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This Report relates to Item 5 in the Agenda

“Eucalyptus Bronze Bug Update”

Biology, ecology, impacts, and control options to protect *Eucalyptus viminalis* from bronze bug (*Thaumastocoris peregrinus*)

Report prepared for the Marlborough Research Centre
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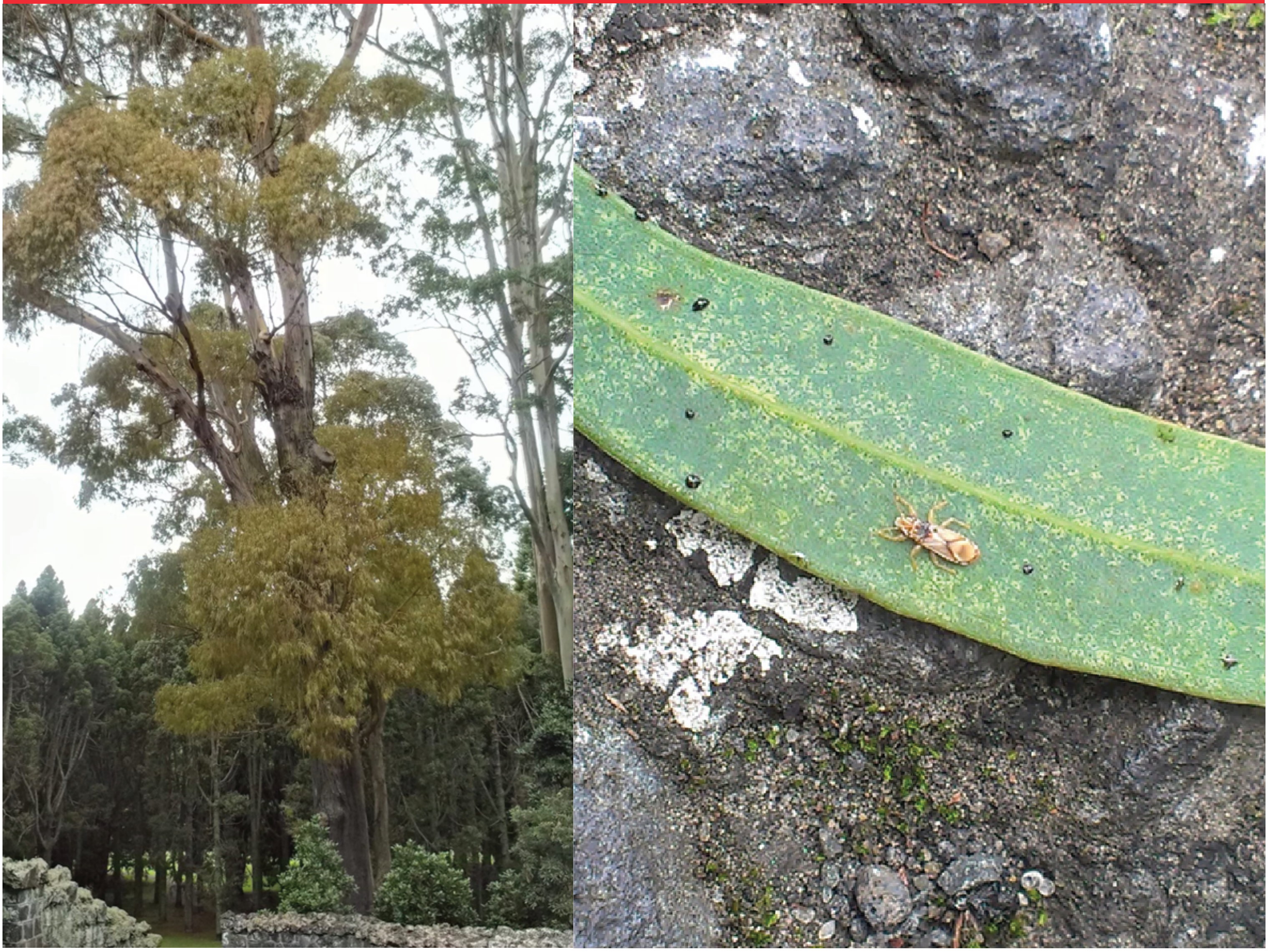

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha

Biology, ecology, impacts, and control options to protect *Eucalyptus viminalis* from bronze bug (*Thaumastocoris peregrinus* (Hemiptera: Thaumastocoridae)).

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Executive Summary

Bronze bug (*Thaumastocoris peregrinus*) is the causal agent of observed eucalypt decline in Marlborough. It is likely that it has been present for at least 3 years. *Eucalyptus viminalis* is the most widely affected species, however bronze bug effects at least 65 eucalypt species and other (yet to be identified) species are also showing signs of moderate to severe dieback. Symptoms of infestation include ‘bronzing’ of canopies in autumn.

Bronze bug has many known hosts and no natural enemies in New Zealand. Climatic modelling shows Marlborough and the east coast of the South Island (as far as Dunedin) to be optimal habitat. It is a sap sucking bug that feeds on fully expanded leaves and causes damage to plant cells as it feeds. It is this damage that results in the yellowing/silvering of foliage that ultimately turned bronze in colour.

Without intervention it is likely that affected *E. viminalis* will eventually succumb to continued heavy infestations. Impacts will be amplified by drought conditions. Affected stakeholders (tree owners, primary sectors, e.g., viticulture, apiculturists, iwi, and other interested parties) need to urgently decide if action should be taken. If it is decided to take action I recommend:

1. Immediate application of a chemical insecticide to provide relief to effected trees so that they can recover. Options include a broad-spectrum aerial insecticide application (registered chemicals are available) or stem injection with imidacloprid (no registered chemicals so an experimental use permit would be required). Both options have potential non-target affects that need to be considered by affected parties.
2. Investigate the feasibility of microbial pesticides as a medium-term solution. These are used effectively overseas but they remain too speculative to apply as an immediate ‘recovery’ treatment.
3. Consider biological control as a long-term solution. *Cleruchoides* noackae is a solitary egg parasitoid that has been released in other countries. This option would take at least 3 years and cost $1-2M.

If it is decided to do nothing it is important to quantify the economic impact to affected parties. I recommend contracting a tree consultant to ascertain the diversity of trees effected and most importantly to quantify approximate economic costs of removing trees (assuming that all *E. viminalis* will eventually succumb) in urban street, parks, golf courses, cemeteries etc, and adjacent to roads, including SH1. This will inform future budgeting of park and street tree maintenance activities.

Introduction

Thaumastocoris peregrinus (Hemiptera: Thaumastocoridae), known as bronze bug is a foliar sap sucking bug that effects the leaves of at least 65 *Eucalyptus* species or hybrids (Saavedra et al. 2015). It was first observed in New Zealand in Auckland on the 10 March 2012 as part of the High Risk Site Surveillance programme (Sopow et al. 2012). At the time there was no attempt made to eradicate it and it has subsequently spread widely in the North Island. Bronze bug is the causal agent of the decline of several *Eucalyptus* species, particularly *Eucalyptus viminalis* in Marlborough that was reported in Autumn 2023. Anecdotal reports of talking with contractors in vineyards in Marlborough suggests that visible bronzing of trees has occurred for 2 to 3 years, but potentially 5 years. These observations are anecdotal, and it remains uncertain exactly when bronze bug established in Marlborough.

This report covers a high-level summary of the taxonomy (understanding related species is important for long-term control options), biology, ecology, potential impacts, and concludes with control options and recommendations to ameliorate the economic, environmental, social, and cultural impacts of this pest incursion.

Taxonomy and related species

Globally there are at least 20 described species of Thaumastocoridae from nine genera. However, there are no native or indigenous species of Thaumastocoridae present in New Zealand. Based on a coarse comparison of the Tree of Life project (http://tolweb.org/Cimicomorpha/10817) with the current national checklist by Larivière and Larochelle (2014), the nearest relatives in New Zealand are from the families Miridae and Tingidae of which we have 127 and 4 species respectively. These totals include indigenous (known only from New Zealand), native, and some introduced taxa. A detailed host specificity analysis would be required if it was decided to pursue biological control as a long-term sustainable control tool for bronze bug.

Distribution, biology, and ecology

Bronze bug was poorly known until the occurrence of ‘outbreak’ populations in 2002 that were caused visible damage to street trees in Sydney (Sopow et al. 2012). Since then, bronze bug been recorded in Europe, Africa, Nth and Sth America and New Zealand (Fig. 1). Bronze bug are sap suckers that feed on fully expanded leaves. Heavy infestations result in severe damage, initially causing chlorosis (yellowing or silvering) of leaves that eventually turn reddish-brown in late summer/autumn. The visible symptoms are referred to as ‘bronzing’ (see picture on report cover).

Fig 1. Distribution of *Thaumastocoris peregrinus* observations from the Global Biodiversity Information Facility (GBIF). Note: Marlborough is not yet recorded as no records have yet migrated from the recent additions on iNaturalist NZ to GBIF.

The most susceptible hosts have varied between countries, however *E. viminalis* and *E. nicholii* are consistently effected. Saavedra et al. (2015) provide a comprehensive global host list. This includes the following species, those highlighted in bold were suggested as heavily impacts in New Zealand by Sopow and Bader (2013).

Corymbia citriodora ssp. *citriodora; Corymbia ficifolia; Corymbia henryi; Corymbia maculate; Eucalyptus argophloia; Eucalyptus benthamii; Eucalyptus botryoides; Eucalyptus bridgesiana;* ***Eucalyptus camaldulensis****; Eucalyptus camaldulensis x largiflorens* (Hybrid)*; Eucalyptus camaldulensis x bicostata* (Hybrid)*; Eucalyptus cypellocarpa; Eucalyptus dorrigoensis; Eucalyptus dunnii; Eucalyptus globulus ssp. Bicostata; Eucalyptus globulus* ssp. *globulus; Eucalyptus globulus* ssp. *pseudoglobulus; Eucalyptus gomphocephala; Eucalyptus grandis; Eucalyptus grandis x camaldulensis* (Hybrid)*; Eucalyptus grandis x nitens* (Hybrid)*; Eucalyptus grandis x urophylla* (Hybrid)*; Eucalyptus exserta; Eucalyptus largiflorens; Eucalyptus leucoxylon; Eucalyptus longirostrata; Eucalyptus macarthurii; Eucalyptus microcorys;* ***Eucalyptus nicholii****; Eucalyptus nitens; Eucalyptus occidentalis; Eucalyptus ovata; Eucalyptus paniculata ; Eucalyptus pauciflora ; Eucalyptus pellita; Eucalyptus pellita x tereticornis; Eucalyptus pilularis; Eucalyptus pulverulenta; Eucalyptus punctate; Eucalyptus propinqua; Eucalyptus resinifera; Eucalyptus robusta; Eucalyptus rudis; Eucalyptus saligna; Eucalyptus saligna x botryoides* (Hybrid)*;* ***Eucalyptus scoparia****; Eucalyptus sideroxylon; Eucalyptus smithii;* ***Eucalyptus tereticornis****; Eucalyptus urophylla; Eucalyptus urophylla x camaldulensis* (Hybrid)*;* ***Eucalyptus viminalis****;*

In addition *E. muelleriana* was heavily impacted at Parakao (Northland) in 2019 (Withers 2019).

Climate modelling by Saavedra et al. (2015) showed that Marlborough, Nelson, and the entire east coast of the South Island as far south as Dunedin represent optimal climate for bronze bug. Almost all of the North Island except the mountainous regions of the central North Island, Taranaki, and the East Cape are also optimal habitat for bronze bug.

Aspects of the bronze bug lifecycle have been studied in New Zealand by Saavedra et al. (2015) who examined survival and development rate on four eucalypt species. Average juvenile development time of bronze bug was reported as 16.8 and 13.3 days on *E. nitens* and *E. nicholii*, respectively at 30 °C in laboratory rearing facilities. This is consistent with laboratory testing by Barbosa et al. (2019) in Brazil who reported 36.4, 32.47, 22.69, 20.0, and 16.1 days at 18, 22, 25, 27, and 30 °C, respectively. Average female longevity was greatest at 22 °C (53 days) (Barbosa et al. 2019). All life stages (eggs, nymphs, adults) are present throughout the year, however population density declines between late May and late August (Saavedra et al. 2015).

Impacts

Globally *Eucalyptus* is a common plantation tree species, several plantation species are known to be impacted by bronze bug. Unfortunately, a coarse review of the literature does not present simple economic impact analyses that include dollar estimates. If desired I could reach out to colleagues in South Africa and Argentina to see if I can get dollar estates. FAO (2012) report that all commercially grown species of *Eucalyptus* are affected. We can deduce that the production impact is likely to be substantial as numerous countries (at least South Africa, Argentina, and Brazil) have been through biological control development programmes. The potential impact of bronze bug must be substantial to justify the cost of such programmes. Furthermore, Australia has taken the step to register a stem injection product for protection from bronze bug.

The actual impact of bronze bug is poorly documented in New Zealand. In part this is because we do not have a plantation forest industry of a susceptible species. A quick drive around rural Marlborough, including the Waihopai Valley and SH1 shows extensive ‘silvering’ and subsequent ‘bronzing’. *Eucalyptus viminalis* was the predominant species affected, but several less common species have sustained significant damage. This includes species of cultural/historical significance to individual families and communities, e.g., old trees planted by ancestors. Damage to a stand of *Eucalyptus muelleriana* was reviewed by (Withers 2019) who observed severe winter bronzing, dieback, and epicormic growth. Trees were also affected by other pests (e.g., *Heliothrips*) and the causal agent is difficult to determine and likely a combination of species during a severe drought. Photographs are consistent with bronze bug induced bronzing.

Despite the lack of a plantation resource of susceptible species there will be economic costs to management agencies and residents of Marlborough. The principal financial cost is the removal and replacement of trees with associated intangible costs of the loss of history and character within the landscape. Specific costs to consider are:

- Costs of removing street, park (e.g., Witherhills Farm), and other amenity trees (e.g., cemeteries and golf courses).

- Costs of removing trees adjacent to rural houses. During a recent tour it was noticeable that many affect *E. viminalis* were proximal to homesteads.
- Traffic management costs associated with the removal of trees in proximity to roads. There are large numbers of big trees on major roads in the Marlborough regions, e.g., SH1 and Waihopai Valley, as well as urban trees in Blenheim.

Understanding the full suite of trees affected is an important step in understanding the scale of the problem. This could be achieved by supporting an undergraduate forestry student to work alongside the Marlborough Research Centre and the NZ Dryland Forests programme to identify and map affected trees as well as disseminating information to landowners.

I also recommend contracting a tree consultant, e.g., Brad Cadwalladar, to undertake a survey in Marlborough to estimate the cost associated with removing trees. This is important for two reasons, firstly it informs longer-term discussions with affected stakeholders. Secondly, it provides budgetary information for councils (and NZTA with reference to roading infrastructure) to plan for future tree removal costs that will be higher than normal given that many trees are likely to die in a short period of time. Essentially, if left unchecked bronze bug will compress mortality related management costs that would otherwise be spread over a longer period.

As this species is having substantial impact to many stakeholders it could be beneficial to produce an article in local media to raise awareness. This will help identify affected parties that may be interested in control discussions.

Controls

Chemical controls

Chemical control is possible but will be costly to deploy at scale over long periods and has potential non-target effects. Application of insecticides presents an opportunity to give trees ‘a reprieve’ whilst long-term options are evaluated. Possible chemical control options are as follows:

- Stem injection of insecticides in urban areas is one option to reduce environmental effects, however correct formulation of insecticides is critical to ensure adequate translocation within the tree (Gous and Richardson 2008). Stem injection with imidacloprid was trialled against bronze bug at three concentrations, with the lowest concentration (0.04 to 0.05 grams of active ingredient per cm of diameter at breast height, as SilvaShield® SL 200g/L AI) providing effective chemical control for 2 to 3 years in residential Sydney (Noack et al. 2009). Silvashield has been registered for use in Australia for the control of bronze bug. A search of the New Zealand ACVM database indicates that no imidacloprid products are registered for stem injection of trees, however numerous registrations are for ground drenches of sap sucking insects, e.g., thrips, mealy bugs etc, on onions, lettuces, brassica, and young non-bearing grapevines or vines destined for removal. It may be possible to apply for an experimental or emergency use permit, I have enquired with the Agricultural Chemicals and Veterinary Medicines group at the Ministry for Primary Industries and they are currently assessing possible options for using SilvaShield in New Zealand. I will advise once I hear back from them. The main difficulty (apart from the regulatory requirements) of using imidacloprid is the known affects of this class of chemical (and aspects of formulation, e.g., inclusion of fungicides) on foraging bees (Sanchez-Bayo and Goka 2014). An examination of current registrations in NZ are all for crops that are either wind pollinated or removed before flowering. One potential option to minimise this affect is to combine the insecticide with plant hormones, e.g., gibberellic acid, that can prevent/minimise flowering. I am unaware of anyone that has implemented this approach, however the use of plant hormones to prevent flowering has been implemented for other reasons. Addition of flowering inhibitors will not be simple and will take substantial research to avoid negative impacts on the trees themselves.

- Aerial spraying of canopies with non-systemic broad-spectrum products can be used to provide knock down control, but do not provide the control longevity of systemic insecticides. Alpha-cypermethrin is sprayed aerially to control *Paropsis charybdis*, another *Eucalyptus* pest, hence a registered product is currently available for use in New Zealand. Various adjuvants (spreader) and ultra-fine droplets are used to achieve adequate coverage of leaves. Such spray profiles are prone to drift, thus aerial spraying in urban environments or adjacent to crops, e.g., vineyards, must account for potential drift and subsequent impacts on landowners. It is possible to spray small areas with UAVs, which minimises but does not eliminate drift.
- Aerial spraying with more targeted chemicals. It may be possible to spray with a more targeted insecticide, e.g., an insect growth regulator (IGR). Such insecticides either interrupt the chemical signalling that controls insect moulting or the production of chitin, the major component of their exoskeleton. A more detailed analysis would need to be conducted of potential IGRs that affect Hemiptera (Insect order that bronze bug is part of), Fenoxycarb may be one potential active ingredient.

Non-chemical controls: Short to medium-term solutions

Insecticide (particularly their aerial application) use is declining in favourability due to their non-target effects on other insects, broader environmental issues, and restrictions posed by various environmental certification schemes, e.g., Forest Stewardship Council. In the last 5 years significant research effort has been undertaken to develop non-chemical bronze bug controls, particularly microbial insecticides. *Beauveria bassiana* has been observed causing natural mortality in Brazil. Isolates subsequently applied to leaves resulted in 72% mortality of bronze bug placed on leaves after 6 days when applied at 1.0 x 10^8 conidia.mL^{-1} (Lorencetti et al. 2017). Further laboratory studies that directly sprayed bronze bug in petri dishes with *Beauveria bassiana* and *Metarhizium anisopliae* resulted in 100% and 83-88% mortality, respectively (Soliman et al. 2019). Wilcken et al. (2019) scaled this to field applications and compared Brazilian strains of *B. bassiana* (application 0.5, 1.0, and 1.5 kg/ha) and *M. anisopliae* (application 0.25, 0.50, and 1.0 kg /ha) with Thiamethoxam, Thiamethoxam + Lambda-cyhalothrin, and Acephate. At 21 days post aerial spray bronze bug control was still 99% for the 0.5kg/ha *B. bassiana* treatment. They note that temperatures were between 27 and 29 °C and monthly rainfall between 20 and 63mm that were acceptable to promote sporulation. Santos et al. (2018) evaluated 7 isolates of *B. bassiana* and 3 of *M. anisopliae* and 2 of the related *M. robertsii* where all were shown to be pathogenic to bronze bug. This further confirms the broad susceptibility of bronze bug to pathogenic fungi.

These entomopathogens were chosen as they are known to have a wide host range, however optimal environmental conditions are between 25 and 30 °C (Hallsworth and Magan 1999). Successful control of insect pests using entomopathogens is more complex than the application of chemical insecticides. Spraying live spores requires appropriate environmental conditions, particularly temperature and humidity, which ensure that they will germinate, persist, subsequently cause mortality and hopefully sporulate to ensure continued action of the applied microbial (Hallsworth and Magan 1999).

There were 23 microbial biopesticides registered in New Zealand in 2019, two were based on *Beauveria* and none of *Metarhizium* (Glare and O'Callaghan 2019). *Beauveria bassiana* Strain K4B1 is registered (Approval P7349, to Ecolibrium Biologicals, now Cellora) for use on aphid, thrips, and whitefly and sold under the tradename Beaugenic. A second strain K4B3 is approved (P7955, Ecolibrium Biologicals, now Cellora) for use against aphids, with control noted on a wide range of sucking insects including psyllids, thrips, and whitefly and sold under the tradename Beaublast. Though neither formulation is specific to bronze bug it is likely that it will exert good, but not optimal, control. I have approached Cellora via their website (no phone number was available) but have had no answer as to whether the product is available, or whether it can be used off label for bronze bug.

Non-chemical controls: long-term sustainable solutions

The only viable long-term economically sustainable solution to protect affected trees is classical biological control. This is via the introduction of natural enemies that may prevent ‘outbreak’ populations of bronze bug. Biological control has been evaluated and implemented internationally using a solitary egg endoparasitoid (*Cleruchoides noackae*) that was recovered from bronze bug infestations in New South Wales in 2009 (Figure 2). This is a minute wasp (<0.5mm) from the family Mymaridae that has the common name fairy flies. It has subsequently been released in several countries, including Argentina, South Africa, Chile, and Uruguay. Brazillian studies have demonstrated field parasitism rates of 52% (Barbosa et al. 2017).

New Zealand has no close relatives of bronze bug, thus it is a good potential candidate for classical biological control in New Zealand. There are strict controls on the release of new organisms into New Zealand and a substantial research programme will be required to support the regulatory requirements. Specifically:

- An approval to develop *Cleruchoides noackae* in a containment facility will be required from the Environmental Protection Agency (EPA).
- A host specificity and environmental impact and benefits assessment will need to be conducted.
- An application to release *C. noackae* will need to be lodged with the EPA. This is a publicly notifiable process.

International evidence demonstrates that it is an effective biological control agent and the lack of close relatives in New Zealand suggests that it is a good potential candidate for release. However, establishing *C. noackae* would take a minimum of 3 years (best case scenario) and likely cost $1-2 million. If biological control was to be considered it could be discussed with Toni Withers and Stephanie Sopow from Scion in Rotorua who both have experience with parasitoids as biological control agents.

Figure 2. *Cleruchoides noackae* parasitising a bronze bug egg. Photo: C.F. Wilkin.

Conclusions and recommendation

Bronze bug will have severe effects on highly susceptible eucalypts, such as *E. viminalis*. Evidence to date suggests that dieback will be common and without intervention this is likely to lead to widespread mortality in coming years. Mitigating this outcome would be best achieved by a short, medium, and long-term approach.

- Short-term: Chemical insecticide application to provide immediate relief to affected trees
- Medium term: Development and application of a microbial pesticides
- Long term: Biological control with the egg parasitoid *Cleruchoides noackae*.

If the heavily affected *E. viminalis* in Marlborough are to be saved there is an urgent need to ‘knock down’ the bronze bug population to allow trees to recover. The approach that is likely to have the best success is a chemical treatment. Although microbial treatments are known to be effective and less environmentally damaging, they are optimal at higher temperatures (>25 °C), and this will not be achieved until mid-summer. Control really needs to be done as soon as practical and immediate options are limited and have potential non-target effects on various stakeholders.

Effective products are registered that could be applied aerially, e.g., synthetic pyrethroids, however there are practical and social considerations of such an approach in urban environments and trees near crops, e.g., vineyards. The best candidate that is proven to work is stem injection with imidacloprid. However, there is no current registered product available to use in New Zealand (although an experimental use permit could be investigated) but there is a potential effect to pollinating insects, e.g., bees. Stem injection with imidacloprid would provide a breathing space of 2 to 3 years to consider further action. Dr Brian Richardson, Scion, Rotorua would be someone that could provide additional advice on insecticide application to trees, including stem injection and aerial application of insecticides by either fixed wing, rotary, or UAV.

Microbial pesticides using *Beauveria* and *Metarhizium* have been proven affective but only provide short-term control and need to be applied seasonally to protect trees. They have fewer unintended consequences and would not be toxic to bees and could be applied aerially with limited impact on vineyard practices. Products are registered in New Zealand but only in cultivated crops and it is unclear if the products are currently manufactured. An experimental use permit could be obtained to trial microbial pesticides applied by UAV. This research phase could provide the necessary data for subsequent registration to support widespread use. Prof Travis Glare, Lincoln University is an expert in microbial pesticides and has a contract manufacturing company for small scale production if required.

Long-term the introduction of *Cleruchoides noackae* is potentially more sustainable. It requires a substantial investment of research. Whether it would be cost-effective could be informed by the suggested impact study of tree removal costs in Marlborough and further south, e.g., into Canterbury and Otago, as bronze bug will eventually spread.

Specific Recommendations

1. Bring affected stakeholders together to discuss whether they support action. Potential stakeholders include tree owners, apiculture, primary sectors, e.g., viticulture, iwi, and public interest parties. Stakeholders must decide if they want to attempt to control the infestation and evaluate which chemical treatment (aerial broad spectrum vs. stem injection imidacloprid) should be applied as a ‘knock down’ control.

Decision is not to control.

2. An impact study should be conducted to quantify which species are affected and what the tree removal costs are likely to be to inform council budgetary processes.

Decision is to proceed with control.

3. Investigate registered microbial pesticides in the summer of 2023/24. Potentially this could form the basis of a student project.
4. Conduct a biological feasibility study to inform investment in long-term control measures.

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