carrying capacity and speed. Preferably the aircraft should be fitted with a differential GPS system. It is important that the pilot be experienced in agricultural pesticide application.

Proper calibration of the spraying system must be carried out before each operation to ensure correct flow rate and droplet size (200-500 μm). In windy conditions the proportion of larger droplets should be increased.

5.6.2 Spraying systems

Several types of nozzles are used for agricultural spraying in Western Australia. Flat fan, hollow cone, “CP” and rotary nozzles are commonly used. Rotary atomiser type nozzles have been used for most aerial spraying carried out by CALM so far, however “CP” nozzles may be more suitable in some conditions to minimse drift.

5.7 MARKING OUT AREAS TO BE SPRAYED

The area to be sprayed needs to be clearly discernible to the pilot so that there is no risk of confusion about where the phosphite is to be applied. Physical markers are usually required although coordinates of the corners of the site can be obtained using GPS (preferably differential) and given to the pilot for entry into his GPS navigation system as a check. The exception is where the site is a reserve surrounded by cleared farmland, when the whole reserve is to be sprayed.

The markers should be bright, eg. ‘Dayglo’ orange, and can be either flags or balloons or pieces of material affixed to the ground. The advantage of flags or balloons over flat markers is that they give some indication of wind strengths across the site. A disadvantage of flags or balloons is that they may be easily visible to people on the ground and may be prone to vandalism. Balloons have the disadvantage of requiring helium gas for inflation, but are better in forest or woodland because they can reach above the canopy. Both flags and balloons are susceptible to 'attack' by eagles and other birds and also to being blown away in very windy areas. These are particular problems in the Stirling Range.

In the Stirling Range 80 cm long bright orange PVC flags with double stitching mounted on 3 metre flag poles (made from 'poly' pipe) placed over one metre long iron rods driven into the ground have been found to be successful. The flags need to have re-enforced margins for extra strength. If the area to be sprayed is rectangular then flags at each corner will be needed. Extra flags can be used if the area is large or if it is irregular. The pilot will probably fly over each flag before spraying to record them in his GPS navigation system.

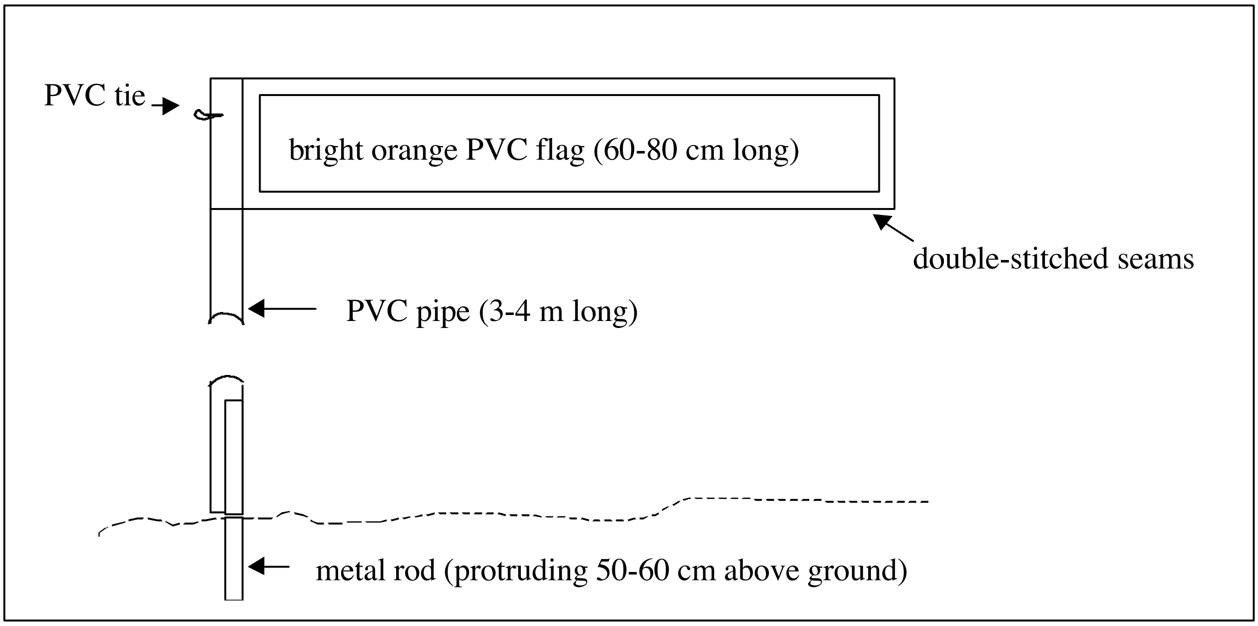

Fig. 2. Flags for marking corners of spray target sites.

Fig. 3. Refilling aircraft with phosphite, Stirling Ranges.

SECTION 6 - MONITORING OF RESULTS

6.1 INTRODUCTION

Monitoring of operational work is carried out to see if that work was effective. That is, did you achieve the result you wanted? Were there any significant side affects? If monitoring is not carried out we have no basis to judge the success of our operation. Proper monitoring will provide us with the information that we need for a more efficient use of resources in the future or for a more effective method of carrying out an operation.

In regard to the application of phosphite to protect native plants – monitoring will tell us such things as;

- Whether the plants were in fact protected by the phosphite
- How long this protection lasts
- Whether there was any non-target damage
- When we will need to apply more phosphite

6.2 MONITORING METHODS

There are many ways by which we may assess the effectiveness of phosphite application, however the following are probably the best for district staff to carry out.

1. Marking of ‘disease fronts’
2. Tagging of live and dead plants
3. Sampling of leaf material for phosphite concentration
4. Use of ‘control’ areas

6.2.1 Marking of ‘disease fronts’

In areas where there are obvious ‘fronts’ of disease progression a recording of the position of this front at a particular point in time, in this case prior to spraying with phosphite, can indicate whether the treatment has been successful in halting the progress of the disease. Ideally the progress of a front should be monitored for a year or two prior to the treatment to ascertain the ‘normal’ rate of spread of the front. Spread of *Phytophthora cinnamomi* by root-root contact has been measured at 1.01-1.13 m year^{-1} in banksia woodland growing on deep sand on the Swan coastal plain (Hill *et al*, 1994) and at 2-3 m year^{-1} in a similar community in the Fitzgerald River National Park.. Spread rates may be much greater when due to dispersal of propagules in sub-surface water flow (Kinal *et al*, 1993)

Marking can be done by placing steel or aluminium stakes along the edge of the ‘front’ or by using a differential GPS unit to record the edge of the infested area. With differential GPS a ‘continuous’ recording of the edge position can be made and this obviously will provide the most accurate data. However, when a differential GPS unit is not available, or where the edge is not continuous metal stakes (with presumed straight lines between them) can provide a useful indicator.

Stakes placed 5 metres to 10 metres apart for about 40 or 50 metres should give a reasonable representation of the position of a 'front' at a particular time. To facilitate finding the line of line again a 'mud map' showing the position of the stakes in relation to some easily identified feature should be produced.

6.2.2 Tagging of live and dead plants

A simple way to determine whether the application of phosphite has been successful in protecting a particular species of plant is to tag a sample of the plants that are a alive before the spraying operation. It also may be useful to tag those that have recently died. As with the marking of 'disease front' it is desirable that deaths in an area programmed for phosphite treatment should be monitored for a year or two prior to treatment.

A numbered, sturdy, metal tag tied loosely to a plant so that it will not be dislodged by the wind provides a long-term record of mortality or survivorship in a plant population. The position of the tagged plants can be recorded with a differential GPS unit, or mapped by use of a tape and compass. If plants die after the application of phosphite these should be tagged at regular intervals (eg. annually) and the number of the tag recorded with the date of tagging.

6.2.3 Censusing of plants

This method of monitoring involves determining the change in population of a particular species over a period of time. Recruitment of the species of interest must be estimated as well as deaths. Usually censusing is done within marked quadrats, with a number of quadrats scattered across the extent of a population, preferably in a random fashion. Data from these quadrats is used as an indicator for the population as a whole. Techniques for censusing are given in Cropper (1993). Censusing, especially if it is started well before treatment takes place, is the most effective and reliable form of monitoring.

6.2.4 Sampling of leaf material for phosphite concentration

Sampling leaf material at regular intervals after spraying is the only reliable way of determining when re-spraying will be needed. Phosphite concentrations fall because of metabolism within the plant and through dilution as the plant grows. Eventually concentrations will fall below the levels required to protect the plant against infection by *Phytophthora*. The rate at which concentrations fall varies according to such factors as environmental conditions and the age of the plant.

Phosphite analysis is expensive and should only be used in a limited number of situations. This may include the monitoring of critically endangered species and where no previous sampling has been done in a particular vegetation type. Arrangement will need to be made with the ChemCentre or Murdoch University for analysis of the samples before they are taken. The laboratory doing the analysis will give instructions on correct sampling and storage procedures.

6.2.5 Photography

Photographs taken from fixed points can be used as a general indicator of changes in plant health. This method is inexpensive but will not give information about the specific causes of changes in plant health. It is probably best used in conjunction with boundary markers to give information about movement of infestation fronts over time.

6.2.6 The use of control areas

In some situations it may be desirable to leave some areas unsprayed, or if stem injection in being used, some plants, untreated. The use of 'controls' allows a proper assessment of the effectiveness of the treatment. Two ways to obtain control areas are;

1. Cover several plots with large sheets of plastic during the spraying operation. This is the most scientifically valid method because it allows the control areas to be chosen randomly. However it is not very practical except for very small areas (a few square metres) and the vegetation needs to be less than about 1 metre tall.

2. Leave a relatively small section of the target area unsprayed. This is probably the easier method but it has the disadvantage of the control area or areas not being randomly chosen. Site differences could then confound the results of monitoring.

When assessment of the effectiveness of treatment is being carried out it should always be borne in mind that causes of death other than by *Phytophthora cinnamomi* infection may be involved, such as from drought or aerial canker infection.

SECTION 7 - ADMINISTRATION AND RECORD SYSTEMS

7.1 NOTIFICATION AND PERMITS

There are several formal procedures required for operational use of phosphite to protect native vegetation on CALM estate. This is because the use of phosphite is a new procedure and much needs to be learnt about its efficient use in a wide range of vegetation types and species. Even though phosphite has been shown to be safe for use on rare flora at certain rates, there is potential to harm rare flora if these rates are inadvertently exceeded, or under unusual circumstances.

At present all phosphite spraying on CALM estate needs to be approved by the Director of Nature Conservation. In addition, spraying operations other than those being carried out entirely using district or regional resources, need to be assessed and ranked according to departmental priorities. The approval procedure consists of ;

- District nature conservation officer forwards a PHOSPHITE APPLICATION PROPOSAL, signed by the Regional Manager, to the Ecologist (Phosphite Program).
- The Ecologist (Phosphite Program) compiles the various proposals into a Proposed Phosphite Program for that year which includes an anticipated cost for each proposed operation.
- The proposed spraying operations are then assessed according to protocols which assign a priority to each (see Appendix I).
- A final list of proposed spraying operations is compiled with regard to priority and resources available. This is then sent to the District and Regional managers in which the site is located for their endorsement.
- The endorsement form then goes to WATSCU, CALMScience, and the Director Nature Conservation.
- **Permission to Take needs to be given by the Minister if the area to be sprayed contains Declared Rare Flora**. This is applied for using the standard form and forwarded to the Clerk (Rare Flora) at Wildlife Branch. If this is given a standard approval to take is supplied and this is also noted on the Annual Phosphite Program endorsement form.

7.2 RECORD SYSTEMS

Recording of all phosphite spraying operations is vital for a number of reasons. Foremost among these is the need to know when another application will need to be made to give continuing protection. Also, because the operational use of phosphite is still in its early stages critical information about particular operations needs to be recorded and collated to ensure present knowledge is built upon.

At present the central record system being used is a combination of hard-copy file and an Access™ computer database. The input to this recording system is the PHOSPHITE APPLICATION RECORD which should be completed by the operations officer and returned to the Ecologist (Phosphite Program).

SECTION 8 - REFERENCES

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APPENDIX I: PHOSPHITE APPLICATION PROPOSAL

DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

PHOSPHITE APPLICATION PROPOSAL

REGION: ______________________________ DISTRICT: ________________________

LOCATION: ____________________________________ DATE: ____/_____/_____

LAT: _____^{o}_____"______' LONG : ______^{o}_____"______' GPS: Diff./ Non diff.

DOMINANT VEGETATION: Forest / Woodland / Tall Shrubland / Heathland / Sedgeland

DOMINANT VEGETATION SPECIES:____

____

THREATENED FLORA SPECIES: ________________________________POP.No.________

OTHER FLORA OF CONCERN: ____

____

POPULATION EXTENT: _______m x _______m NUMBER OF PLANTS:__________

PHYTOPTHORA INFORMATION

Entirely infected (positive ID) Partly infected (positive ID) _____%

Entirely infected (probable) Partly infected (probable) _____%

Infection pattern Front Scattered

At risk of infection Distance to infection: ________ m.

Field susceptibility of Threatened Flora Abundant Some No

NOTES ON HEALTH OF RARE FLORA: ____

____

NOTES ON ACCESSIBILITY (AIR/GROUND): _____________________________________

____

OTHER COMMENTS: ____

____

SIGNATURE OF DISTRICT/REGIONAL MANAGER : ___________________________________

NB: Fill in RARE FLORA REPORT FORM and complete MAP ON BACK of this form ➡

Created: 12/10/99
Authorised by: Director Regional Services
Custodian: Phytophthora Management Coordinator

PHOSPHITE APPLICATION PROPOSAL (page 2)

SKETCH MAP OF AREA INSPECTED

Scale = ____m.

N

Show approx. boundaries of rare flora population with a heavy line.

Using hachures //// show extent of apparent *Phytophthora cinnamomi* infected area, if any.

Show location(s) of positive *Phytophthora* recovery.

If the *Phytophthora cinnamomi* ‘front’ (if there is a distinct front) has not reached the population show its approx. position and the direction of slope.

Show point/s where GPS readings were taken with a **X** and the number of the reading.

Show physical features that would be useful in locating the population.

Created: 12/10/99
Authorised by: Director Regional Services
Custodian: Phytophthora Management Coordinator

APPENDIX II: PHOSPHITE APPLICATION PROTOCOLS
(INCL. ANNUAL PHOSPHITE APPLICATION PROGRAM ENDORSEMENT FORM)

Created: 12/10/99
Authorised by: Director Regional Services
Custodian: Phytophthora Management Coordinator

APPENDIX III: PHOSPHITE APPLICATION RECORD

Created: 12/10/99
Authorised by: Director Regional Services
Custodian: Phytophthora Management Coordinator

DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

PHOSPHITE APPLICATION RECORD

Location of operation

Region: ________________________ District:______________________________

Estate name & type:__________________ Location: (Lat/Long):________N________E

Application number: 1st / 2nd/ 3rd Site name: ___________________________________

Details of operation

Date of operation: ___/____/____

Time of application:: _____-_____

Application method: aerial / backpack mister / stem injection

Area sprayed: __________ha Phosphite: ______litres Surfactant: _____litres

Application rate: ______l/ha

Number of trees injected:______________ Phosphite solution: _____%

Total amount injected:____________ ml

Phosphite brand name:_________________ Surfactant brand name________________

Weather

Wind speed/direction _________ Air temperature: ____°C Humidity: _____%

Comments on weather:____

Did significant rain fall within 24 hours of the application?: Yes/No

Previous Treatment

Date(s) site last sprayed: ______________

Details of last spraying operation:____

____

Operations Officer:___________________________________

Date: ____/____/_____

Attach map at 1: 25,000 scale showing area sprayed

APPENDIX IV: INFONOTE- TRUNK INJECTION OF THE FUNGICIDE *PHOSPHITE* FOR PROTECTION AGAINST *PHYTOPHTHORA* DISEASE