Application to introduce *Tetramesa romana* and *Rhizaspidiotus donacis* for biological control of *Arundo donax* (giant reed) in the Cook Islands

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Ara Tapu,
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# Contents

# 1. Summary

The Cook Islands Ministry of Agriculture seeks approval for the release of a gall-forming wasp *Tetramesa romana* and an armoured scale insect *Rhizaspidiotus donacis* into Rarotonga for biological control (biocontrol) of the introduced plant giant reed *Arundo donax* (Poales: Poaceae).

*Arundo donax* is native to the Old World from the Iberian Peninsula of Europe to south Asia, including North Africa and the Arabian Peninsula. It has been cultivated in the Old World for thousands of years and has been widely introduced around the world as an ornamental, and for its fibre uses. Subsequently, it has become naturalized and invasive in many tropical, subtropical, and warm-temperate regions of the world, including throughout much of the Pacific region. It has been nominated one of the '100 World's Worst Invasive Alien Species' http://www.issg.org/database/species/search.asp?st=100ss.

In the Cook Islands, giant reed is localised and currently confined to Rarotonga. However, it is becoming increasingly widespread and forms very dense thickets that are extremely difficult to eradicate (http://cookislands.bishopmuseum.org/species.asp?id=5771).

Giant reed grows best where water tables are near or at the soil surface. It establishes in moist places such as ditches, streams, and riverbanks, growing best in well drained soils where abundant moisture and sunlight is available. Dense populations of giant reed consume large quantities of water, affect stream channels, compete with and displace native plants and interfere with flood control. Giant reed is extremely flammable increasing the likelihood and intensity of fires. It may establish an invasive plant-fire regime as it both causes fires and recovers from them quicker than native plants. Once established, giant reed has the ability to outcompete and completely suppress native vegetation, reduce habitat for wildlife, and inflict drastic ecological change (http://www.issg.org/database/species/ecology.asp?si=112).

The use of systemic herbicides such as glyphosate or fluazipop applied after flowering either as a cut stump treatment or foliar spray have been found to control giant reed (http://www.issg.org/database/species/ecology.asp?si=112). However, use of herbicides near to streams (where giant reed commonly grows) risks negative impacts due to herbicide run-off.

Hand pulling may be effective at removing small infestations, but care must be taken to remove all rhizomes to prevent re-establishment, which is very labour intensive.

Cutting is not recommended unless the rhizomes are also dug up, as tiny rhizomes can grow into new colonies. Burning is not recommended either as it has been demonstrated to aid the growth of giant reed because it can regrow faster than competing plants after fire (http://www.issg.org/database/species/ecology.asp?si=112).

Biocontrol is preferable over current control methods because once established, biocontrol agents will persist, offering the potential for permanent weed suppression by reducing giant reed abundance and, therefore, the negative impacts of this weed. This could greatly reduce the need for repeated use of chemical or mechanical weed control of giant reed.

Evidence is provided that *Tetramesa romana* and *Rhizaspidiotus donacis* are both highly host-specific plant herbivores that are likely to reduce the harmful impacts of giant reed in the Cook Islands and pose no threat to other plant species growing in the Cook Islands. Reductions in giant reed will, therefore, benefit other plant species (native plants, crops or other weed species). The risk of a host-shift resulting in non-target attack on native species, or plants of economic or cultural importance in the Cook Islands is vanishingly small.

Biological control of giant reed has not previously been tried in the Pacific region. *Tetramesa romana* and *Rhizaspidiotus donacis* have been introduced into the USA for biocontrol of giant reed (Goolsby & Moran 2009; Goolsby *et al.* 2009).

As giant reed is a weed of agricultural land and alongside streams in the Cook Islands, the most likely species to benefit from a reduction in giant reed are crops and riverine native plants and associated fauna.

This EIA has been prepared in accordance with Section 36 of the Cook Islands Environment Act 2003 (Box1, below) and section 68 of the Cook Islands Biosecurity Act 2008 (Box 2, below).

| BOX 1. SECTION 36 OF THE COOK ISLANDS ENVIRONMENT ACT 2003 |
|---|
| Environmental Impact Assessment –<br>(1) No person shall undertake any activity which causes or is likely to cause significant environmental impacts except in accordance with a project permit issued under this section.<br>(2) A person who proposes to undertake an activity of the kind referred to in subsection (1) shall apply to the permitting authority for a project permit in respect of the activity in accordance with the procedures (if any) prescribed by regulations.<br>(3) Every application for a project permit shall be submitted to the Service and shall include an environmental impact assessment, setting out details of -<br>(a) the impact of the project upon the environment and in particular -<br>(i) the adverse effects that the project will have on the environment; and<br>(ii) a justification for the use or commitment of depletable or non-renewable resources (if any) to the project; and<br>(iii) a reconciliation of short-term uses and long-term productivity of the affected resources; and<br>(b) the proposed action to mitigate adverse environmental effects and the proposed plan to monitor environmental impacts arising out of the project; and (c) the alternatives to the proposed project.<br>(4) Every application for a project permit shall be accompanied by an application fee prescribed by regulations.<br>(5) The Service shall undertake public consultation for the issuance of the project permit and in so doing –<br>(a) publish details of the project in such a manner that these become accessible to the affected public;<br>(b) make available copies of the environmental impact assessment report |

prepared by the project developer for review by the public; and

(c) receive comments within 30 days from the date of public notice from the general public and other interested parties;

(6) The Service shall request comments from any Government department or agency, or person affected by or having expertise relevant to the proposed project or its environmental impact.

(7) After the permitting authority has reviewed and assessed the application and all relevant information including the environment impact assessment, it shall, subject to guidelines (if any) prescribed by regulations-

(a) issue a permit for the proposed project specifying the terms and conditions subject to which the permit is issued; or

(b) request the applicant to submit modifications regarding the proposed project; or

(c) where there are reasonable grounds to do so (taking particular account of the purpose of this Act), refuse to issue a permit for the proposed project and state the reasons for such refusal.

(8) The Service shall immediately convey to the applicant the decision of the permitting authority.

(9) Within 14 days of receiving notice of a refusal under subsection (7)(c) the applicant may by letter to the Minister, request that the Minister consider the permitting authority's decision. The Minister shall review the permitting authority's decision and all information relevant thereto and shall notify the applicant and the permitting authority in writing of the Minister's decision to either -

(a) uphold the permitting authority's decision to refuse a permit for the proposed project; or

(b) direct the Service to request that the applicant submit specified modifications to the Service regarding the proposed project for reconsideration by the permitting authority.

(10) If the Minister is required to make a decision under subsection (9) in any case where the Minister is the applicant for the permit, or is otherwise directly or indirectly interested in the permit application otherwise than as the reviewing authority, the Minister shall –

(a) with the concurrence of the permitting authority concerned, convene an independent panel to review the permitting authority's decision and submit a recommendation to the Minister; and

(b) follow that panel's recommendation in making the decision under subsection (9); and

(c) make those recommendations public.

(11) Every person commits an offence who, without reasonable excuse or lawful justification, fails or refuses to comply with subsection (1), and shall upon conviction be liable -

(a) in the case of a body corporate, to a fine not exceeding $100,000;

(b) in any other case, to a fine not exceeding $50,000.

(12) In addition to any penalty imposed under subsection (11), the Court may order that the person convicted –

(a) under the supervision and to the satisfaction of a person appointed by the Court, clear up and remove the damage caused to the environment as a consequence of the offence within such period and upon such conditions as may be specified in the order;

(b) pay such amount as the Court may assess in respect of the expenses and costs that have been or are likely to be incurred-

(i) in restoring the environment to its former state (its state immediately before the offence was committed); or

(ii) in removing or cleaning up or dispersing any oil or noxious liquid, or other harmful substance to which the offence relates.

(13) For the purposes of subsection (1), any designation, or issue or re-issue of approval of any land (whether by a Minister or any other public officer or authority, and whether under this or any other Act) for the disposal of any kind of waste is deemed to be an activity that is likely to cause significant environmental impacts.

BOX 2. SECTION 68 OF THE COOK ISLANDS BIOSECURITY ACT

68. Beneficial organisms and biocontrol agents –

(1) The Secretary[1] may in writing approve the release of beneficial organisms or biocontrol agents that he considers necessary or appropriate for the control or eradication of a particular pest or disease in the Cook islands.

(2) An approval under subsection (1) shall identify –

(a) the organism or agent;

(b) the pest or disease which it is intended to control;

(c) the area where it may be released;

(d) the period during which it may be released;

(e) the person or persons who may release it; and

(f) any conditions subject to which the approval is granted.

(3) No liability attaches to the Secretary, Director [2] or any public officer in respect of the release of organisms or biocontrol agents in accordance with this section, except on proof of negligence or malice.

(4) The Director shall keep a biosecurity register of –

(a) the names of any beneficial organisms or biological agents released under this section; and

(b) the place of and extent of release of such organisms and agents.

(5) In this section, "beneficial organism" and "biocontrol agent" mean a natural enemy, antagonist or competitor of a pest or disease, and any other self-replicating biotic entity used for pest and disease control.

[1] Secretary to the Ministry of Agriculture

[2] Director of Biosecurity

# 2. Background and aims of the proposal

*Arundo donax* is native to the Old World from the Iberian Peninsula of Europe to south Asia, including North Africa and the Arabian Peninsula. It has been widely introduced around the world as an ornamental, and for its fibre uses. Subsequently, it has become naturalized and invasive in many tropical, subtropical, and warm-temperate regions of the world (Goolsby & Moran 2009), including throughout most of the Pacific region (http://www.hear.org/pier/species/arundo_donax.htm).

In the Cook Islands *A. donax* is listed as a very serious weed in Rarotonga (http://cookislands.bishopmuseum.org/species.asp?id=5771), where it infests cultivated land, pastures and stream margins. The origin of *A. donax* in the Cook Islands is uncertain.

Impacts of *Arundo donax* listed on the global invasive species database include displacing native plants, interference with flood control, and increasing the likelihood and intensity of fires: Once established, *A. donax* has the ability to outcompete and completely suppress native vegetation, reduce habitat for wildlife, and inflict drastic ecological change (http://www.issg.org/database/species/impact_info.asp?si=112&fr=1&sts=&lang=EN).

In addition *A. donax* consumes large quantities of water to support its rapid growth. In Mexico, it is called 'el ladron de agua,' the water thief and is stated to consume 3,800 acre-feet of water per 1,000 acres per year amounting three times more water than typical native vegetation (Seawright *et al.* 2009). This is potentially a major concern in the Cook Islands, where *A. donax* is invading stream margins because the Rarotongan water supply comes from just 12 stream water intakes (Anon 2013).

**FIGURE 1** *ARUNDO DONAX* INFESTATIONS IN RAROTONGA.

*Arundo donax* can be suppressed by herbicides, but extensive use of chemical herbicides threatens water resources and the fragile lagoon environment in the Cook Islands because, during heavy rains, runoff washes directly into the lagoon within minutes (Matepi, De Romilly & Waugh 2010). Mechanical control is extremely difficult because every piece of rhizome must be removed and root masses can be more than 1 m thick (http://www.issg.org/database/species/ecology.asp?si=112&fr=1&sts=&lang=EN). Fire is an ineffective control option.

Biological control is, therefore, seen as a potentially useful control option for this weed in the Cook Islands. The gall-forming wasp *Tetramesa romana* occurs throughout much of the native range of *Arundo donax* including southern France, Italy and Egypt. Based based on field studies in Europe it has the potential to significantly impact *A. donax* by stunting growth and killing stems (Kirk *et al.* 2003).

The armoured scale insect *Rhizaspidiotus donacis* is one the most widespread and damaging arthropods associated with *A. donax* in the subtropical regions of its native range in Mediterranean Europe (Goolsby *et al.* 2009).

*Rhizaspidiotus donacis* has a major negative impact on *A. donax* growth in field conditions in the native range (Cortés *et al.* 2011) and a combination of *R. donacis* and *T. romana* had a major negative impact on *A. donax* growth in a laboratory impact trial (Goolsby, Spencer & Whitehand 2009), indicating both are likely to be successful biocontrol agents when used in combination.

This proposal recommends obtaining *Tetramesa romana* and *Rhizaspidiotus donacis* from biocontrol researchers based in the USA and shipping them to the Cook Islands, following processing at the Beever Plant Pathogen Containment Facility in Auckland, New Zealand, to ensure the shipments are free of potential contaminants.

## 2.1 INFORMATION ON *TETRAMESA ROMANA* AND *RHIZASPIDIOTUS DONACIS*

**Taxonomy of *Tetramesa romana***

Phylum: Arthropoda

Class: Insecta

Order: Hymenoptera

Family: Eurytomidae

Genus: *Teramesa*

Species: *P. romana* Walker

**Biology and Native Range of *Tetramesa romana***

*Tetramesa romana* is a herbivorous gall-forming wasp (note the wasp is tiny – about 5 mm long – and does not sting) that is native to the Mediterranean region, where it is widespread and commonly infects *Arundo donax* (Goolsby & Moran 2009). *Tetramesa romana* females produce eggs parthenogenetically and deposit them into shoot tips leading to the formation of gall tissue and shoot distension within 2 weeks (Moran & Goolsby 2009). Field studies in Europe indicate *T. romana* has the potential to significantly impact *A. donax* by stunting growth and killing stems (Kirk *et al*. 2003).

**FIGURE 2** *TETRAMESA ROMANA* OVIPOSITING INTO THE STEM OF A GIANT REED PLANT (PHOTO: HTTP://CISR.UCR.EDU/GIANT_REED_ARUNDO.HTML)

### Taxonomy of *Rhizaspidiotus donacis*

Phylum: Arthropoda

Class: Insecta

Order: Hemiptera

Family: Diaspididae

Genus: *Rhizaspidiotus*

Species: *R. donacis* (Leonardi)

### Biology and Range of *Rhizaspidiotus donacis*

*Rhizaspidiotus donacis* is a sap-sucking armoured scale insect that is native to the Mediterranean region, where it is widespread and commonly infects *Arundo donax.* The life cycle of *R. donacis* is described by Goolsby *et al.* (2009) as follows: Females produce up to 300 live crawlers which emerge from the edge of the female's waxy scale covering. Crawlers disperse up and down on *A. donax* shoots and settle on leaf collars, axillary leaf sheaths at the bases of lateral shoots, and rhizomes within 48 h of release under laboratory conditions. Settled first-instar crawlers become immobile and began feeding within 3 days of release, as indicated by the appearance of a waxy 'whitecap' covering. First instars then secrete a brown waxy covering around the edge of the 'whitecap' and moult to the immobile second instar within 25 days of release, as indicated by the appearance of a first instar exuvia on top of the scale covering. At this stage, males and females can be distinguished by their oyster-shaped and round scale coverings, respectively. Males complete one prepupal and one pupal stage and emerge as winged adults. The life cycle is approximately 40 days long. Adult male *R. donacis* live only 2-3 days, during which time they crawl on and probe females. Females moult to the immobile third instar or adult stage 45-70 days after the start of the crawler stage. Adult females require three months of continued feeding and expansion and embryonic development of crawlers before reaching reproductive maturity.

**FIGURE 3** *RHIZASPIDIOTUS DONACIS* SCALE ON *ARUNDO DONAX* (PHOTO: GOOLSBY *ET AL.* 2009)

## 2.2 HOST-RANGE TESTING

### Scientific rationale for predicting the host-range of *T. romana* and *R. donacis*

A centrifugal phylogenetic method (Wapshere 1974) has long been used to determine the host-range of a potential biological control agent by sequentially testing plant taxa most closely related to the target weed followed by increasingly distantly related taxa until the host-range has been circumscribed. This approach is supported by recent advances in molecular techniques: for example, host-shifts in lineages of specialist phytophagous insects are strongly linked to the evolution of host-plant lineages, and in particular plant chemistry. Such insects show a strong phylogenetic conservatism of host associations (Briese 1996; Briese & Walker 2002). This pattern of strong phylogenetic conservatism in diet suggests the non-target plants of greatest risk are those closely related to known hosts (Futuyma 2000), and this has been validated by recent reviews of non-target attack by insect (Pemberton 2000; Briese & Walker 2002; Louda *et al.* 2003; Paynter *et al.* 2004) and fungal (Barton 2004) weed biological control agents.

Host-range tests vary in complexity. The simplest tests to interpret are 'no-choice' starvation tests where, most commonly, the immature stages of candidate agents are confined on a particular test plant and either feed and develop, or starve and die. Results are extremely robust and can be used to reliably define the 'fundamental' host range of a particular species. Reliance on no-choice starvation tests, however, carries a risk of needlessly rejecting specific agents because, given no choice, candidate biocontrol agents are often inclined to feed on species that they would not attack under natural field conditions. Under such circumstances, a range of other tests may be conducted, ranging from choice tests (where an agent may be given a choice between attacking the target weed and a potential non-target plant), to field tests conducted in natural field conditions. These additional tests are often not necessary if agent performance is poor on a test plant, relative to the target weed: recent research that has investigated the predictive value of quantifying the relative performance of biocontrol agents on test and target plants during host-range testing indicates that there are threshold performance levels in no-choice tests that predict host use in the field (Paynter *et al.* in press.).

## The target weed; nomenclature and phylogeny

### Taxonomy of *Arundo donax*

Division: Magnoliophyta

Class: Liliopsida

Order: Poales

Family: Poaceae

Subfamily Arundinoideae

Genus: *Arundo*

Species: *A. donax* L.

*Arundo donax* L. common names include giant reed and giant cane. *A. donax* belongs to subfamily Arundinoideae, which is part of the PACMAD clade (note: the name of the clade comes from the first initials of the included subfamilies Panicoideae, Arundinoideae, Chloridoideae, Micrairoideae, Aristidoideae, and Danthonioideae. It is one of two large monophyletic clades within the grass family). The major clades of the PACMAD clade are given in Figure 4.

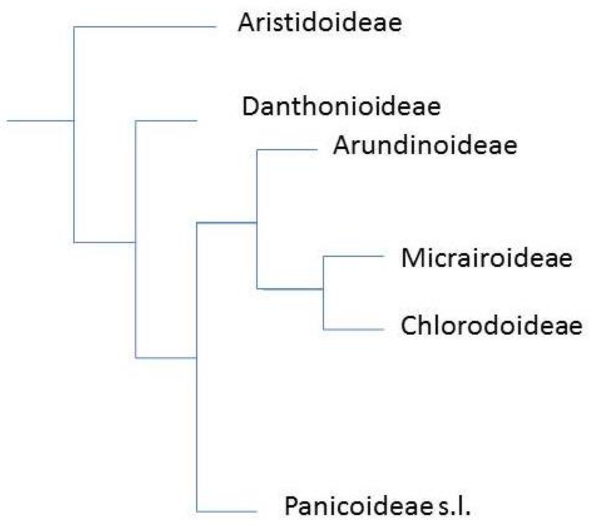


**FIGURE 4** PHYLOGENETIC RELATIONSHIPS BETWEEN SUBFAMILIES OF THE PACMAD CLADE OF GRASSES (BASED ON FIG. 1. MORRONE *ET AL.* 2012)

The sub-family Arundinoideae is further subdivided into two tribes: tribe Arundineae, to which *A. donax* belongs, and tribe Amphipogoneae as well as two genera that are currently placed *incertae sedis* within the sub-family Arundoinoideae (http://species.wikimedia.org/wiki/Arundinoideae).

## Relatives of *Arundo donax* growing in the Cook Islands

The entire sub-family Arundinoideae is absent from the Cook Islands native flora. Based on the phylogenetic tree presented by Morrone *et al.* (2012), the most closely-related native plant species present in the Cook Islands are *Isachne distichophylla* and *Lepturus repens* (which belong to the sub-families Micrairoideae and Chlorodoideae, respectively). Valued exotic grasses that are grown in the Cook Islands include sugar cane *Saccharum officinarum* and sweetcorn *Zea mays* (both subfamily Panicoideae). None of the exotic grass species listed in the Cook Islands Biodiversity Database belong to the sub-family Arundinoideae.

## Summary of host-range testing results and field records for *Teramesa romana*

Field collection records indicate that *Teramesa romana* only attacks *Arundo donax* and the closely-related *Arundo plinii* in its native range (Goolsby & Moran 2009).

Goolsby and Moran (2009) tested French and Spanish populations of *T. romana* against 35 plant species, including *Arundo formosana*, which supported development of *T. romana*, but was clearly a marginal host as development on this plant took twice as long, compared to development on *A. donax*, and there was a significant difference between the number of offspring produced by *T. romana* females on *A. donax* and *A. formosana*. The mean number of offspring produced per female on *A. formosana* was a fraction (c. 6-14%) of that produced on *A. donax*. They also tested representatives from the core genera of the Arundinoideae tribe

Arundineae (*Molinia, Hakonechloa, Phragmites*), none of which were hosts of *T. romana*, as well as more distantly-related plants that belong to other subfamilies within the PACMAD clade (*Aristida*, *Cynodon, Spartina*, *Uniola*, *Leptochloa*, *Danthonia*, *Cortaderia*, *Panicum, Sorghum, Zea, Saccharum*). Goolsby and Moran (2009) concluded that *T. romana* is specific to plants in the genus *Arundo.*

In summary, *T. romana* is clearly highly host-specific. Plant species from different genera in the same tribe (*Molinia*, *Hakonechloa, Phragmites*), were not hosts and relative performance on a plant species that is congeneric with the target weed (*A. formosana*) was so poor that a recent analysis of quantitative host-range testing data (Paynter *et al.* in press.) indicates that even *A. formosana* is unlikely to be a suitable field host for *T. romana*.

**Summary of host-range testing results and field records in relation to plant species of importance in the Cook Islands**

*Tetramesa romana* does not pose a threat to native or valued exotic plants in the Cook Islands: Host-range testing indicates that *T. romana* is specific to the genus *Arundo* and, with the exception of *Arundo donax*, there are no native representatives and no other introduced species that belong to this genus (or indeed the subfamily Arundinoideae) that occur in the Cook Islands.

**Summary of host-range testing results and field records for *Rhizaspidiotus donacis***

Field collections of this insect are solely from *Arundo donax*, with one exceptional record of a collection from common reed (*Phragmites australis*), which is considered to be the result of misidentification of the host plant (Goolsby *et al.* 2009).

Goolsby *et al.* (2009) conducted no-choice tests using *R. donacis* collected in France and Spain against 47 plant species, including *Arundo formosana* and representatives from the core genera of the Arundinoideae tribe Arundineae (*Molinia, Hakonechloa, Phragmites*). They also tested more distantly-related plants that belong to the PACMAD clade (*Aristida, Bouteloua, Cynodon, Dichanthelium, Eragrostis, Muhlenbergia, Spartina, Sporobolus, Tridens, Uniola*, *Leptochloa*, *Danthonia, Cortaderia, Andropogon*, *Digitaria*, *Panicum, Pennisetum, Schizachyrium, Sorghum, Tripsacum, Zea, Saccharum*).

Forty of the tested plant species supported no development of *R. donacis.* On two plant species, crawlers settled, and commenced feeding, but failed to complete development. Development to adult did occur on closely-related *A. formosana* (*c.* 30% of the numbers reared from *A. donax*), indicating that it is a marginal host. Very low numbers were reared on *Phragmites*, *Leptochloa* and *Spartina*. Indeed only a handful of males and no females were reared from *Phragmites*, while the numbers reared from *Leptochloa* and *Spartina* were *c.* 1% and 0.1% of the numbers reared from *A. donax*, indicating that these species are very poor hosts: Recent research that has investigated the predictive value of quantifying the relative performance of biocontrol agents on test and target plants during host-range testing indicates that *R. donacis* performance on *Spartina* and *Leptochloa*, relative to on *A. donax* was far below the threshold level that would predict host use in the field (Paynter *et al.* in press.). Moreover, field tests conducted in Europe confirmed that *Spartina* and *Leptochloa* were not hosts of *R. donacis* under field conditions. Goolsby and Moran (2009) concluded that *R. donacis* is specific to plants in the genus *Arundo* under field conditions.

**Summary of host-range testing results and field records in relation to plant species of importance in the Cook Islands**

*Rhizaspidiotus donacis* does not pose a threat to valued native or exotic plants in the Cook Islands: *R. donacis* is specific to the genus *Arundo* under field conditions and, with the exception of *Arundo donax*, there are no native representatives and no other introduced species that belong to this genus (or indeed the subfamily Arundinoideae) that occur in the Cook Islands.

## 2.3 ALTERNATIVE CONTROL OPTIONS

### 2.3.1 NO CONTROL.

If *A. donax* is not controlled, its negative impacts will undoubtedly persist and potentially increase as it continues to invade new areas.

### 2.3.2 CHEMICAL CONTROL.

The use of systemic herbicides such as glyphosate or fluazipop applied after flowering either as a cut stump treatment or foliar spray have been found to control giant reed (http://www.issg.org/database/species/ecology.asp?si=112). However, use of herbicides near to streams (where giant reed commonly grows) risks negative impacts due to herbicide run-off.

### 2.3.3 MECHANICAL CONTROL AND FIRE.

Mechanical control can be done, but is extremely difficult because every piece of rhizome must be removed and root masses can be more than 1 m thick (http://www.issg.org/database/species/ecology.asp?si=112&fr=1&sts=&lang=EN).

Fire temporarily clears giant reed, but the rhizomes survive fire and rapidly grow back. Burning is, therefore, not recommended as it has been demonstrated to aid the growth of giant reed because it can regrow faster than competing plants after fire (http://www.issg.org/database/species/ecology.asp?si=112).

### 2.3.4 OTHER BIOLOGICAL CONTROL OPTIONS.

No other biological control agent species are currently available.

# 3. Environmental consequences

It is unlikely that the introduction of *T. romana* and *R. donacis* could be reversed. It is, therefore, important to determine the potential environmental consequences of its introduction.

- No action will result in continued invasion and a range of negative impacts such as costs to agriculture, water pollution (e.g. herbicide run-off), native species, medicinal plants and aesthetic values.
- Chemical and mechanical control are labour intensive and time consuming.
- Biocontrol, if successful, is unlikely to produce instantaneous results and will more likely result in a gradual reduction in plant vigour and competitiveness, by slowly draining plant resources and reducing the production of new ramets. For example, *A. donax* biomass has declined by 20-50% in five years following the introduction of *R. donacis* (J. Goolsby, personal communication).
- Permanent reductions in *A. donax* biomass could result in replacement by other invasive species (but note that the current MFAT-funded project will target other major weed species such as *M. micrantha* that have the greatest potential to replace *A. donax*).

## 3.1 UNCERTAINTIES

**Risk of non-target attack:**

Non-target impacts of weed biological control are very rare: The vast majority of agents introduced for classical biological control of weeds (>99% of 512 agents released) have had no known significant adverse effects on non-target plants thus far (Suckling & Sforza 2014). Moreover, the few cases where significant non-target attack has occurred (e.g. *Rhinocyllus conicus* on native thistles *Cactoblastic cactorum* on native cacti) were predictable from host-range testing and these introductions would not be permitted today (Suckling & Sforza 2014). The host-range testing and field surveys conducted on *T. romana* and *R. donacis* indicate that both species are specific to the genus *Arundo* and the risk of significant unanticipated non-target attack is therefore minimal.

## 3.2 PROPOSED PROTOCOL FOR INTRODUCTION OF *T. ROMANA* AND *R. DONACIS*

Infested plant material with will be imported from the USA[1] into the Landcare Research Beever Pathogen Containment Facility in Auckland, New Zealand (note Landcare Research has all the necessary permits to propagate arthropod weed biocontrol agents into the Beever Containment Facility). In Auckland, Landcare Research staff shall:

1. Inoculate potted *A. donax* plants in containment in New Zealand;
2. Eliminate any sources of contamination (e.g. parasitoids) that may be present;
3. Consult with insect systematists based at Landcare Research to ensure the agents have been correctly identified;

Once the agents have been formally identified and determined to be free from any contaminants they will be shipped to the Cook Islands for mass-rearing field release (see below) by air, in sealed containers within a sealed box.

4. Mass-rearing will be done in shade house conditions by Cook Islands Ministry of Agriculture staff (with the assistance of a Landcare Research entomologist, who will travel on the same flight as the shipment), prior to field releases.
5. Monitoring plots will be set up to assess impacts of *T. romana* and *R. donacis* in the Cook Islands.

[1]Note permission is not required from US Authorities to export *T. romana* and *R. donacis* from the USA to New Zealand.

**Procedure for field release and monitoring.**

Field releases and monitoring will be done by Cook Islands Ministry of Agriculture staff, with assistance from Landcare Research staff (who will accompany the first shipment of *P. xanthii* and make regular (annual) visits to assist monitoring and data analysis and train Cook Islands Ministry of Agriculture staff).

1. *Arundo donax* plants will be propagated by the Cook Islands Ministry of Agriculture approximately 4-5 weeks prior to importation of *T. romana* and *R. donacis*.
2. These plants will be inoculated with *T. romana* and *R. donacis*, using the techniques described by Goolsby and Moran (2009) and Goolsby *et al.* (2009).
3. The infected plants will be planted out among *A. donax* infestations in Rarotonga.
4. Culture of *T. romana* and *R. donacis* will be maintained by Cook Islands Ministry of Agriculture staff in case further releases are required to ensure their establishment.
5. Monitoring will be done on a hierarchical basis. Initially, signs of establishment will be looked for by visually searching for *T. romana* and *R. donacis* on *A. donax* plants growing near to the release sites. If establishment is confirmed, then regular searches will be conducted along transects from the release site to investigate the rate of spread and permanent quadrats will be set up to investigate the impact of *T. romana* and *R. donacis* on *A. donax* over time.

**Summary of roles and responsibilities**

Landcare Research will process the pathogen through the Landcare Research Beever Pathogen Containment Facility in Auckland, New Zealand, ensuring that:

(1) All relevant permits are obtained;
(2) That the pathogen to be shipped to the Cook Islands has been correctly identified and is free from contaminants.

Landcare Research will accompany the first shipment and assist/train Cook Islands Ministry of Agriculture Staff in how to mass-rear the fungus.

Landcare Research staff will assist/train Cook Islands Ministry of Agriculture Staff in how to set up monitoring plots to observe the spread and impacts of the pathogen.

The Cook Islands Ministry of Agriculture shall mass-rear the pathogen, carry out releases and conduct regular monitoring of its impacts, with assistance from farmers and other landowners who are willing to provide release and monitoring sites. The Cook Islands Ministry of Agriculture, together with Landcare Research, shall ensure that the general public is made aware of the project, through media releases and public consultation.

The National Environment Service is responsible for ensuring that the EIA is followed as described within this document.

The Technical Advisory Group, which consists of representatives from Landcare Research; Cook Islands Ministry of Agriculture; Cook Islands Natural Heritage Project; and the Cook Islands National Environment Service will help coordinate biocontrol release and monitoring activities and deal with operational problems that may arise

**Areas where releases will be made**

Release sites on Rarotonga will be selected by the Cook Islands Ministry of Agriculture, in consultation with the Technical Advisory Group, if required. It is anticipated that releases will commence within two months after the Environmental Impact Assessment permit has been granted.

## 3.3 EDUCATION AND AWARENESS

It is recommended that some form of education and awareness programme be undertaken prior to and during the release of *T. romana* and *R. donacis*, awareness beyond just the EIA to inform the public of the Ministry's intent to introduce. Education is more so important to inform the public of the expected impacts on *A. donax*, the expected consequences, a request not to tamper, destroy or export inoculated plants from the release sites. Although EIA are advertised in stores, libraries and online and notification of the availability of EIA for viewing is made in local papers, not everybody actually picks up and reads an EIA

To this end, the weed biocontrol project against *A. donax* and other major weeds in the Cook Islands has been publicised on Cook Islands Radio, Television and in the Cook Islands News.

News articles can be seen here:

*http://www.cookislandsnews.com/item/46267-biological-agents-to-control-weeds/46267-biological-agents-to-control-weeds*

and here:

*http://www.cookislandsnews.com/item/12777-weeds-list-highlights-biological-control/12777-weeds-list-highlights-biological-control*

A video of a television article regarding the selection of plant targets for biological control is available here: http://www.youtube.com/watch?v=v1F8Bw2z3CE, but a more recent television and radio interview is unavailable to the author.

Further press releases are planned to coincide with the release of the EIA and (assuming the release is approved) the subsequent release of *T. romana* and *R. donacis* in the Cook Islands.

## 3.4 ECONOMIC CONSIDERATIONS

No formal cost-benefit analysis has been done for the introduction of *T. romana* and *R. donacis* in the Cook Islands because economic data regarding the cost of *A. donax* (control costs and lost production) are lacking.

Agriculture accounts for 5.1% of the Cook Islands GDP (Anon 2013). Although there is little published information on the impacts of weeds on agricultural production in the Cook Islands, data regarding herbicide usage are available. Herbicide use increased dramatically (>400%) over the 15 years from 1995-2009, yet concurrent production of the three main production crops dwindled, indicating that weed problems are worsening (Fig. 5). If the use of biological control can reduce the need for herbicide usage than this will result in economic benefits (reduced costs associated with purchasing and labour costs of applying herbicides) and environmental benefits through reduced herbicide run off.

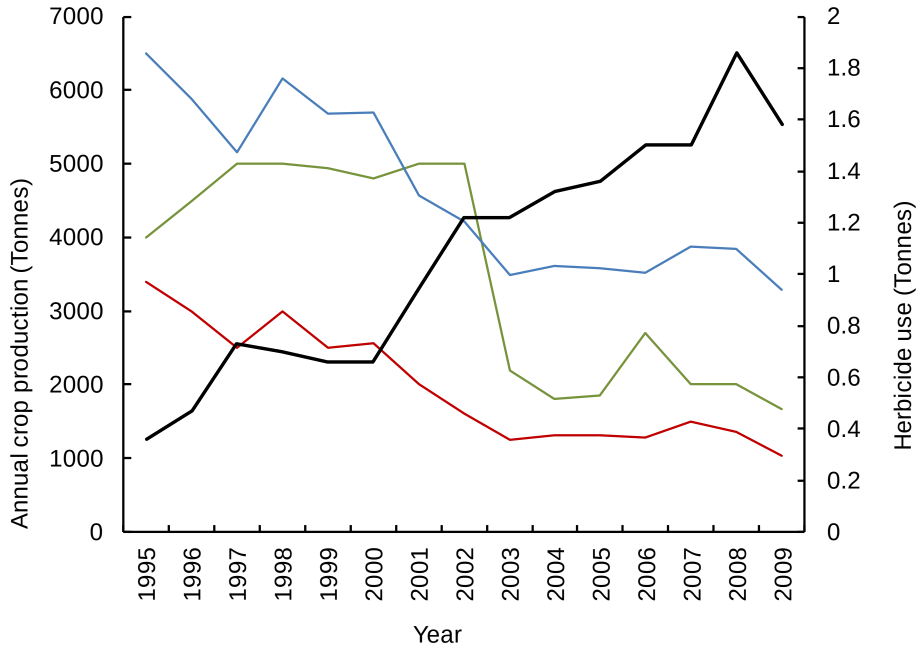


FIGURE 5. PRODUCTION OF THE THREE MAIN CROPS IN THE COOK ISLANDS: ROOTS AND TUBERS (BLUE LINE); COCONUTS (GREEN LINE); AND CASSAVA (RED LINE) AND HERBICIDE USE (BLACK LINE) IN THE FIFTEEN YEARS FROM 1995-2009 (DATA SOURCE: FAOSTAT: HTTP://FAOSTAT.FAO.ORG/SITE/424/DEFAULT.ASPX#ANCOR).

Moreover, in other countries, *A. donax* has been shown to reduce water availability (Seawright *et al.* 2009). Hajkowicz and Okotai (2005) noted that the watersheds of the Cook Islands provide residents and visitors with a wide range of environmental services such as drinking water supplies, natural filtration of freshwater runoff, recreational opportunities and scenery. While important, the value of these services is not readily apparent in economic terms. This means they can easily be overlooked in decision making and policy formulation. There is a pressing need to better understand the economic value of the nation's watersheds to raise awareness and inform investment and regulatory decisions.

The Rarotongan water supply comes from just 12 stream water intakes (Anon 2013) and *A. donax* is invading stream margins in Rarotonga, so it is a potentially serious threat to the Rarotongan water supply.

# 4. Conclusions

*Arundo donax* is a major weed on Rarotonga and successful biocontrol will not only reduce the impacts where *A. donax* is already abundant, but has the potential to reduce the risk of invasion of islands that are currently free of *A. donax*.

The risks of conducting biocontrol using *T. romana* and *R. donacis* are minor, compared to the potential benefits.

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