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Tiakitanga Pūtaiao Aotearoa

MPI 18607 Project Report

Chemical control – review of control methods and fungicides

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1 Project background

To better understand myrtle rust and limit its impact in New Zealand, the Ministry for Primary Industries commissioned a comprehensive research programme in 2017 with more than 20 projects valued at over $3.7 million. Projects in this programme were completed by June 2019.

The projects covered research in the following themes:

- Theme 1 - Understanding the pathogen, hosts, and environmental influence.
- Theme 2 – Building engagement and social licence: Improved understanding of public perceptions and behaviours to allow better decisions about investment, improved design of pathway control strategies and maintain social license for use of management tools.
- Theme 3 – Te Ao Māori: Greater understanding of Te Ao Māori implications of myrtle rust in order to support more effective investments, and improved use of Mātauranga, specific Māori knowledge, and kaupapa Māori approaches in management regimes.
- Theme 4 – Improving management tools and approaches: Improved diagnostic and surveillance speed, accuracy and cost-effectiveness, supporting eradication efforts and enabling scaling up of surveillance efforts for a given resource. More effective treatment toolkits to avoid emergences of MR resistance to treatments and to enable disease control over increasingly large scales that will lead to reduced or avoided impacts.
- Theme 5 - Evaluating impacts and responses: Improved understanding of environmental, economic, social and cultural, impacts to inform risk assessment and management and to communicate implications to decision/makers and stakeholders.

This report is part of the MPI commissioned research under contract MPI18607 which addressed research questions within Theme 2, 4 and 5.

Text in the report may refer to other research programmes carried out under the respective theme titles.

This report forms part of the larger desktop review titled “Potential disease control tools” and was undertaken at the very beginning of the research programme. Subsequently a project to investigate Chemical control tools was undertaken as part of the MPI18607 programme and results on this work are written up in the report “Chemical Control tools and recommendations”.

2 Background to chemical control

Chemicals have long been used to control pests and diseases in agriculture (Zhang *et al.,* 2018; Conway, 1991) with fungicides being used since the early 1800s. The use of chemicals, or fungicides, for disease control is still a significant component of any effective integrated pest management (IPM) programme, and this will most likely be the case for the management of myrtle rust in New Zealand. Fungicides have been made available and designed to control plant diseases based on a mode of action. The mode of action refers to the specific process in the metabolism of the fungus that is targeted, for example, arresting a key protein synthesis pathway or other relevant processes such as respiration or energy production. There has been extensive knowledge generated on the modes of action of fungicides impacting membranes, nucleic acids and protein synthesis, signal transduction, respiration, mitosis and cell division, and multisite activity (Yang *et al.,* 2011). Successful approaches for effective identification and use of fungicides to control diseases is highly dependent on understanding some key factors of fungicides which include the physiological, biochemical and molecular modes of action of the fungicides and the mechanisms required to avoid development of resistance. Modes of action and potential non-target effects on soil microorganisms should also be considered in the selection of fungicide in order to protect the biological functions of soil and optimize the benefits derived from fungicide use.

Besides what has been occurring operationally in the national response to the incursion of myrtle rust in New Zealand, there is currently no published report evaluating fungicides known to be highly efficacious against this disease on susceptible, local Myrtaceae species. Hence, there is a need to identify potential chemicals to support, and improve on, the already existing control and management practices. The purpose of this review is to:

- Evaluate chemical treatments that have been effective for control of myrtle rust elsewhere and identify potential fungicides that would be good to test on key susceptible species in New Zealand; and
- Describe chemical application techniques that could be considered for application of fungicides in different scenarios.

2.1 Fungicides

Definition: A fungicide is a form of pesticide or physical agent that kills or inhibits the growth of fungi or its spores (McGrath, 2004; Horst, 1999). *There are at least three names of every fungicide found on the label and these are the chemical name, the active ingredient (a.i.) and the trade (product) names. For the purpose of this review, where possible, reference to the active ingredient(s) only has been made as trade or product names can vary widely between regions.*

Several reports have comprehensively elaborated on the names of fungicides as well as their classifications (Yang *et al.,* 2011; Mueller, 2006; McGrath, 2004). Fungicides are classified based on numerous ways which includes: mobility of a.i. in the plant, role in protecting the plant, spectrum or breath of activity, mode of action and chemical group. These are described below.

In terms of mobility, fungicides can be sub-divided into contact and systemic. Contact fungicides remain on the application surface with no after-infection activity (Mueller, 2006). Because contact fungicides can be easily disintegrated by sunlight or washed off by rain or irrigation, there is always the need to undertake repeated applications to protect new growth. The efficacy of contact fungicides is based on their being present before the pathogen arrives and before infection occurs (Martins *et al.,* 2011; Goes *et al.,* 2004). Systemic fungicides are absorbed into the plant tissue either moving upward or locally (i.e. move into treated leaves) and thus redistribute to some degree within the treated portion of the plant and, as a result, may at times offer some after-infection activity.

Fungicides play a protection role to a particular host plant by acting against pathogens through controlling early-infection and sporulation if possible. The preventative fungicides (mainly contact) are applied on the plant to act as a protective barrier before the pathogen arrives, or begins to grow, to prevent infection from occurring. Early-infection activity occurs when the active ingredient of the fungicide has the ability to penetrate the plant and stop the pathogen in the plant tissues. This is usually effective when such fungicides are sprayed on the host-plant within 24 to 72 hrs of infection. Fungicides able to prevent early-infection activity in the plant are also called curative. However, most fungicides reported on to date do not “cure” plants. Fungicides with early infection activity have the ability to stop the development of disease after symptoms express. Such fungicides are extremely important to control disease, however, are very few (Mueller, 2006). Finally, the anti-sporulant activity fungicides can potentially prevent sporulation from occurring. Thus, the disease continues to exist (and lesions continue to expand) but spores are not produced or released which eventually attenuates the level of inoculum available to infect neighbouring plants. Most fungicides that have protective and curative properties with systemic action (such as tebuconazole, triadimenol, propiconazole, procymidone and flusilazol) serve as flexible windows for users when required and have become a mainstay for a variety of pathogens (McLaren, 1994).

The spectrum or breadth of activity of a fungicide can either be single-site or multi-site. Single-site simply refers to the ability of the fungicide to act against only one point in the metabolic pathway or against a single key enzyme or protein that is needed by the pathogen for survival. Such fungicides have been reported to be less toxic to plants and also have systemic properties. In contrast, multi-site fungicides have activity affecting a number of different metabolic sites within the pathogen. To control many plant pathogens, multi-site fungicides are necessary (Hirooka and Ishii, 2013).

The chemical group or class refers to the name given to a group of chemicals that share a common biochemical mode of action, such as the strobilurins, triazoles, thiophanates and dicarboximides, to name but a few. Such a chemical group may not necessarily share a similar chemical structure and the type of chemical could be organic or inorganic. The organic fungicides are those that contain carbon atoms as part of their structure but the inorganic do not. Earlier, most of the chemicals produced were inorganic and based on the sulphur or metal ions such as copper, tin, cadmium and mercury. Most of the fungicides now used are organic (McGrath, 2004).

2.2 Chemical control options currently used against myrtle rust

Myrtle rust is currently a key threat to *Myrtaceae* in natural forest ecosystems (Masson *et al.,* 2013) and the forestry sector at large in New Zealand, with 29 indigenous Myrtaceae species potentially at risk. Development of in-depth knowledge on the fungicides likely to control myrtle rust in New Zealand is therefore a high priority since the pathogen is going to require ongoing management.

Generally, diseases caused by rusts such as myrtle rust are difficult to control but the severity of infection and its spread can be reduced via fungicide application (Furtado and Moraes, 2011; Masson *et al.,* 2011; Zauza *et al.,* 2008). There have been a relatively low number of trials testing fungicides against myrtle rust under field conditions over the past years (Masson *et al.,* 2013; Zauza *et al.,* 2008; Goes *et al*., 2004; Ferrari *et al*., 1997) with none, as yet, conducted in New Zealand. According to Masson *et al.* (2013), the most effective chemical groups against myrtle rust are the triazole fungicides (triadimenol, cyproconazole and tebuconazole) and the strobilurins (such as azoxystrobin and trifloxystrobin) mixed with triazole fungicides (such as azoxystrobin + cyproconazole + tiametoxam; azoxystrobin + difenoconazole and trifloxystrobin + tebuconazole). Trials have also shown that to prevent the development of pathogen resistance from occurring the use of a protective fungicide separately or in combination with a systemic active ingredient, or the alternation of a protective fungicide with an application of systemic fungicide, must be considered (Tamra *et al.,* 2016).

Definition: Strobilurin and triazole fungicides are both considered "locally systemic", meaning they are absorbed into plant tissue and do not remain on the outer plant surfaces exposed to the elements. While both fungicide groups are systemic, they break the disease cycle at different points and thus differ in their role in protection of plants from infection (Mueller and Robertson, 2008). The strobilurins act as a specific inhibitor of respiration by binding to the center Qp of cytochrome b, while triazoles prevent production of sterols – the key components of fungal cell membranes (Yamaguchi and

Earlier research testing the efficacy of fungicides for control of myrtle rust in Brazil on guava (*Psidium guajava*) by Ferrari *et al.* (1997) showed that application of chlorothalonil, mancozeb and copper oxychloride in the field post-infection did not significantly reduce disease levels, although chlorothalonil showed some efficacy. Chlorothalonil and mancozeb are protectant fungicides which remain on the surface of the leaf and are generally most effective when applied prior to infection (Miles *et al.,* 2007). Goes *et al.* (2004) demonstrated that copper fungicides (oxychloride, hydroxide and oxide) applied pre-infection in the field for control of myrtle rust on *Psidium guajava* were equally effective as the systemic tebuconazole. These authors also found that copper fungicide or a combination of mancozeb and copper fungicide applied post-infection in the field reduced myrtle rust infection levels compared to mancozeb applied as a single treatment. Although mancozeb has been reported to be less effective when compared to the systemic fungicides (such as triadimenol, tebuconazole and azoxystrobin), it has also been shown to be promising and preventive against myrtle rust in some field trials (Goes *et al*., 2004; Ferrari *et al*., 1997) and greenhouse studies (Ruiz *et al.,* 1991). There is therefore a need to consider and test copper fungicides and mancozeb for use in potential chemical management and control programmes for myrtle rust in New Zealand, along with other reported effective systemic fungicides.

Field experiments to evaluate the efficacy and economic viability of fungicides for control of myrtle rust on commercial crops have been carried out on the north coast of Bahia State, Brazil (Masson *et al.,* 2011). Natural infection of young sprouts of a susceptible *Eucalyptus grandis* clone were used in this study, based on the higher susceptibility of young branches and leaf shoots to infection by myrtle rust. Masson *et al.* (2011) evaluated the efficacy and economic viability of three systemic fungicides (azoxystrobin, tebuconazole and trifloxystrobin) to control myrtle rust, each applied at three doses via a ground application method (using a coastal sprayer). The treatments applied were: control, azoxystrobin (strobilurin), tebuconazole (triazole), combination of tebuconazole + trifloxystrobin (triazole + strobilurins) at respective rates of 0.5, 1.0 and 1.5 mL or g of a.i. per litre (L) of solution. Generally, higher fungicide levels led to a greater reduction of the disease in the host plants at 7 and 15 days after fungicide application. However, the combination of tebuconazole + trifloxystrobin in 1.5 mL L was found to be the most effective against myrtle rust, reducing infection by 95% in the host plant. According to Masson *et al.* (2011), the fungicide tebuconazole was the most economically viable at the three tested levels, though costs were not shown in their report.

The effectiveness of the triazole fungicides, such as tebuconazole and triadimenol, can be explained by their uptake and systemic movement in plants which facilitates early accumulation in the plant, and in sufficient amounts in plant tissue, to act against fungal growth even at later stages of infection (Erincik *et al.,* 2016). It is due to these attributes that the importance and efficacy of these fungicides has been widely demonstrated (Masson *et al.,* 2013; Martins *et al*.*,* 2011; Zauza *et al.*, 2008). Furtado and Marino (2003) carried out field trials to assess which active ingredient could be used as a preventive or curative fungicide against myrtle rust on *Eucalyptus grandis* in Brazil. The fungicides tested were: propiconazole, triadimenol, tebuconazole and cyproconazole (triazoles); oxycarboxin (an anilide); chlorothalonil (a phthalonitrile); mancozeb (a dithiocarbamate) and cuprous products (copper oxychloride and cuprous oxide). Applications were performed every 14 days, with a total of six applications made. Material used in the curative trial included naturally infected *Eucalyptus grandis* trees aged seven months with more than 70% symptomatic shoots prior to the application of fungicides. In the preventative trial un-infected *E. grandis* trees aged four months were used. In the preventive test cyproconazole, triadimenol and tebuconazole showed the best results. In the curative trial all treatments were effective, especially mancozeb (preventing the development of new lesions), difenoconazole, tebuconazole, propiconazole and triadimenol, which reduced the disease to less than 10% symptomatic shoots. Moreover, where plants were treated with propiconazole or triadimenol the symptomatic condition remained close to zero.

In the Central-South region of São Paulo State, a field assay was carried out using naturally infected *E. grandis* aged six months (Masson *et al.,* 2013). Applications of fungicide were carried out at 14-day intervals using a coastal sprayer to apply treatments in the equivalent of 200 L/ha (water) application volume. The results of the treatments showed that the most effective treatments in three applications, were: azoxystrobin + cyproconazole + tiametoxam in 400 mL/ha, azoxystrobin + difenoconazole in 300 to 500 mL/ha with or without adjuvant, azoxystrobin + cyproconazole and trifloxystrobin + tebuconazole all in 750 mL/ha. This result confirmed previous work by Masson *et al.* (2011) that assessed the severity of rust disease after application of different fungicides on infected host plants in field. According to Masson *et al.* (2011), upon seven or 15 days after application of fungicide solutions, the most efficient treatment was combination of tebuconazole + trifloxystrobin in 1.5 mL/L.

Martins *et al*. (2011) also evaluated systemic and protective fungicides under field conditions for their efficacy against myrtle rust on *Psidium guajava*. They tested five systemic fungicides namely: azoxystrobin, pyraclostrobin, cyproconazole, tebuconazole, triadimenol and a protectant, mancozeb. In their first trial, the application of fungicides was carried out at two weekly intervals, intercalated with bi-weekly sprays of copper oxychloride. Whereas in a second trial, copper oxychloride sprays were applied only when disease incidence was low (7%) on flower buds. They ensured that azoxystrobin, tebuconazole, triadimenol and mancozeb treatments were started nine days after a second application of copper oxychloride and maintained the same concentrations as the first trial. In this work, Martins *et al.* (2011) confirmed that triadimenol is one of the best fungicides against myrtle rust*,* a finding that supports earlier trials (Alfenas *et al.,* 1993; Demuner and Alfenas, 1991). Zauza *et al.* (2008) also showed that triadimenol can be effective when applied in later phases of the disease cycle, i.e. as a curative treatment that will reduce inoculum levels and slow the progress of the disease. In addition, the results in South America testing efficacy of fungicides against myrtle rust on guava (Martins *et al.,* 2011; Ruiz *et al.,* 1991) and *Eucalyptus cloeziana* (Alfenas *et al.,* 1993) affirms the superiority of triadimenol, also confirmed in an unpublished report by Horwood *et al.* (2013) in Australia, results of which are described below.

Horwood *et al.* (2013) screened several fungicides (mostly triazoles and strobilurins) in Australia both in the field and greenhouse against myrtle rust infection on *Syzygium jambos* and *Rhodamnia rubescens* plants (Table 3.1). They applied the fungicide to both upper and lower leaf surfaces to the point-of-runoff with a hand-held atomiser. The controls were treated or sprayed with tap water. Spray residues were allowed to dry for 24 hr before the plants were inoculated. The protectant activity of fungicides was tested by spraying the plants prior to inoculation and the eradicant activity tested by spraying five days after inoculation.

Table 1: List of fungicides tested by Horwood et al. (2013) for protective and eradicant activity.

Fungicides (a.i.)	**Group**	**Full label rate (mg a.i./L)**
Azoxystrobin	Strobilurin	300
Azoxystrobin+ Cyproconazole	Strobilurin+Triazole	200+80
Copper oxychloride	Protectant	2000
Triadimenol	Triazole	100
Difenoconazole	Triazole	125
Tebuconazole+Trifloxystrobin	Triazole+ Strobilurin	300+150
Triforine	Piperazine	285
Mancozeb	Dithiocarbamate	1500
Epoxiconazole	Triazole	63
Myclobutanil	Triazole	48
Oxycarboxin	Carboxamide	975
Prothioconazole+Tebuconazole	Triazoles	63+63
Propiconazole+Cyproconazole	Triazoles	80+26

To test protectant activity in greenhouse trials chemicals were applied at quarter, half and full label rates and for assessment of eradicant activity in greenhouse trials fungicides were applied at the full label rate. For the field study, diluted fungicides were mixed with a spray adjuvant (600 g/L nonyl phenol ethylene oxide condensate, non-ionic organic surfactant) and applied at a rate of approximately 200 L/ha water using a knapsack sprayer. Their results for the greenhouse study showed that all fungicides tested at full-label rate for protectant activity significantly reduced myrtle rust pustule formation in *S. jambos* compared to controls, with the exception of copper oxychloride. There was also minimum rust development (0 to 3.33 % leaf area covered by pustules) observed with application of the following fungicides:

- azoxystrobin + cyproconazole,
- triadimenol,
- tebuconazole,
- prothioconazole + tebuconazole,
- triforine,
- tebuconazole + trifloxystrobin,
- myclobutanil
- and propiconazole + cyproconazole

at any application rate tested in their study.

At all application rates of a.i. it was reported no rust development was observed with applications of azoxystrobin + cyproconazole, triadimenol, tebuconazole, epoxiconazole, prothioconazole + tebuconazole, triforine, tebuconazole + trifloxystrobin, myclobutanil, propiconazole or propiconazole+cyproconazole. On *R. rubescens* there was significantly more myrtle rust pustule formation on plants treated with mancozeb at the full-label rate than on control plants. Horwood et al.

(2013) continued to show that for the experiment conducted under greenhouse conditions, the single-active ingredient fungicides that consistently prevented rust development were the demethylation inhibitors namely: triadimenol, tebuconazole, triforine, myclobutanil, propiconazole, and the strobilurin, azoxystrobin. Their field study showed that, the efficacy of azoxystrobin, azoxystrobin + cyproconazole, triadimenol and tebuconazole + trifloxystrobin were relatively high as was the demethylation inhibitor, difenoconazole (Martin *et al.*, 2014).

Based on the Australian, Hawaiian and Brazil research work the Ministry for Primary Industries (MPI) has recommended and identified some fungicides for the treatment or control of myrtle rust in New Zealand (Table 2; www.nzppi.co.nz). Among these listed fungicides, only mancozeb and copper oxychloride are used for protective/preventive measures (Martins *et al.,* 2011; Furtado and Marino, 2003). None of these fungicides have, as yet, been able to eradicate infection in New Zealand and it is recommended that all prospective users, such as nurseries or food crops, apply the active ingredients at the stipulated generic rates as indicated for similar types of pathogens on the individual fungicide product labels (www.nzppi.co.nz). There are, as yet, no label recommendations for management of myrtle rust. An example of two management regimes in use by commercial or research nurseries is shown in Appendix 1 (Chang personal communication, July 2018; Keech, personal communication, July 2018).

Table 2: MPI identified fungicides for myrtle rust treatment or control.

Fungicide active ingredient	Fungicide activity	Product available in NZ	Chemical group (Triazole/Strobilurin)	Minimum re-treatment interval between consecutive applications
Triadimenol	Systemic, curative and protectant	Vandia 250 EC and Agpro Jupiter	3 (Triazole)	10-14 days
Triforine	Systemic, slightly curative and protectant	Saprol®	3 (None)	7-10 days
Mancozeb	Non-systemic protectant	Several available	M3 (None)	7-10 days
Azoxystrobin	Systemic, slightly curative and protectant	Amistar® SC	11 (Strobilurin)	14-21 days
Copper Oxychloride	Non-systemic protectant	Several available	M1 (None)	7-14 days
Propiconazole	Systemic, curative and protectant (Note: This has shown some phytotoxicity in Australian work)	Tilt® EC	3 (Triazole)	7-10 days
Tebuconazole	Systemic curative and protectant	Folicur®WG	3/11 (Triazole)	10-14 days
Trifloxystrobin	Systemic, curative and protectant	Flint® …and others	3/11 (Strobilurin)	10-14 days
Oxycarboxin	Systemic, curative and protectant	No NZ product (Aust product Plantvax750 WP)	7 (None)	10-14 days

*These are all recommended as protectants for foliar treatments by MPI (www.nzppi.co.nz)

Besides the triazoles, there are more active ingredients in the strobilurin group that require further research and this includes: kresoxim-methyl, metominostrobin, pyraclostrobin and picoxystrobin (Bartlett *et al.,* 2002). Among the known strobilurins, only azoxystrobin and trifloxystrobin are in the list provided by MPI (Table 3.2) but it is reported that kresoxim-methyl, metominostrobin, pyraclostrobin and picoxystrobin are all commercialised strobilurin fungicides (Bartlett *et al.,* 2002) available for agricultural use and extremely promising on a wide range of fungal pathogens. However, there is no current report on their use against myrtle rust in New Zealand and further, they are not in the list of the MPI recommended fungicides. With the exception of metominostrobin, kresoxim-methyl, pyraclostrobin and picoxystrobin are available in New Zealand.

Studies with some strobilurins such as, kresoxim-methyl, trifloxystrobin and pyraclostrobin have shown that spore germination stages of fungal development are particularly sensitive to them (Bartlett *et al.,* 2002). This is due to their biochemical mode of action which disrupts the production of energy demanded by fungal development at various stages. This mechanism contrasts with that of the triazole fungicides which inhibit ergosterol biosynthesis and therefore do not prevent spore germination and early germ-tube development because the pathogen obtains a supply of ergosterol or its precursors from reserves within the spore (Godwin *et al.,* 1994). Strobilurins are best to apply before infection or in the early stages of disease development (Bartlett *et al.,* 2002; Ypema and Gold, 1999). This information is important with respect to application timing when these three strobilurins (kresoxim-methyl, trifloxystrobin and pyraclostrobin) are employed for the control of myrtle rust. The strobilurin fungicides have also become valuable tools beside the triazoles and are very unique in that, they are the first synthetic, site-specific compounds to provide significant control of plant diseases caused by the highly diverse phylum Basidiomycota (Heim *et al.*, 2018) which includes the causal agent of myrtle rust disease, *A. psidii.*

The name strobilurin was formed for the chemical family of fungicides called quinone outside inhibitors (Q_oI), in recognition of the source of the first compounds of this type (Reddy, 2013). Several of the Q_oI fungicides have been registered and considered by the Environmental Protection Agency (EPA), United States and New Zealand as well. As at now, the most sort after strobilurin is azoxystrobin because of its excellent toxicological profile (Reddy, 2013). Azoxystrobin is a xylem-systemic with studies on cereal crops showing that 8% of the active ingredient entering the leaf above the point of uptake within eight days of application (Godwin *et al.,* 1999). In broad-leaved crops the movement of azoxystrobin to new growth areas occurred from initial spray deposition on the stem (Bartlett *et al.,* 2002). However, further work showed that movement of azoxystrobin to new growth areas was insufficient to provide robust disease control on subsequently emerging leaves (Bartlett *et al.,* 2002).

The strobilurin kresoxim-methyl offers an effective resistance management tool, because its efficacy against target pathogens is not affected by the occurrence of strains resistant to other fungicides (Ypema and Gold, 1999). Special physical and chemical properties of kresoxim-methyl result in its novel mode of action against plant pathogenic fungi, as well as unique uptake and diffusion properties (Ypema and Gold, 1999). In addition, under laboratory, greenhouse, and field research, kresoxim-methyl has demonstrated protective, post-infection, and anti-sporulant activity against economically important fungal diseases (Ypema and Gold, 1999). Reddy (2013) has also made some general suggestions that kresoxim-methyl is locally systemic and the surface deposits ensure a slow release into the plant over a period of time and that rain washing off is minimal. In addition, the spray residue on the leaf surface is reactivated by rainfall or dew wetting, enabling repeat uptake over a longer period of time. Generally, trials using mist blowers and knapsack sprayers have shown that robust disease control can be achieved using low-volume (50-100 L/ha) and a high-volume (>3000 L/ha) application, however, the crop(s) on which such applications were made, is lacking in the report by Reddy (2013). Though Reddy (2013) has admitted that application rates are still undergoing extensive trials on other ornamental crops, there is the need to explore the possibility of how effective this active ingredient may be on *Myrtaceae* spp. and myrtle rust in New Zealand.

Though fungicides in Table 3.2 have been recommended by MPI, there are other promising combinations of fungicides listed in Table 3.3 in addition to numerous fungicides (triazole or strobilurin) mentioned in this current review that need to be incorporated into trials in New Zealand to ascertain if these are indeed potential sources for myrtle rust control. When successfully tested and confirmed, these can be subsequently registered for application. Further, once a combination of fungicides has been selected there is the need to critically assess the type of adjuvant to use. This is extremely pertinent as the presence of an adjuvant will improve coverage and also potentially enhance absorption and therefore efficacy of the fungicide (Gent *et al.,* 2003). Adjuvants can improve adhesion and retention of spray droplets, allowing a longer interval between sprays, provided the adjuvant is properly selected (Gent *et al.,* 2003).

Chemical control of myrtle rust has undergone much evolution from earlier use of cuprous and, dithiocarbamates to recent chemical products which includes triazoles and strobilurins. There is still much to be done to expand the scope of fungicides from which selection could be made for the control of myrtle rust in New Zealand, especially, for areas of higher risk. If successful, control will allow the maintenance of iconic forest trees that are highly susceptible to the disease in New Zealand. Furthermore, understanding the effect of these fungicides on the beneficial activities of human and the environment is important as we consider various chemical options to battle myrtle rust disease in New Zealand.

2.3 Fungicide application techniques for treatment of myrtle rust

2.3.1 General principles of fungicide application

The main purpose of the application technique or method used to apply a fungicide is to ensure optimum coverage of the target or host plant is achieved for pathogen control while, at the same time, minimising contamination of non-target organisms and also drift (Ryley *et al.,* 2003). Ultimately, the selected application method will ensure delivery of the fungicide to the targeted plant or host in a manner that achieves coverage that is appropriate for the mode of action of the selected fungicide. Recommendations on the best method to apply the fungicide are important because while a systemic or curative fungicide has some room for applicator error, due to uptake and translocation throughout the vegetative material, the same is not the case for non-systemic protectants, such as chlorothalonil, copper or mancozeb. For these products a “protective” film covering the plant surface is required, meaning greater precision in the fungicide application or delivery technique on the plant of interest is necessary.

There are a number of different application techniques that can be considered for application of fungicides including: stem/bole injection, trunk implantation, trunk basal spraying; other ground rig application methods such as hand-held boom sprayers and tractor mounted-hydraulic booms and finally; aerial application methods using fixed winged aircraft, helicopters or unmanned aerial vehicles (Baillie *et al.,* 2017; Carvalho, 2017; Durao *et al.,* 2017; Kanaskie *et al.,* 2009; Gachomo *et al.,* 2008; Miles *et al.,* 2007; Strand *et al.,* 2014; Richardson *et al.,* 2017). Regardless of the application method, for the application to be a success, aspects of the spray environment will need to be considered including ease of access to the host plants, height above ground of the target, air temperature, relative humidity, wind speed, the presence of dew and the occurrence of rainfall (Stefanello *et al.,* 2016). In addition, since for most plant species transpiration rate is low at night, gradually increasing during the day, the timing of the application is important as this can affect the absorption and translocation of the fungicide and ultimately its performance (Stefanello *et al.,* 2016). Climatic and environmental conditions will thus play a critical role in choosing a particular application method, ranging from manual and ground spraying to aerial based spraying techniques (Nansen *et al.,* 2015). For application of fungicides to control myrtle rust in New Zealand a wide range of techniques (ground based and/or aerial) will need to be considered that will be appropriate for either isolated trees (either in natural, urban or sub-urban areas) or small patches of native forest (either in sub-urban or natural areas), all of which will require niche tools to ensure an optimum fungicide delivery protocol, either preventative or curative. Deciding which method of chemical application to use will be highly dependent on finances, the nature of the tree (hard bark, height, and canopy foliage), its location and whether preventative or curative fungicides are applied. Methods that do not harm the tree, especially if they are done repeatedly, should be considered first.

According to Poole and Arnaudin (2014), combining the knowledge of fungicide effect on the crop canopy with soil water and nutrient availability enables better matching of fungicide product, dose and timing to a specific disease risk. In the field, securing effective disease control from fungicide applications is dependent upon the disease pressure and the effectiveness of the fungicide to control that disease (Poole and Arnaudin, 2014). The influence of biological and meteorological factors on spray efficacy are not always predictable, but must also be considered in addition to the volume of fungicide (i.e. active ingredients) and the operational parameters (flow rate of a.i. or nozzle types) (Nansen *et al.,* 2015). Further, the complete knowledge of the pathogen life cycle or epidemiology is important to define the stage in the life cycle most vulnerable to the fungicide and to define the place on the host where it is most likely to be found (i.e. on foliage, under the leaves, at the root zone). The most susceptible stage of the pathogen for control measures, together with consideration of the host plant physiology, will determine the optimum time of application. The mode of action of fungicide, its relative toxicity and other physicochemical properties, together with the biology of the pathogen will help to determine the optimum droplet size and coverage required to optimise efficacy. For myrtle rust it will be important to assess which fungicide is best to use as a protectant or eradicant, or both, and how various application techniques could be implemented to provide the highest probability of success in different scenarios.

Table 3: Potential fungicides to consider for field or nursery trials against myrtle rust.

Active	Rate (a.i.)	Experimental Site	Reference	Availability in New Zealand
Cuprous oxide	160-200 g/100L	Nursery	Ferreira (1989)	Yes
Cuprous oxide Difenoconazole Cyproconazole Difeniconazole+propiconazole	352 g/100L 100 mL/100L 50 mL/100L 80 mL/100L	Nursery and Field	Furtado and Marino (2003)	Yes Yes Yes Yes+Yes
Copper Oxychloride	160-200 g/100L	Nursery	Alfenas *et al.* (2004)	Yes
Triadimenol+Azoxystrobin	Not described	Nursery	Krugner and Auer (2005)	Yes+Yes
Azoxystrobin+Tebuconazole	500-1500 mL/ha	Field	Masson *et al.* (2011)	Yes+Yes
Azoxystrobin+Cyproconazole Azoxystrobin+Cyproconazole Azoxystrobin+Cyproconazole	0.3 L/ha 0.45 L/ha 0.45 L/ha+ (mineral oil 0.6 L/ha)	Field	Monraes *et al.* (2011)	Yes+Yes Yes+Yes Yes+Yes
Azoxystrobin+Cyproconazole+ Tiametoxam Azoxystrobin+Difenoconazole Azoxystrobin + Cyproconazole Pyraclostrobin+ Epoxiconazole Trifloxystrobin + Tebuconazole	250 –400 mL/ha 300 – 500 mL/ha 300 – 450 mL/ha 500 mL/ha 750 mL/ha	Field	Furtado *et al.* (unpublished)	Yes+Yes+No Yes+Yes Yes+Yes Yes+Yes Yes+Yes
Azoxystrobin + Difenoconazole	300 to 500 mL/ha	Field	Masson *et al.* (2013)	Yes+Yes
Azoxystrobin + Cyproconazole +Tiametoxam	400 mL/ha	Field	Masson *et al.* (2013)	Yes+Yes+No
Tebuconazole + Trifloxystrobin	1.5 mL / L	Field	Masson *et al.* (2013)	Yes+Yes

2.3.2 Ground-based application techniques

For most application trials from which fungicide efficacy data have been generated, the fungicides have been applied using ground application tools such as backpack sprayers (Ferrari *et al.,*1997; McLaren, 1994) or hand sprayers (Horwood *et al.,* 2013). The Australian Nursery Industry Myrtle Rust Management Plan (ANIMRMP, 2012) suggested equipment used for the ground application of fungicides should be appropriate for the development of droplets that are within 150-250 µm. This droplet size was recommended for application of non-systemic fungicides (mancozeb, copper and chlorothalonil) as protectants and to ensure good leaf coverage. For ground application of such droplet sizes the tools suggested were powered-hydraulic handguns/booms fitted with either solid or hollow cone nozzles and three-point linkage/backpack powered misters.

Figure 1: (a) pressurized capsule injection system; (b) drilled hole injector; (c) injection system without drilled holes; (d) pressurized reservoir and tubing system**.**

While fungicide application via back pack sprayer technique has merit in some situations, particularly for ground vegetation and small patches of low-stature shrubbery, it will have major disadvantages for application of fungicide to trees, particularly the inability to target the part of the plant to be treated (i.e. tall foliage > 2m or large inaccessible canopy). Stem/trunk injection, on the other hand, provides a possible ground-based application technique for foliar pathogens if effective systemic fungicides are available. There are several types of stem injection techniques that may use either low pressure (i.e. using plastic capsules that are pressurized by depressing a plunger that locks in place) or higher pressure (i.e. using a syringe or tubing, tees, and a chemical reservoir designed to be under pressure) for injecting fungicides such as tebuconazole (in capsule form) or propiconazole (liquid form) respectively into the stem of a tree (www.arborjet.com) (Figure 1). Helson *et al.* (2001) designed the injection system without drilling holes into the plants as shown in Fig. 1c, to overcome plants that blocked the drilled holes for fungicide application by releasing resins, such as pines and conifers.

- No literature on the use of stem injection for control of myrtle rust could be found, however, stem injection was used by Kanaskie *et al.* (2009) to apply systemic fungicides for control of *Phytophthora ramorum* which causes sudden oak death in mature tanoak trees located in Oregon, USA. Further, in vineyard experiments conducted over five years in Bordeaux France, Darrieutort and Lecomte (2007) evaluated the effectiveness of the fungicides propiconazole and difenoconazole applied via trunk injections for control of eutypa dieback disease in grape trees (*Vitis vinifera*). The injection system delivered the fungicides under high hydraulic pressure in a few minutes into *V. vinifera* but could not control eutypa dieback. Düker and Kubiak (2011) also attempted to control powdery mildew in grape tree (*Vitis vinifera*) by injecting myclobutanil, penconazole and tebuconazole with ChemJet tree injector and all yielded efficiency factors of over 60% but tebuconazole was more positive comparatively.

- No literature on the use of basal bark application of fungicides for control of myrtle rust could be found. However, using a basal bark application technique (applied via hand-held CO_2-pressurized sprayers) Rosenberger and Cox (2009) compared the efficacy of mancozeb with phosphite fungicides for control of apple scab disease. Extensive testing provided no evidence that phosphite fungicides with an adjuvant (Pentra-Bark) applied via trunk basal bark spraying controlled apple scab, however, mancozeb applied to the bark provided 99% control.

2.3.3 Aerial application techniques

Aerial application of pesticides via helicopters is widely used by the forestry sector in New Zealand because it provides an efficient method to cover large areas of forest and also enables targeting of the canopy foliage for control of foliar pathogens/pests.

The use of specialized professionals and complete regulation and supervision of aircraft spraying activities make aerial application a safe and effective tool for fungicide application in most areas with low risk of environmental contamination if used appropriately (Furtado and Moraes, 2011). During the application of fungicides droplet size is very important if they are to be applied accurately and efficiently with minimum off target drift.

A comprehensive report provided by the Ministry for the Environment (MfE), New Zealand focused on a technical overview of the agricultural aviation industry to set standards for agrichemical application via aerial technique in 2013 (www.nzaaa.co.nz). Droplets smaller than 200 µm are generally considered to be more prone to drift than larger droplets, which leads to the common "rule of thumb" that a spray quality no finer than coarse (droplets with size of 326-400 µm) will minimise spray drift in most situations.

Though aerial application of fungicides is widely used in the New Zealand primary industry, there is no known or published report on the efficacy of this method for application of any fungicide to control myrtle rust in New Zealand. Further, aerial application of fungicides for control of myrtle rust on native New Zealand Myrtaceae tree species is likely to involve targeted or "spot spraying" rather than the more typical broadcast spraying operations (with an aerial boom) that are used in the forestry situation. Several field trials have been carried out in New Zealand testing the targeting efficiency of various aerial spot application methods, though none of these specifically for application of a fungicide for control of myrtle rust (Strand *et al.,* 2014; Richardson *et al.,* 2017). Spot application methods applied via an aerial platform with helicopters (Fig. 3.2) include that using part of a standard boom or partial boom situated below the craft (Strand *et al.,* 2014), an extended wand operated by a person seated next to the pilot (Gous *et al.,* 2014; Strand *et al.,* 2014) and a ring boom tethered below the craft (Richardson *et al.,* 2017).

Spot application of herbicides using an extended wand is a commonly used technique to control isolated and difficult to reach wilding conifers where systemic herbicides are applied to the foliage and bark of the tree in an oil (Gous *et al.,* 2014). However, spot application of pesticides via use of a ring boom, or partial boom, has only been trialled and not operationally deployed. Less is known about the efficacy and practicality of these methods for control of pests in different environments.

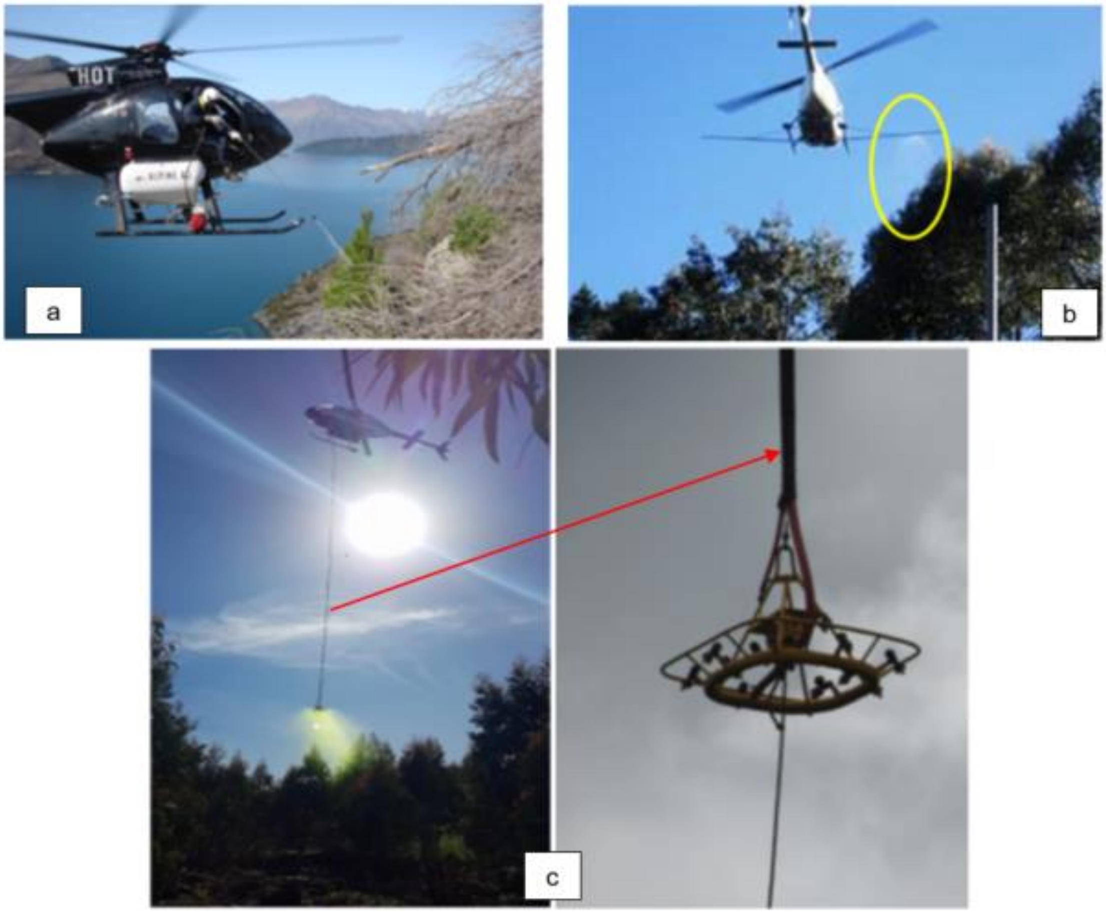

Figure 2: Targeted aerial spraying platforms with helicopter showing (a) a custom-built spot gun; (b) use of a partial boom (yellow circled) and (c) underslung ring boom (red arrow pointing to clear view of ring boom).

Richardson *et al*. (2017) conducted a trial to validate the potential of the ring boom suspended on a tether for targeted spraying of individual trees or clumps of trees during pest eradication operations in an urban environment. This study was to evaluate the effectiveness of an approximately circular 'ring' boom suspended on a tether below the craft to apply spray mix on individual trees (Figure 2c). This promising technique could be tested for isolated cases of myrtle rust-infected trees in the forest or in urban/sub-urban areas. However, there were some concerns with this method, including:

- The helicopter moved slowly over the crown, until the pilot was convinced adequate spray coverage through the canopy had been achieved which could be subjective.
- The technique used, with the helicopter hovering close to the canopy top, increased the downwash velocities, a factor dependent on tether length. While high downwash velocities may improve spray penetration into lower canopy levels, potential negative consequences include reduced spray retention on leaf surfaces and the increased likelihood of the helicopter wake encouraging dispersal of pathogen spores, for example.

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When testing the potential of the manually operated custom built spot-gun (or extended wand) for spot application of non-systemic pesticides to tree foliage from a helicopter, Strand *et al.* (2014) also raised concerns about the impact of the rotor downwash on pest dispersal. Further, these authors also identified potential issues with reduced leaf coverage in the lower crown when using this method possibly also an effect of the downwash pushing droplets off or away from leaf surfaces.

If aerial spot application methods, either with a ring boom or manually operated extended wand, were therefore to be considered for the application of preventative or curative foliar fungicides to trees infected with myrtle rust further work would need to be carried out to ensure either adequate coverage was achieved or that downwash velocities did not pose a risk for spore dispersal. Some enquiries about the operational experience of commercial aerial pesticide applicators were made to clarify this point. The Heli Team, a company based in the USA, claimed that aerial application does not spread fungal spores as one the advantages when using helicopters for pesticide application (http://theheliteam.com/aerial-application/). However, upon contacting them to ascertain the validity of this information, they failed to reply to our inquiries. Other interviews conducted in New Zealand, showed that similar assertions were not validated (Andrew Neal, personal communication, July 13, 2018). Generally, research on the use of aerial application techniques for fungicides (particularly spot application) effective against myrtle rust is lacking.

Success has been recorded in Australia, with the evaluation of the efficacy of fungicide (tebuconazole and triadimenol) application by fixed wing aircraft (Ryley *et al.* 2003) on other pathogens but not on myrtle rust or Myrtaceae. Though success has been reported with fixed winged aircraft, the use of a helicopter for fungicide application, particularly for spot application, is preferred due to their ability to operate at lower speeds, manoeuvre in irregular areas, easily change direction and also land suitably in various locations (Miller *et al.,* 2010; www.nzaaa.co.nz). There may be several situations where of use of an aerial boom, either on a helicopter or fixed wing aircraft, to broadcast fungicide (as opposed to spot control) will be advantageous. Broadcast aircraft applications would allow the treatment of large areas with a preventative fungicide within an appropriate and relatively short time and as a result, reduce inoculum loads and prevent the increase in areas with and/or new incidences of myrtle rust in the field (Furtado and Moraes, 2011). Further, applications using an aerial boom provide good application uniformity and allow treatment of canopy foliage, for foliar treatment of trees not easily accessible from the ground (Furtado and Moraes, 2011). Most importantly, it should be noted that for aerial application technique to be considered, it will depend on many conditions including: disease intensity; inoculum load, time requirement of fungicide to be applied soon after infection starts and the distance of the targeted field from the runway. The spraying cost is directly related to the size of area to be treated, i.e., the larger the area the lower the aerial spraying cost (Masson *et al.,* 2013). Unmanned aerial vehicles (UAVs), or drones, have been successfully used to detect and monitor myrtle rust infected areas in the forest (Heim *et al.,* 2018; Sandino *et al.,* 2018). There is also the potential that UAVs can be used for targeted application of fungicides, as a form of aerial application, as comparatively, they may have advantages over helicopters or winged aircraft in certain situations, such as: lower visibility and noise in urban and sub-urban areas, lower operating costs, and also a more precise and controlled method of spray application particularly in difficult to reach, sensitive, urban and sub-urban areas. A main disadvantage is the low payload meaning they cannot carry large quantities of fungicides when compared to helicopters or winged aircraft. A main advantage is that UAVs could be used in urban and sub-urban environments to treat individual or isolated cases of myrtle rust where visibility and accessibility for the pilot are feasible. Research on the use of UAVs for fungicide application in New Zealand is generally lacking, but several pilot trials testing the use of UAVs for pesticide application are currently in progress at Scion (Richardson, personal communication, July 12, 2018). This research will help researchers and operators make an informed decision as to whether UAVs can play a role in the management of myrtle rust.

Moraes *et al.* (2011) compared three fungicide application techniques for control of myrtle rust in eucalyptus forests, namely: manual coastal sprayer, tractor turbo atomizer and aerial application. They used the fungicides azoxystrobin and cyproconazole applied at different rates and application volumes. The spray volumes were 200 L/ha water for the coastal sprayer, 350 L/ha water for the atomizer and 20 L/ha water for aerial application. For their study, natural field epidemic conditions were used. The results showed that all methods of fungicide application and levels were effective in controlling myrtle rust in the field. They also reported no observation of anomalies regarding the effect of phytotoxicity of the fungicides via all the application techniques used in their study.

In as much as we test different fungicides from various chemical groups with different modes of actions, we will need to take a further step by considering the most appropriate application technique for the situation i.e. infected commercial crop in rural area or nursery (large scale spraying), woodlot or smaller area of shrub-land vegetation (smaller area of medium to tall trees) or isolated tall trees, either in a native forest, forest patch, suburban and/or urban area. This is important as some active ingredients may be more effective when applied via a particular application method and/or on a particular host when treating myrtle rust in New Zealand. As at now, there is no record of any research that has shown that various application methods support or enhance the effectiveness of a certain group of fungicides on a particular plant host. This calls for research to effectively assess the efficacy of certain fungicides (a.i.) based on their application methods.

2.4 The economics of myrtle rust chemical control in iconic Myrtaceae species

Susceptible Myrtaceae species of importance have been identified, selected and listed in an unpublished report by Scion and Plant & Food, New Zealand (Ganley and Beresford, 2018). In their report Ganley and Beresford (2018) selected species to be used as potential myrtle rust indicator species based on the known distribution of species known to be susceptible to myrtle rust and also able to be detected using visual or remote sensing methods. Some of the most important species that were identified to be of moderate (to higher) susceptibility to myrtle rust were:

a. Ramarama (*Lophomyrtus bullata* x *Lophomyrtus obcordata*): It is a native tree-like shrub with a reported disease and severity incidence as high.
b. Pōhutukawa (*Metrosideros excelsa*): It is a native tree with a reported disease and severity incidence as moderate to high.
c. Rohutu (*Lophomyrtus obcordata*): It is a native tree-like shrub with a reported disease and severity incidence as low to moderate.

The potential debatable or topical issue with regards to managing myrtle rust on some of these native tree species will be the cost of control, or *more specifically, who will pay for control*? For instance, Martins *et al.* (2011) showed that the cost involved in spraying *Psidium guajava* (guava) with triadimenol to control myrtle rust in the field was more expensive than other fungicides tested, yet the potential income from this product (i.e. the benefit) was the highest (U$3,906.47/ha/season). There was a return on the proposed investment in control because guava is an edible fruit and therefore marketable. However, for iconic, native Myrtaceae found in New Zealand it will be more difficult to directly evaluate the costs and benefits associated with chemical control of myrtle rust. Ultimately, the cultural, social and biological value of these species will need to be evaluated against the cost of control and the risk of their loss through infection with myrtle rust.

Myrtaceae is represented by some of the best-known New Zealand native plants such as the iconic pōhutukawa (*Metrosideros excelsa*), rātā (*Metrosideros diffusa*), kānuka (*Kunzea spp.*) and mānuka (*Leptospermum scoparium*), as well as lesser-known species such as swamp maire (*Syzygium maire*) and ramarama (*Lophomyrtus bullata*) (Clark, 2011). Species that are considered nationally critical in New Zealand, such as *Metrosideros bartlettii*, has only 29 individuals left in the wild (De Lange *et al.*, 2004). In addition, the WAI 262 claim 'Ko Aotearoa Tēnei' (This is Aotearoa or This is New Zealand) (Waitangi Tribunal, 2011) reported that, "iwi have relationships with species which are emblematic and have a spiritual element to them and their connection to the wider ecosystem particularly with regard to native plants such as harakeke, koromiko, pōhutukawa, kōwhai, puawānanga, poroporo, kawakawa, mānuka and kūmara". Though a number of New Zealand's Myrtaceae species are extensively used by Māori for medicine, construction, food and also have significant cultural value (Scheele, 2014), it is extremely difficult to attach a monetary value to most of them as these benefits are considered intangible. More so, information on the current use of these plants by Māori is likely to be iwi- and hapu-specific and difficult to obtain and catalogue according to Scheele (2014). Furthermore, Teulon *et al.* (2015) have shown that a number of plant species from the Myrtaceae have been explicitly identified as taonga species and this has been confirmed (Waitangi Tribunal, 2011), especially, the importance of pōhutukawa and mānuka to Māori (Waitangi Tribunal, 2011).

All these issues make it near-impossible to perform fungicide application cost-benefit-analysis when treating myrtle rust diseases on majority of these iconic Myrtaceae species in New Zealand. The question will be who bears the cost for fungicide treatment of *A. psidii* on the iconic Myrtaceae species in New Zealand?

3 Myrtle rust response to date

Since the incursion of myrtle rust in New Zealand, several governmental bodies, including the Ministry for Primary Industries (MPI), have taken steps to manage the spread of the pathogen. The Department of Conservation (DOC) has been involved in the surveillance response to determine the distribution of myrtle rust in New Zealand and to inform decision-making about activities to suppress the infection. An Interim Long-Term Management (ILTM) programme has also been established by MPI to provide parameters for Assure Quality (AQ) to conduct movement control operations (i.e. manage movement of infected Myrtaceae and associated human pathways as the recognised main pathway for spread of myrtle rust is wind).

The outcome of the ILTM operations over the past year has generated steps that aim to minimise the impact of myrtle rust on economic, environmental, social and cultural values in New Zealand, these include:

- Use of a concrete sealer at labelled rates on infected plants to lock spores before removal of infected trees. When trees are too large to be covered by concrete sealing (and deemed to be prone to off-target drift or OSH hazard), MPI has recommended a a copper oxide spray be used instead of the concrete sealer, although this remains untested. Copper oxide spray may also be considered a day before concrete sealing and removal for better penetration and coverage of copper fungicide into large canopies to kill spores not locked in by the concrete sealer. Following concrete sealing, infected trees must be removed to stump level by chainsaw. This is to be achieved by cutting the trees into smaller pieces with each piece triple bagged or putting them through a chipper into triple lined fadges or shipping containers.
    - Plant debris within a 10 m vicinity of infected plants/trees must be removed using triple bagging.
    - The ground/area up to 20 m radius from each infected tree must be sprayed with copper oxide (e.g. Nordox 75 WG™, AgCopp 75) diluted in accordance with label rates (preferably 150 g product per 100 L) to remove any myrtle rust. The radius can be reduced where practical access is restricted.
- Issuing of certificates in the form of permits for certified contractors only to manage removal of waste and also to transport or move waste of trees to ensure that myrtle rust does not spread to other areas via such practices.

Currently, species of Myrtaceae that may be susceptible to myrtle rust have been documented by Scion and MPI for use as indicator species to monitor the spread and severity of infection (Ganley and Beresford, 2018).

To date, the most reliable method of controlling myrtle rust in nurseries has been the use of fungicides recommended by MPI in New Zealand as strategies including, biological control, resistant plant-bred lines are yet to be discovered or implemented to support existing approaches. Though MPI has released a list of fungicides to be used against myrtle rust, there is a need to broaden the scope of this list and identify fungicides that may be more efficient or effective against the pathogen, particularly for the highly susceptible and iconic New Zealand Myrtaceae species

4 Recommendations and conclusions

This review has highlighted numerous information gaps and research needs with respect to chemical control of myrtle rust in New Zealand. If addressed, these would improve options for chemical control of myrtle rust, taking into consideration:

- *The outcome of existing trials conducted by MPI* in Australia on a range of fungicides applied either preventatively or curatively for control of myrtle rust on key New Zealand host species;
- *The scenario of highest priority for control* such that appropriate application techniques can be considered in combination with appropriate fungicides, i.e. ground application (manual spray with knapsack or ground spray with atomizers or trunk injection) or aerial application (broadcast or spot application with a drone or helicopter);
- *Targeting the most highly susceptible iconic and native Myrtaceae in New Zealand* such as ramarama (*Lophomyrtus bullata* x *Lophomyrtus obcordata*), rohutu (*Lophomyrtus obcordata*) and pōhutukawa (*Metrosideros excelsa* Sol. ex Gaertn) for chemical control trials with selected fungicides.
- *The testing of the individual listed fungicides* (Appendices 1 and 2) *that are either* absent from the existing MPI list (Table 3.2), *not tested by MPI or not available in New Zealand* and working with EPA to secure their registration;
- *An evaluation of the efficacy of different fungicide(s) and mixes applied at different times/seasons* and under both natural and controlled conditions to ascertain a fair assessment of their potency against myrtle rust on New Zealand host species, as this is important to reduce inoculum levels and levels of infection;
- *The best alternative method to replace use of the concrete sealant to treat isolated cases of myrtle rust in tall trees or determine methods to reduce drift* during application there-of as currently this is a major public health concern when treating very tall trees with concrete sealer;
- *Establishing or validating the putative effect of aerial application systems (UAV or helicopter) on the possibility of spore spread* during fungicide applications;
- *The response of different populations of myrtle rust spores to selected fungicides* to ascertain which reproductive stages (urediniospores, teliopores, and basidiospores) of the pathogens development are disrupted.
- Creating a database that has all used/identified fungicides, their efficacy against myrtle rust, availability status in New Zealand and if possible, such database accessible for all stakeholders that play key role in monitoring myrtle rust in New Zealand.

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Appendix 1

Fungicide used against myrtle rust to date (September 2018)

Active ingredient (a.i.)	Application rate of a.i.	Application method	Host species in field conditions	Host species in glasshouse/ controlled conditions	Host species in nursery	Comments/ success recorded	Research location	References
Propiconazole	0.63 g/L [2.5 ml /L	Knapsack Sprayer	N	N	Manuka	Effective - 0, First application (mid Oct)	New Zealand	Falloon (2018) unpublished
Azoxystrobin	0.2 g/L [0.8 g/L]	Knapsack Sprayer	N	N	Manuka	Effective - 2 weeks (1 Nov)	New Zealand	Falloon (2018) unpublished
Copper Oxychloride	2.4 g/L [3 g/L]	Knapsack Sprayer	N	N	Manuka	Effective - 5 weeks (22 Nov)	New Zealand	Falloon (2018) unpublished
Propiconazole	0.63 g/L [2.5 ml /L]	Knapsack Sprayer	N	N	Manuka	Effective - 7 weeks (6 Dec)	New Zealand	Falloon (2018) unpublished
Azoxystrobin	0.2 g/L [0.8 g/L]	Knapsack Sprayer	N	N	Manuka	Effective - 10 weeks (27 Dec)	New Zealand	Falloon (2018) unpublished
Mancozeb	1.5 g/L [2 g/L]	Knapsack Sprayer	N	N	Manuka	Effective - 13 weeks (17 Jan)	New Zealand	Falloon (2018) unpublished
Copper Oxychloride	2.4 g/L [3 g/L]	Knapsack Sprayer	N	N	Manuka	Effective - 15 weeks (31 Jan)	New Zealand	Falloon (2018) unpublished
Mancozeb	1.5 g/L [2 g/L]	Knapsack Sprayer	N	N	Manuka	Effective - 17 weeks (14 Feb)	New Zealand	Falloon (2018) unpublished
Propiconazole + Mancozeb	0.63 + 1.5 g/L [2.5 ml + 2 g/L]	Knapsack Sprayer	N	N	Manuka	Effective - 19 weeks (28 Feb)	New Zealand	Falloon (2018) unpublished
Azoxystrobin	0.2 g/L [0.8 g/L]	Knapsack Sprayer	N	N	Manuka	Effective - 23 weeks (28 Mar)	New Zealand	Falloon (2018) unpublished
Mancozeb	1.5 g/L [2 g/L]	Knapsack Sprayer	N	N	Manuka	Effective - 27 weeks (25 April)	New Zealand	Falloon (2018) unpublished
Copper Oxychloride Or Mancozeb	2.4 g/L [3 g/L] or 1.5 g/L [2 g/L]	Knapsack Sprayer	N	N	Manuka	Effective -(During Winter Season-If disease appears)	New Zealand	Falloon (2018) unpublished
Mancozeb	210 g/100L	Knapsack	N	N	All Myrtaceae in scion	Protectant	New Zealand	Keech (2018) personal communication
Triforine	100 ml/100L	Knapsack	N	N	All Myrtaceae in scion	Protectant	New Zealand	Keech (2018) personal communication

Active ingredient (a.i.)	Application rate of a.i.	Application method	Host species in field conditions	Host species in glasshouse/ controlled conditions	Host species in nursery	Comments/ success recorded	Research location	References
Tebuconazole	40 g/100L	Knapsack	N	N	All Myrtaceae in scion	Protectant	New Zealand	Keech (2018) personal communication
Chlorothalonil	300 ml/100L	Knapsack	N	N	All Myrtaceae in scion	Protectant	New Zealand	Keech (2018) personal communication
Copper Oxide	300-500 g/100L	Knapsack	N	N	All Myrtaceae in scion	Protectant	New Zealand	Keech (2018) personal communication
Triadimenol	250 g/L	NM	All Myrtaceae	N	All Myrtaceae	Protectant and/or curative	New Caledonia	(Giblin 2013)
Triforine	190 g/L	NM	All Myrtaceae	N	All Myrtaceae	Protectant and/or curative	New Caledonia	(Giblin 2013)
Mancozeb	750-800 g/kg	NM	All Myrtaceae	N	All Myrtaceae	Protectant and/or curative	New Caledonia	(Giblin 2013)
Azoxystrobin	250 g/L	NM	All Myrtaceae	N	All Myrtaceae	Protectant and/or curative	New Caledonia	(Giblin 2013)
Copper Oxychloride	500 g/kg	NM	All Myrtaceae	N	All Myrtaceae	Protectant and/or curative	New Caledonia	(Giblin 2013)
Propiconazole	250 g/L	NM	All Myrtaceae	N	All Myrtaceae	Protectant and/or curative	New Caledonia	(Giblin 2013)
Azoxystrobin	300 mg/L	Hand-Held Atomiser	*B. citriodora*	*S. jambos, R. rubescens, B. citriodora, G. inophloia & M. alternifolia*	N	Good protectant	Australia	Horwood *et al.* (2013) unpublished
Azoxystrobin+ Cyproconazole	200+80 mg/L	Hand-Held Atomiser	*B. citriodora*	*S. jambos, R. rubescens, B. citriodora, G.*	N	Good protectant	Australia	Horwood *et al.* (2013) unpublished

Active ingredient (a.i.)	Application rate of a.i.	Application method	Host species in field conditions	Host species in glasshouse/ controlled conditions	Host species in nursery	Comments/ success recorded	Research location	References
				inophloia & M. alternifolia				
Triadimenol	100 mg/L	Hand-Held Atomiser	*B. citriodora*	*S. jambos, R. rubescens, B. citriodora, G. inophloia & M. alternifolia*	N	Good protectant & Best eradicant	Australia	Horwood *et al.* (2013) unpublished
Difenoconazole	125 mg/L	Hand-Held Atomiser	*B. citriodora*	NM	N	Effective eradicant	Australia	Horwood *et al.* (2013) unpublished
Tebuconazole+Trifloxystrobin	300+150 mg/L	Hand-Held Atomiser	*B. citriodora*	*S. jambos, R. rubescens, B. citriodora, G. inophloia & M. alternifolia*	N	Good protectant	Australia	Horwood *et al.* (2013) unpublished
Triforine	285 mg/L	Hand-Held Atomiser	N	*S. jambos, R. rubescens, B. citriodora, G. inophloia & M. alternifolia*	N	Good protectant & Least effective eradicant	Australia	Horwood *et al.* (2013) unpublished
Mancozeb	1500 mg/L	Hand-Held Atomiser	*B. citriodora*	*S. jambos & R. rubescens*	N	Least effective eradicant	Australia	Horwood *et al.* (2013) unpublished
Epoxiconazole	63 mg/L	Hand-Held Atomiser	N	*S. jambos & R. rubescens*	N	Best eradicant	Australia	Horwood *et al.* (2013) unpublished
Oxycarboxin	975 mg/L	Hand-Held Atomiser	N	*S. jambos & R. rubescens*	N	Least effective eradicant	Australia	Horwood *et al.* (2013) unpublished
Prothioconazole+ Tebuconazole	63+63 mg/L	Hand-Held Atomiser	N	*S. jambos & R. rubescens*	N	Best eradicant	Australia	Horwood *et al.* (2013) unpublished
Propiconazole+Cyproconazole	80+26 mg/L	Hand-Held Atomiser	N	*S. jambos & R. rubescens*	N	Best eradicant	Australia	Horwood *et al.* (2013) unpublished

Active ingredient (a.i.)	Application rate of a.i.	Application method	Host species in field conditions	Host species in glasshouse/ controlled conditions	Host species in nursery	Comments/ success recorded	Research location	References
Azoxystrobin + Difenoconazole	300 to 500 mL/ha	Coastal Sprayer	*Eucalyptus sp. sp.*	N	N	Most effective	Brazil	(Masson et al. 2013)
Azoxystrobin + Cyproconazole +Tiametoxam	400 mL/ha	Coastal Sprayer	*Eucalyptus sp. sp.*	N	N	Most effective	Brazil	(Masson et al. 2013)
Azoxystrobin + Ciproconazole+ Trifloxystrobin + Tebuconazole	750 mL/ha	Coastal Sprayer	*Eucalyptus sp. sp.*	N	N	Most effective	Brazil	(Masson et al. 2013)
Azoxystrobin	0.5 mL/L	Coastal Sprayer	*Eucalyptus sp. sp. grandis*	N	N	Most effective	Brazil	(Masson et al. 2013)
Tebuconazole	1.0 mL/L	Coastal Sprayer	*Eucalyptus sp. sp. grandis*	N	N	Effective	Brazil	(Masson et al. 2013)
Azoxystrobin+ Tebuconazole	500-1500 ml/ha	Coastal Sprayer	*Eucalyptus sp. sp.*	N	N	Effective	Brazil	(Masson et al. 2013)
tebuconazole + trifloxystrobin	1.5 mL/L	Coastal Sprayer	*Eucalyptus sp. sp. grandis*	N	N	Effective	Brazil	(Masson et al. 2013)
Azoxystrobin+Cyproconazole	0.45 L/ha	Coastal Sprayer	*Eucalyptus sp. sp.*	N	N	Effective	Brazil	(Moraes et al. 2011)
Azoxystrobin+Cyproconazole	0.3 L/ha+(0.6 L/ha mineral oil)	Coastal Sprayer	*Eucalyptus sp. sp.*	N	N	Effective	Brazil	(Moraes et al. 2011)
Azoxystrobin+Cyproconazole	0.3 L/ha+(0.6 L/ha of mineral oil),	Atomizer	*Eucalyptus* sp.	N	N	Effective control	Brazil	(Moraes et al. 2011)
Azoxystrobin+Cyproconazole	0.45 L/ha	Atomizer	*Eucalyptus* sp.	N	N	Effective control	Brazil	(Moraes et al. 2011)
Azoxystrobin+Cyproconazole	0.3 L/ha+(0.6 L/ha of mineral oil),	Aerial	*Eucalyptus* sp.	N	N	Effective control	Brazil	(Moraes et al. 2011)
Azoxystrobin+Cyproconazole	0.45 L/ha	Aerial	*Eucalyptus* sp.	N	N	Effective control	Brazil	(Moraes et al. 2011)
Mancozeb	1600 mg/L	Tractor-Mounted Sprayer & Back-Pack Sprayer	*Psidium guajava*	N	N	Least efficient	Brazil	(Martins et al. 2011)
Azoxystrobin	100 mg/L	Tractor-Mounted Sprayer & Back-Pack Sprayer	*Psidium guajava*	N	N	Best control	Brazil	(Martins et al. 2011)

Active ingredient (a.i.)	Application rate of a.i.	Application method	Host species in field conditions	Host species in glasshouse/ controlled conditions	Host species in nursery	Comments/ success recorded	Research location	References
Tebuconazole	150 mg/L	Tractor-Mounted Sprayer & Back-Pack Sprayer	*Psidium guajava*	N	N	Best control	Brazil	(Martins et al. 2011)
Triadimenol	310 mg/L	Tractor-Mounted Sprayer & Back-Pack Sprayer	*Psidium guajava*	N	N	Best control	Brazil	(Martins et al. 2011)
Pyraclostrobin	100 mg/L	Tractor-Mounted Sprayer	*Psidium guajava*	N	N	Best control	Brazil	(Martins et al. 2011)
Cyproconazole	150 mg/L	Tractor-Mounted Sprayer	*Psidium guajava*	N	N	Best control	Brazil	(Martins et al. 2011)
Copper Oxychloride	2400 mg/L	Tractor-Mounted Sprayer	*Psidium guajava*	N	N	Good when rotated with all the systemics	Brazil	(Martins et al. 2011)
Triadimenol+Azoxy strobin	NM	ND	NM	NM	Nursery trial	NM	NM	(Krugner & Auer 2005)
Copper Oxychloride	160-200 g/100L	ND	*Eucalyptus* clones	N	N	Effective protectant	Brazil	(Alfenas 2004)
Azoxystrobin	0.1 g/L	ND	*Eucalyptus* clones	N	N	Most Effective protectant	Brazil	(Alfenas 2004)
Mancozeb	1.6-2.0 g/L	ND	*Eucalyptus* clones	N	N	Effective protectant	Brazil	(Alfenas 2004)
Triadimenol	0.125 g/L	ND	*Eucalyptus* clones	N	N	Most Effective protectant	Brazil	(Alfenas 2004)
Tetraconazole	NM	ND	*Eucalyptus* clones	N	N	Curative	Brazil	(Alfenas 2004)
Tebuconazole	NM	ND	*Eucalyptus* clones	N	N	Effective protectant	Brazil	(Alfenas 2004)
Epoxiconazole +Pyraclostrobin	NM	ND	*Eucalyptus* clones	N	N	Effective protectant	Brazil	(Alfenas 2004)
Copper Oxychloride	NM	ND	*Psidium guajava*	N	N	Effective	Brazil	(Goes et al. 2004)
Copper Hydroxide	NM	ND	*Psidium guajava*	N	N	Effective	Brazil	(Goes et al. 2004)
Copper Oxide	NM	ND	*Psidium guajava*	N	N	Effective	Brazil	(Goes et al. 2004)
Cyproconazole	50 ml/100L	ND	*Eucalyptus* sp.	N	N	Effective protectant	Brazil	(Furtado & Marino 2003)

Active ingredient (a.i.)	Application rate of a.i.	Application method	Host species in field conditions	Host species in glasshouse/ controlled conditions	Host species in nursery	Comments/ success recorded	Research location	References
Triadimenol	NM	ND	*Eucalyptus* sp.	N	N	Effective protectant	Brazil	(Furtado & Marino 2003)
Tebuconazole	NM	ND	*Eucalyptus* sp.	N	N	Effective protectant	Brazil	(Furtado & Marino 2003)
Mancozeb	NM	ND	*Eucalyptus* sp.	N	N	Curative effect	Brazil	(Furtado & Marino 2003)
Difenoconazole	100 ml/100L	ND	*Eucalyptus* sp.	N	*Eucalyptus* sp.	Curative effect	Brazil	(Furtado & Marino 2003)
Tebuconazole	NM	ND	*Eucalyptus* sp.	N	N	Curative effect	Brazil	(Furtado & Marino 2003)
Propiconazole	NM	ND	*Eucalyptus* sp.	N	N	Curative effect	Brazil	(Furtado & Marino 2003)
Triadimenol	NM	ND	*Eucalyptus* sp.	N	N	Curative effect	Brazil	(Furtado & Marino 2003)
Difenoconazole+ Propiconazole	80 ml/100L	ND	*Eucalyptus* sp.	*Eucalyptus* sp.	*Eucalyptus* sp.	Curative effect	Brazil	(Furtado & Marino 2003)
Cuprous oxide	352 g/100L	ND	*Eucalyptus* sp.	N	*Eucalyptus* sp.	Effective	Brazil	(Furtado & Marino 2003)
Chlorothalonil	150 g/100L	Back Power Sprayer	*Psidium guajava*	N	N	Efficacy (<10%)	Brazil	(Ferrari et al. 1997)
Copper Oxychloride	100 g/100L	Back Power Sprayer	*Psidium guajava*	N	N	Efficacy (10-20%)	Brazil	(Ferrari et al. 1997)
Mancozeb	160 g/100L	Back Power Sprayer	*Psidium guajava*	N	N	Efficacy (10-20%)	Brazil	(Ferrari et al. 1997)
Triadimenol	200 L/ha	Manual Coastal Sprayer	*E. cloeziana coppice*	N	N	Protective and Curative effect	Brazil	(Alfenas et al. 1993)
Diniconazole	30 g/L	Manual Coastal Sprayer	*E. cloeziana coppice*	N	N	Efficacy (65%)	Brazil	(Alfenas et al. 1993)
Oxycarboxin	210 g/L	Manual Coastal Sprayer	*E. cloeziana coppice*	N	N	Efficacy (90%)	Brazil	(Alfenas et al. 1993)
Triadimenol	100 g/L	Manual Coastal Sprayer	*E. cloeziana coppice*	N	N	Efficacy (40%)	Brazil	(Alfenas et al. 1993)
Chlorothalonil	NM	Atomizer Regulated Electric Compressor	*Eucalyptus cloeziana*	N	N	Not effective	Brazil	(Demuner & Alfenas 1991)
Copper oxychloride	NM	Atomizer Regulated Electric Compressor	*Eucalyptus cloeziana*	N	N	Not effective	Brazil	(Demuner & Alfenas 1991)

Active ingredient (a.i.)	Application rate of a.i.	Application method	Host species in field conditions	Host species in glasshouse/ controlled conditions	Host species in nursery	Comments/ success recorded	Research location	References
Diniconazole	0.075 g/L	Atomizer Regulated Electric Compressor	*Eucalyptus cloeziana*	N	N	Effective for only 14 days	Brazil	(Demuner & Alfenas 1991)
Mancozeb	NM	Atomizer Regulated Electric Compressor	*Eucalyptus cloeziana*	N	N	Not effective	Brazil	(Demuner & Alfenas 1991)
Oxycarboxin	1.125 g/L	Atomizer Regulated Electric Compressor	*Eucalyptus cloeziana*	N	N	Effective for only 7 days	Brazil	(Demuner & Alfenas 1991)
Triadimenol	0.4 g/L	Atomizer Regulated Electric Compressor	*Eucalyptus cloeziana*	N	N	Effective for only 28 days	Brazil	(Demuner & Alfenas 1991)
Triforine	NM	Atomizer Regulated Electric Compressor	*Eucalyptus cloeziana*	N	N	Not effective	Brazil	(Demuner & Alfenas 1991)
Triadimenol	0.5 g/L	Atomizer Regulated Electric Compressor	N	*Psidium guajava*	N	Most Protective and Curative effect	Brazil	(Ruiz et al. 1991)
Triadimenol	0.75 g/L	Atomizer Regulated Electric Compressor	N	*Psidium guajava*	N	Protective and Curative effect	Brazil	(Ruiz et al. 1991)
Triforine	0.28 mL/L	Atomizer Regulated Electric Compressor	N	*Psidium guajava*	N	Protective and Curative effect	Brazil	(Ruiz et al. 1991)
Oxycarboxin	0.75 g/L	Atomizer Regulated Electric Compressor	N	*Psidium guajava*	N	Protective and Curative effect	Brazil	(Ruiz et al. 1991)
Chlorothalonil	150 g/100L	Back Power Sprayer	*Psidium guajava*	N	N	Efficient	Brazil	Ferrari (1989)
Mancozeb	160 g/100L	Back Power Sprayer	*Psidium guajava*	N	N	Good	Brazil	Ferrari (1989)
Copper Oxychloride	100 g/100L	Back Power Sprayer	*Psidium guajava*	N	N	Good	Brazil	Ferrari (1989)
Cuprous oxide	160-200 g/100L	Back Power Sprayer	*Psidium guajava*	N	N	Good	Brazil	Ferrari (1989)
Azoxystrobin+Cyproconazole+ Tiametoxam	250-400 mL/ha	ND	*Eucalyptus* sp.	N	N	Effective	Brazil	Furtado *et al.* (unpublished)
Azoxystrobin+Difenoconazole	300-500 mL/ha	ND	*Eucalyptus* sp.	N	N	Effective	Brazil	Furtado *et al.* (unpublished)
Azoxystrobin + Cyproconazole	300-450 mL/ha	ND	*Eucalyptus* sp.	N	N	Effective	Brazil	Furtado *et al.* (unpublished)
Pyraclostrobin+ Epoxiconazole	500 mL/ha	ND	*Eucalyptus* sp.	N	N	Effective	Brazil	Furtado *et al.* (unpublished)

Active ingredient (a.i.)	Application rate of a.i.	Application method	Host species in field conditions	Host species in glasshouse/ controlled conditions	Host species in nursery	Comments/ success recorded	Research location	References
Trifloxystrobin + Tebuconazole	750 mL/ha	ND	*Eucalyptus* sp.	N	N	Effective	Brazil	Furtado *et al.* (unpublished)

Appendix 2

List of fungicides and their availability status in New Zealand

Active Ingredient (a.i.)		Availability Status In New Zealand	Chemical Group	Products Names	Rate
1	*Mancozeb**	YES	Dithiocarbamate	Adama Mancozeb contains mancozeb Defensor contains mancozeb Dithane Rainshield Neotec contains mancozeb Manco 75WG contains mancozeb Mazate Evolution contains mancozeb Penncozeb DF contains mancozeb Promanz contains mancozeb Unize contains mancozeb Penncozeb and Unizeb contain Hexamine	750 g/kg 750 g/kg 750 g/kg 750 g/kg 750 g/kg 750 g/kg 750 g/kg 25 g/kg
2	*Triforine**	YES	Amide	SA-N	NA
3	*Azoxystrobin**	YES	Strobilurin	Amistar WG Mirado 500 WG	500 g/kg 500 g/kg
4	*Triadimenol**	YES	Triazole	Triadimenol+plus N-methyl-2-pyrrolidinone (except cereous). AGPRO Jupiter also contains ethoxylated dodecyl alcohol.	250 g/litre 250 g/litre
5	*Trifloxystrobin**	YES	Strobilurin	SA-N	NA
6	*Oxycarboxin*	YES	Organic fungicide	SA	NA
7	*Copper Oxychloride**	YES	Inorganic copper	Fruitfed copper oxychloride contains copper as copper oxychloride Oxi-Cup 50WG contains copper as copper oxychloride in the form of water dispersible granules. AGPRO copper oxychloride 800 WP contains copper oxychloride in the form of a wettable powder.	500 g/kg 500 g/kg 800 g/kg
8	*Tebuconazole**	YES	Triazole	AGPRO tebuconazole 430 SC contains tebuconazole Compass contains tebuconazole Folicur SC contains tebuconazole Hornet 430SC contains tebuconazole Rebuke 430 contains tebuconazole AGPRO envy contains tebuconazole	430 g/litre 430 g/litre 430 g/litre 430 g/litre 430 g/litre 250 g/litre

Active Ingredient (a.i.)		Availability Status In New Zealand	Chemical Group	Products Names	Rate
				AGPRO envy contains 2-pyrolidone, 1-methyl Orius 250 EW contains tebuconazole	50 g/litre 250 g/litre
9	*Epoxiconazole+Azoxystrobin*	YES	Triazole+Azoxystrobin	NSA	NA
10	*Propiconazole**	YES	Triazole	SA-N	NA
11	*Thiametoxam**	YES	Neonicotinoid	SA-N	NA
12	*Prothiconazole+Fluoxystrobin*	YES	Triazole+Strobilurin	NSA	NA
13	*Prothiconazole+Trifloxystrobin*	YES	Triazole+Strobilurin	NSA	NA
14	*Azoxystrobin+Chlorothalonil*	YES	Strobilurin+Nitrile	NSA	NA
15	*Copper (I) Oxide/Cuprous oxide**	YES	Inorganic copper	SA-N	NA
16	*Difenoconazole**	YES	Triazole	Glacier also contains N-methyl-2-pyrrolidone and xylene. Divino also contains hydrocarbon liquids. Score also contains hydrocarbon liquids and 2-pyrolidinone, 1-methyl.	30 g/litre + 610 g/litre 617 g/litre 508 g/litre+120 g/litre
17	*Epoxiconazole**	YES	Triazole	Epoxiconazole	125 g/litre
18	*Prothioconazole**	YES	Triazole	SA-N	NA
19	*Cyproconazole**	YES	Triazole	SA-N	NA
20	*Pyraclostrobin**	YES	Strobilurin	SA-N	NA
21	*Tetraconazole*	YES	Triazole	SA	NA
22	*Kresoxim-Methyl*	YES	Stobilurin	SA	NA
23	*Copper Hydroxide**	YES	Inorganic copper	AGPRO Cupric hydroxide 350 SC contains copper Champ Flo contains copper as copper hydroxide Champ WG contains copper Kocide Opti contains copper Champ DP contains coopper as copper hydroxide Hortcare Copper Hydroxide 300 contains copper hydroxide	350 g/litre 334.5 g/kg 500 g/kg 300 g/kg 375 g/kg 300 g/kg
24	*Paclobutrazol*	YES	Triazole	SA	NA
25	*Flutriafol*	YES	Strobilurin	SA	NA
26	*Myclobutanil**	YES	Triazole	SA-N	NA
27	*Diniconazole*	NO	Triazole	SA	NA
28	*Metconazole*	NO	Triazole	SA	NA
29	*Flusilazole**	NO	Triazole	SA-N	NA

Active Ingredient (a.i.)		Availability Status In New Zealand	Chemical Group	Products Names	Rate
30	*Uniconazole*	NO	Triazole	SA	NA
31	*Boscalid**	NO	Carboximide	SA-N	NA