Feasibility of using natural enemies to control *Cordia* (*Cordia alliodora*) in Tonga and the wider Pacific region

Summary

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1 Project and client

- The feasibility of developing a biological control programme targeting a tree species, *Cordia alliodora*, within Tonga and the wider Pacific region was assessed by the Bioeconomy Science Institute, Manaaki Whenua – Landcare Research Group,[1] for the Secretariat of the Pacific Regional Environment Programme (SPREP).
- The work fell under the GEF-6 Regional Invasives Project funded by the Global Environment Facility as part of the United Nations Environment Programme.

2 Objectives

- Undertake a literature review to identify potential biocontrol agents for *C. alliodora* and determine the feasibility of releasing them in the Pacific region.
- Assess the achievability of successful biocontrol of *C. alliodora* in the Pacific region.
- Estimate and outline the cost of implementing a biocontrol programme for *C. alliodora* in the Pacific region.

3 Background

Cordia alliodora is a neotropical tree species native to Central and South America that has become increasingly invasive in parts of the Pacific. In Tonga, *C. alliodora* is the main invasive weed dominating the Toloa Rainforest canopy (Atherton 2014), and it affects two Protection Areas: the ‘Eua National Park and ‘Eua Forest Plantation on ‘Eua (S. Hamni, Ministry of Agriculture, Food and Forests ‘Eua, pers. comm., 30 October 2025). It is also invasive in Vanuatu and Solomon Islands, and in Samoa, where it is interfering with the regeneration of native species in the Faleata Recreation Reserve at Tuanaimato, Faleata (Space 2002; Bakeo & Qarani 2005; G. Harunari, Biosecurity Solomon Islands, pers. comm., 10 October 2025; SPREP 2022).

The global distribution of *C. alliodora* has expanded significantly through human-mediated introductions in the past century. It is a desirable tree for agroforestry systems because it has fast growth, a straight and cylindrical bole that is often clear of branches for 50–60% of its height (i.e. it is self-pruning), and a compact crown (Greaves & McCarter 1990). Its open, high crown structure provides filtered shade that reduces heat stress for understorey crops without excessively reducing photosynthesis (CATIE 2000).

C. alliodora also improves soil fertility through rapid decomposition of its nutrient-rich leaf litter, contributing organic matter, nitrogen, calcium, and potassium to the soil (Nichols et al. 2001). Its deep rooting system allows it to access water and nutrients from deeper soil layers, reducing direct competition with shallow-rooted crops (Beer et al. 1997). The timber has an attractive grain and is easy to work, making it suitable for high-quality carvings, furniture, cabinetry, and decorative veneer (Greaves & McCarter 1990). It is a moderately heavy wood, resistant to decay and dimensionally stable (it experiences minimal shrinking and swelling from changes in moisture

[1] On 1 July 2025 Landcare Research New Zealand Ltd became the New Zealand Institute for Bioeconomy Science Ltd. Manaaki Whenua – Landcare Research operates as an internal group within this Institute, which is less formally known as the Bioeconomy Science Institute (BSI).

content) (Greaves & McCarter 1990), making it useful for general light construction as well as flooring, joinery, boat timbers and oars, and plywood manufacture (Evans 1992; CATIE 2000; Greaves & McCarter 1990).

C. alliodora was originally introduced to Fiji, Hawaii, Samoa, Solomon Islands, Tonga, and Vanuatu in the mid to late 19th century in forestry/agroforestry trial plots. However, its use as a forestry/agroforestry species has declined since its introduction, and harvesting has not kept up with the natural spread of the plant, so it has subsequently become invasive. In Tonga it is still being used for fencing, light construction, and a small amount of carving (S. Hamni, Ministry of Agriculture, Food and Forests 'Eua, pers. comm., 30 October 2025). It is unknown if *C. alliodora* is being used for any of its beneficial qualities elsewhere in the Pacific region.

C. alliodora is highly invasive. It has a high propagule pressure that allows it to colonise disturbed areas rapidly. It produces a large number of viable seeds that are wind and water dispersed, and the young plants have a rapid growth rate, allowing them to outcompete native species. At better quality planting sites in Vanuatu, it has recorded growth rates of up to 15 m height and 12 cm d.b.h. at 5 years old, increasing to 23 m height and 27 cm d.b.h. at 10 years (Hudson 1984). *C. alliodora* requires full sun to grow (Parresol & Devall 2013), meaning it is unlikely to penetrate established intact forest, but it does opportunistically spread into cleared forest areas caused by disturbance events such as tropical cyclones, which are expected to increase under climate change (Edward et al. 2009). This behaviour has already been observed in the Pacific following cyclone Evan in 2012 and is the main cause of the massive spread of *C. alliodora* in Tonga and Samoa's protected forest areas (SPREP 2022).

Current control efforts require manual felling combined with chemical treatment with systemic herbicides due to the plant's ability to resprout vigorously from the stump and spread short distances through root suckering (Atherton 2014). In native forest areas replanting with natives in the controlled area is also needed to stop other weeds from reinvading the large open spaces created by the removal of *C. alliodora.* These control efforts are labour intensive and costly. In Tonga, the cost of C. *alliodora* control in 'Eua National Park ranges from NZ$100,000 to NZ$150,000 per year, from an operational scale to a comprehensive project if expenses such as monitoring, technical advice, and logistics are considered (J. Pisi, SPREP, pers. comm., 31 October 2025).

It is clear that a longer-term solution for controlling *C. alliodora* needs to be found, but there may be opposition to a biocontrol programme for *C. alliodora* in communities in the Pacific where it is used for its wood or as part of an agroforestry system. Information about the harmful impacts of *C. alliodora* on the environment will need to be widely communicated. Consultation with local communities regarding the potential introduction of biocontrol agents targeting this tree will also be required.

Biology, phylogeny, and taxonomy

C. alliodora is a medium to large deciduous tree, usually growing 15–25 m in height, but capable of reaching up to 35 m tall. It has a straight bole that can exceed 100 cm in diameter (Greaves & McCarter 1990). The root system consists of large, spreading, surface laterals and a deep tap root (Johnson & Morales 1972). Leaves are simple, elliptic to ovate in shape, typically 6–18 cm long and 3–7 cm wide, and shed during the dry season. The leaves produce a characteristic garlic-like odour when crushed – the feature from which the species takes its epithet *alliodora* ('garlic-scented') (Greaves & McCarter 1990). The tree produces small, white to cream-coloured flowers that are hermaphroditic and pollinated primarily by insects (Murillo & Gutiérrez 2012) (Figure 1).

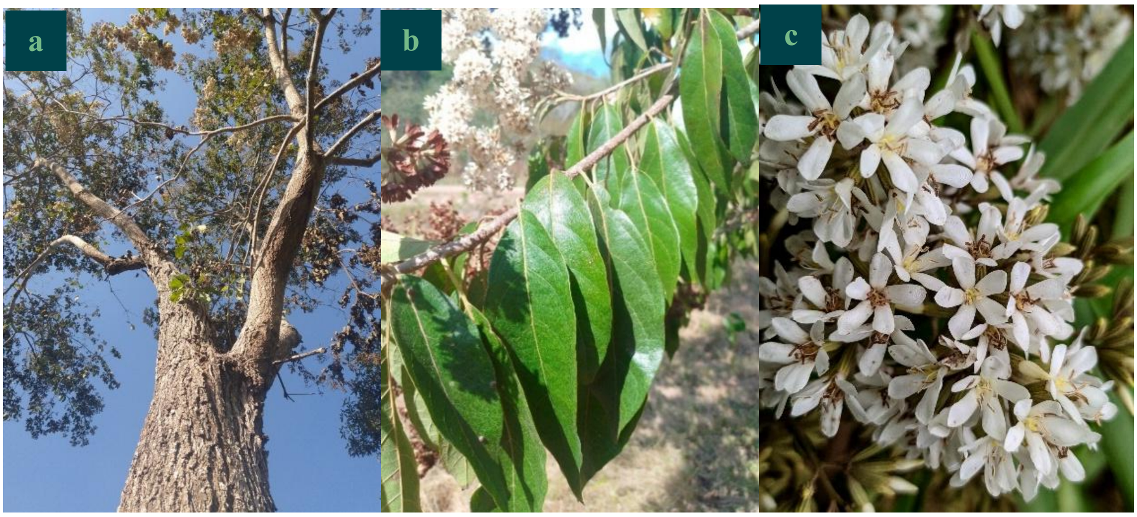

Figure 1. **(a)** ***Cordia alliodora*** **mature tree** (source: © JOSE JAVIER MAY CHAN, https://inaturalist.nz/observations/106129502 [CC-BY-NC)]); **(b)** ***Cordia alliodora*** **leaves** (source: © JOSE JAVIER MAY CHAN, https://inaturalist.nz/observations/108780349 [CC-BY-NC]); **(c)** ***Cordia alliodora*** **flowers** (source: © Mayk Oliveira, https://inaturalist.nz/observations/56481119 [CC-BY-NC]).

C. alliodora (Ruiz & Pav.) Oken, to give it its full taxonomical name, was traditionally assigned to the Boraginaceae family, but more recently it has been considered by many to be in its own family, the Cordiaceae (Gottschling et al. 2005; Weigend et al. 2014; Luebert et al. 2016). Modern molecular data support the division of the traditional Boraginaceae into 11 distinct families (Figure 2).

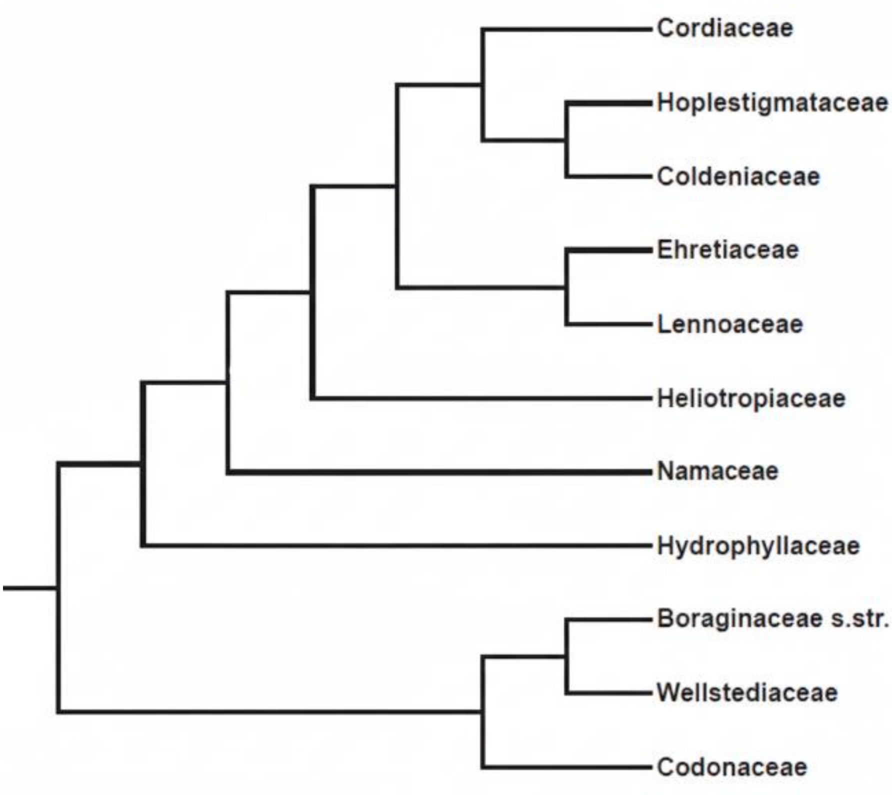

Figure 2. Eleven clades of the Boraginales order, accepted by the Boraginales Working Group as morphologically well-defined and monophyletic families. (Source: adapted from Luebert et al. 2016)

C. alliodora has many common names. In Samoa and Tonga it is referred to as kotia (Space & Flynn 2001), and in other countries it can be referred to as Spanish elm, salmwood, cypre, laurel, guarumo, laurel blanco (Central America), salmwood (Caribbean), maria, and louro (South America) (Orwa et al. 2009; CABI 2022).

Among the Cordiaceae family there are four indigenous species (*Cordia aspera* G.Forst., *Cordia dichotoma* G.Forst., *Cordia lutea* Lam., and *Cordia subcordata* Lam.) and three introduced species (*Cordia myxa* L., *Cordia sebestena* L., and *Varronia cylindristachya* Ruiz & Pav.) present in Pacific countries where *Cordia alliodora* is present. The importance of all these species to local communities will need to be determined before host-range testing can be undertaken. Closely related native and introduced species valued by local communities will need to be tested for their susceptibility to any potential biocontrol agents. For Samoa, Tonga, and Vanuatu, in particular, host-range testing should include *C. dichotoma* (native to Vanuatu), *C. aspera*, and *C. subcordata* (both are native to Samoa, Tonga, and Vanuatu).

4 Methods

Identifying closely related plants in the Pacific

Closely related plants in the Pacific were limited to plants belonging to the Cordiaceae *sensu* Boraginales Working Group and close families present in Pacific countries and territories where *C. alliodora* is known to be present. Information was acquired by searching online databases (Global Biodiversity Information Facility [GBIF.org 2025], Plants of the World Online [POWO 2025], and Flora of Solomon Islands [http://siflora.nmns.edu.tw/specimens/]), published literature, and consulting SPREP member country representatives.

For published literature, Google Scholar and Google were searched using the terms '*Cordia',* 'Cordiaceae', 'Boraginaceae', and 'Boraginales', paired with each current country member of SPREP: 'American Samoa', 'Northern Mariana Islands', 'Cook Islands', 'Fiji', 'French Polynesia', 'Guam', 'Kiribati', 'Marshall Islands', 'Nauru', 'New Caledonia', 'Niue', 'Palau', 'Papua New Guinea', 'Samoa', 'Solomon Islands', 'Tokelau', 'Tonga', 'Tuvalu', 'Vanuatu', and 'Wallis and Futuna'.

Identifying arthropod and non-arthropod invertebrate biological control agents for *Cordia alliodora*

A list of arthropods and non-arthropod invertebrates reported as associated with *C. alliodora* in both its native and introduced ranges was compiled from information acquired by searching online databases: HOSTS (Robinson et al. 2023), SCALENET (Garcia et al. 2016), and CABI Invasive Species Compendium (CABI 2022).

The internet sites Current Contents, Google, Google Scholar, Science Direct, and Web of Science were searched using the terms '*Cordia alliodora*' or '*C. alliodora*' or 'laurel' or 'Spanish elm' or 'salmwood' and 'invertebrate' or 'arthropod' or 'insect' or 'herbivor*'.

Species belonging to the family Formicidae (ants) were not included. Many ant species are found associated with *C. alliodora* (Wheeler [1929] recorded 58 species), using the tree as a nesting site while obtaining no direct food source from it (Novais et al. 2021).

Identifying fungal pathogens of *Cordia alliodora*

A table was also compiled of the fungi that have been reported associated with *C. alliodora*. The information was obtained by searching the following online databases: USDA Fungus-host database (Farr & Rossman 2023), MyCoPortal (https://www.mycoportal.org/portal/), and Biota of New Zealand (https://biotanz.landcareresearch.co.nz/).

Internet sites CAB Abstracts, Current Contents, PubMed, Ingenta, Web of Science, Agricola, Science Direct, and Google were searched using the terms '*Cordia alliodora*' or '*Cerdana alliodora'*, and sub-searched using the terms 'pathogen' or 'fungi' or 'disease'. Once a list had been created, we sought further information about each fungus in the published literature as well as in online databases: Index Fungorum database (http://www.indexfungorum.org/Names/Names.asp), Global Biodiversity Information Facility (GBIF.org 2025), and MycoBank database (https://www.mycobank.org/).

Identifying current unpublished practices and traditional knowledge

A questionnaire was sent to representatives of member countries and territories of SPREP, via email, to seek input on the local experience of *C. alliodora*. Countries where *C. alliodora* is known to be present were asked the following questions:

- Is *Cordia alliodora* classed as invasive or potentially invasive? Are there any important areas or species impacted by the plant invasion?
- What do you use *Cordia alliodora* for in your country?
- How do landowners or the government control *Cordia alliodora*?
- How much does *Cordia alliodora* cost to control?
- Does *Cordia alliodora* have any socio-economic impacts?
- Are there any groups that you think would oppose a control programme for *Cordia alliodora*?
- Is there any traditional knowledge in relation to *Cordia alliodora* that might be important to know?

Countries where *C. alliodora* is not known to be present were asked if the plant was present in their country and if it was a plant of concern. These countries were also sent a description of the plant with some images. Respondents that did recognise the plant, or noted it as being of concern, were then asked the aforementioned questions. The respondents are listed in Table 1.

On 30 October 2025 a meeting was held online to determine the ecosystem and socioeconomic impact scores for *C. alliodora.* Lynley Hayes, Stephanie Morton, and Dr Quentin Paynter (all from BSI) met with Pacific representatives David Moverley and Josef Pisi of SPREP.

Table 1. Respondents from Pacific Islands countries and territories who provided feedback on *Cordia alliodora*

Country/territory	Respondent
American Samoa	Tavita Togia, Office of the Governor
French Polynesia	Christophe Brocherieux, Cellule biodiversité, Direction de l'environnement
New Caledonia	Patrick Barriere, Pôle Menaces – Coordinateur, Agence néo-calédonienne de la Biodiversité
Niue	Huggard Tongatule, Biodiversity and Conservation Officer, Department of Environment, Fonuakula, Alofi South, Niue Island
Tonga	Steven Temaric Hamni, OIC, Ministry of Agriculture, Food and Forests ‘Eua
Papua New Guinea	Michelle Pius (Ms), Botanist – Plant Health, Technical and Advisory Division, National Agriculture Quarantine Inspection Authority
Solomon Islands	George Harunari, Biosecurity officer – Biosecurity Solomon Islands
Wallis and Futuna	Sosefo Malau, Technicien d’intervention en Environnement, Service Territorial de l’Environnement (based in Wallis)
Wallis and Futuna	Alefosio Taugamoa, Technicien de surveillance des milieux, Service Territorial de l'Environnement (based in Futuna)

5 Results

A total of 171 arthropods were found associated with *C. alliodora* from online and literature searches, representing nine arthropod orders. Five of these species appear to be specialists of *C. alliodora* or *Cordia* species.

Akermes cordiae and *Cyclolecanium hyperbaterum* are scale insects from the family Coccidae reported from Panama and have only been reported as present on *C. alliodora*. *Stauripodes persimilis* is a noctuid moth described as a *Cordia* specialist and found in Central America. The chrysomelid beetle *Amblycerus atkinsoni* is a bruchid (seed feeder) endemic to Mexico and only recorded from *C. alliodora*. A second chrysomelid beetle, *Coptocycla leprosa*, is recorded from Belize, Costa Rica, Mexico, Nicaragua, and Panama. It is described as a *Cordia* specialist with *C. alliodora* potentially as a main host. It has been recorded as highly damaging on *Cordia* when the beetle reaches high population densities, causing near defoliation of plants.

Thirty-five fungal species were found to be associated with *C. alliodora*. Among the fungal pathogens, *Puccinia cordiae* has been described as the most important disease on *C. alliodora*. Symptoms include rust pustules on leaves, deformed tissues and inflorescences, witch’s broom and canker. It has only been found on *Cordia* species. Two additional pathogens, *Pyrrhoderma noxium* and *Necator salmonicolor*, cause root rot and stem canker, respectively, on *C. alliodora* in Vanuatu, although both have a broad host range.

Leafy mistletoes from the genus *Phoradendron* parasitise *C. alliodora*, reducing tree vigour and occasionally causing death. However, species from this genus are usually not host specific.

6 Conclusions

No fungal pathogens or insects have been used as biocontrol agents against *C. alliodora*, but there are some promising natural enemies that could be investigated as biocontrol agents.

The leaf-feeding chrysomelid beetle *Coptocycla leprosa* is the strongest arthropod candidate worth investigating further as a potential biocontrol agent for *C. alliodora*, as it is reported as both a *Cordia* specialist and capable of high damage. The noctuid moth *Stauripodes persimilis* and the bruchid beetle *Amblycerus atkinsoni* are also potential biocontrol candidate agents that could be pursued if *C. leprosa* proves unsuitable. The two coccid scale insects *Akermes cordiae* and *Cyclolecanium hyperbaterum* may be worth following up as they are reportedly host-specific to *C. alliodora*. However, their associations with ant species will need to be investigated to determine if this would affect their efficacy as suitable biocontrol agents. One fungal pathogen, *Puccinia cordiae,* would also be worth pursuing as a potential biocontrol agent. *Puccinia cordiae* causes a variety of symptoms on *C. alliodora*, including leaf pustules, witch's broom, and canker.

Host range testing should include the closely related species *Cordia dichotoma* (native to Samoa and Vanuatu), *C. aspera*, and *C. subcordata* (both native to Samoa, Tonga, and Vanuatu). Comprehensive surveys of the natural enemies of *C. alliodora* in the native range have not been undertaken and may well reveal other potential invertebrate and fungal candidates.

It is unusual for a single biocontrol agent alone to achieve full control, and multiple species may be required for greatest efficacy.

7 Recommendations

A project to develop natural enemies for a novel target typically costs between NZ$1.5 and NZ$3.5 million for up to a 10-year period, depending on the complexity of the work involved. Our recommendations and the estimated costs for key aspects of a biocontrol programme targeting *C. alliodora* in the Pacific region are shown below. (Note: all cost estimates are in New Zealand dollars.)

- If *C. alliodora* seed source records are unavailable, complete a genetic analysis to determine the variability of *C. alliodora* in the Pacific region and its origin in the native range. **Estimated cost:** $100,000–$200,000.
- Organise shipment of the potential biocontrol agents identified in this report to containment facilities in New Zealand/Australia to establish rearing colonies. **Estimated cost per species:** $50,000–$100,000.
- Undertake rearing of agents in containment. **Estimated cost per species per year:** $50,000–$100,000.
- Undertake host-range testing. **Estimated cost per species:** $100,000–$200,000.
- If potential biocontrol agents identified in this report are not appropriate, conduct surveys of *C. alliodora* in climatically similar areas of the native range to identify other potential arthropod and pathogen biocontrol candidates. **Estimated cost:** $200,000–$600,000.
- Conduct studies to determine the impact of other potential biocontrol agents found in surveys, their life-cycle, and how to rear them. **Estimated cost per species per year:** $50,000–$150,000.

- If other potential biocontrol agents are identified, continue with the import, rearing, and host-range testing steps listed above.
- Assist Pacific Island nations seeking biocontrol against *C. alliodora* by preparing applications and going through the process to release agents. **Estimated cost per country:** $16,500–$30,000.
- Mass-rear and release agents in Pacific countries. **Estimated cost per country per species:** $50,000–$100,000.
- Monitor the establishment success of biocontrol agents. **Estimated cost per country:** $50,000–$100,000.
- Evaluate the biocontrol programme's success. **Estimated cost per country:** $50,000–$100,000.

Note: *Estimated costs are exclusive of GST and are based on 2025/26 figures. New estimates will need to be provided if work is to be undertaken beyond those years, and/or if complicating factors arise (e.g. disease infecting imported agents, ongoing disruptions due to global pandemics).*

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