

Biological Control of Invasive Weeds

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25/5/16

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KNOWLEDGE FOR LIFE

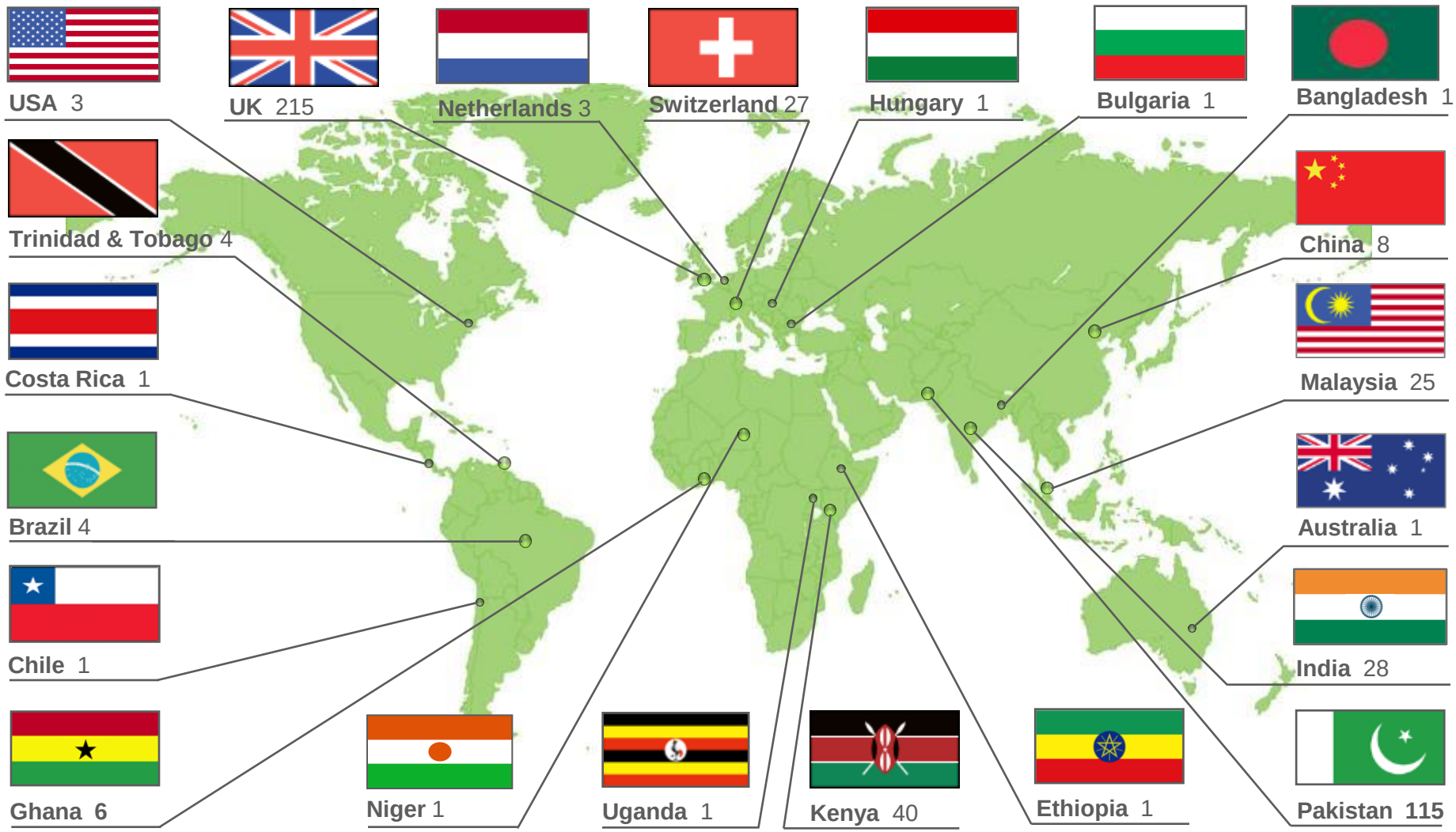
Overview

- About CABI
- Invasive Species
- Biological Control
- Mycoherbicides
- Classical Biological Control
- Railway weeds as targets

About CABI

- Established in **1910** 'Commonwealth Agricultural Bureau' now operates as simply 'CABI'
- CABI is a **not-for-profit** science-based development and information organization
- Owned by **48** member countries
- CABI specialises in **agriculture** and the **environment**
- Activities and expertise include:
  - Scientific publishing
  - Research and project delivery
  - Consultancy and science communication

Global reach We have 480+ staff across 21 locations worldwide



We work on behalf of 48 member countries

* UK Overseas Territories. **Associate Member

our activities

Publishing

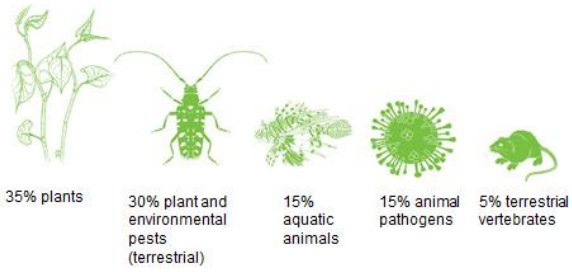
CABI publishes **high quality scientific resources** within the applied life sciences:

- bibliographic databases, including CAB Abstracts and Global Health
- full text electronic resources
- multimedia compendia
- books and eBooks

Invasive Species Compendium

http://www.cabi.org/ISC

- An encyclopaedic reference tool of invasive plants and animals
- Over **1,500** datasheets
- Bibliographic database of nearly **75,000** records
- Extensive glossary, a taxonomic framework and access to statistics
- Library of over **1000** full text documents and links
- **Open Access** **model**



our activities

Microbial Services

CABI offers a range of professional microbial services:

- microorganism supply
- testing and consultancy services
- microbiological identifications
- preservation & patenting
- collection screening

our activities

International Development

CABI researches and finds solutions to agricultural and environmental problems:

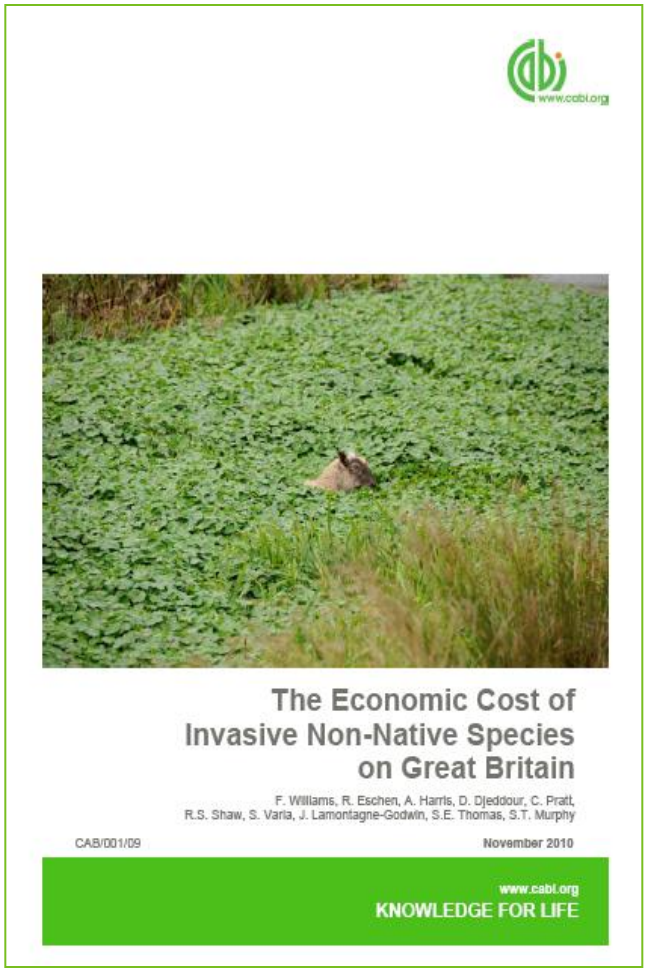
- improving food security to help alleviate poverty
- improving access to agricultural and scientific knowledge
- supporting farmers through training and advice on good agricultural practice
- protecting biodiversity by managing pests and diseases

The UK Invasive Weeds Team

Invasive Weeds

- Invasive weeds are those that are not native to a specific location (an introduced species), and which have a tendency to spread to a degree that cause damage to the environment, human economy or human health
- Can also be referred to as non-indigenous, alien or exotic plant species
- Non-native plant species arrived in the exotic range without the natural enemies that keep them in check in their native range
- Those native species which do attack them do not cause enough damage
- Some of the many insects and diseases in the native range may be safely released as biological control agents

Economic assessment for GB



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Biological Control

The use of natural enemies to provide environmentally sound pest (weed) control thereby reducing the need for chemicals.

2 main approaches

Inundative

The mass production and periodic release of large numbers of biocontrol agents to control a pest (often as a mycoherbicide).

Classical (CBC)

The utilisation of co-evolved natural enemies from the centre of origin of the pest (weed) to provide self-sustaining control after a single release.

The Inundative Approach

- Used in high value horticulture, agriculture, golf courses to reduce chemical input/ combat resistance
- Or where conflicts of interest would exclude classical biocontrol
- Better described as COMMERCIAL as applied like a chemical product from a bottle with a label and a user and is formulated

Mycoherbicides

- Fungus formulated and applied like a chemical herbicide
- Foliar or Stump
- Spot treatment applications without chemicals
- Active kill of plant not necessarily dependent on leaf area
- Stump treatment could be useful outside growing season
- Can be used near waterways
- Environmentally safe

Bioherbicide Products

(Landcare Research, New Zealand, 2008)

- Plant pathogens
- Began in 1940s
- *Fusarium oxysporum* against prickly pear in Hawaii
- In the 1950s, Russians developed *Alternaria cascutacidae* for the parasitic weed, Dodder
- Many products available today:

Where and When	Product and Pathogen	Target weed	Status
USA: 1960	*Acremonium diospyri*	Persimmon (*Diospyros virginiana*) trees in rangelands	Status unknown
China 1963	Lubao: *Colletotrichum gloeosporioides f. sp. cuscutae*	Dodder (*Cuscata* spp.) in soybeans	Probably still available
USA:1981	DeVine®: *Phytophthora palmivora*	Strangler vine (*Morrenia odorata*) in citrus orchards	Status unknown, may no longer be marketed
USA: 1982	Collego™: *Colletotrichum gloeosporioides f. sp. aeschynomene*	Northern joint vetch (*Aeschynomene virginica*) in rice & soybeans	Not produced or distributed since 2003, but rice producers are showing renewed interest
USA: 1983	CASST™: *Alternaria cassiae*	Sickle pod & coffee senna (*Cassia* spp.) in soybeans & peanuts	No longer available due to lack of commercial backing
USA: 1987	Dr BioSedge: *Puccinia canaliculata*	Yellow nutsedge (*Cyperus esculentus*) in soybeans, sugarcane, maize, potato & cotton	Product failed due to uneconomic production system & resistance in some weed biotypes, no longer available
Canada: 1992	BioMal®: *Colletotrichum gloeosporioides f. sp. Malvae*	Round-leaved mallow (*Malva pusilla*) in wheat, lentils & flax	No longer commercially available but made on request
South Africa: 1997	Stumpout™: *Cylindrobasidium leave*	Acacia species in native vegetation & water supplies	Still available for sale, though demand has declined due to lack of advertising. May be taken up by "Working for Water"
Netherlands: 1997	Biochon™: *Chondrostereum purpureum*	Woody weeds, e.g. black cherry (*Prunus serotina*) in plantation forests	Available until end of 2000. Marketing/production stopped due to low sales & regulatory concerns
Japan: 1997	Camperico™: *Xanthomonas campestris pv poae*	Turf grass (*Poa annua*) in golf courses	Probably commercially available
South Africa: 1999	Hakatak: *Colletotrichum acutatum*	*Hakea gummosis* & *H. sericea* in native vegetation	Never registered, but will be produced on request
USA: 2002	Woad Warrior: *Puccinia thlaspeos*	Dyers woad (*Isastis tinctoria*) in farms, rangeland, waste areas, & roadsides	Registered, but never commercially available due to lack of commercial backer. Once registered, the fungus was spread by researchers.
Canada: 2004	Chontrol™ = Ecoclear™: *Chondrostereum purpureum*	Alders, aspen & other hard-woods in rights of way & forests	Commercially available
Canada: 2004	Myco-Tech™ paste: *Chondrostereum purpureum*	Deciduous tree species in rights of way & forests	Commercially available
USA: 2005	Smolder: *Alternaria destruens*	Dodder species: in agriculture, dry bogs & ornamental nurseries	Only just registered. Company planning to do more field trials & then market it in 2007
Canada: 2007	Sarritor: *Sclerotinia minor*	Dandelion (*Taraxacum officinale*) in lawns/turf	Commercially available

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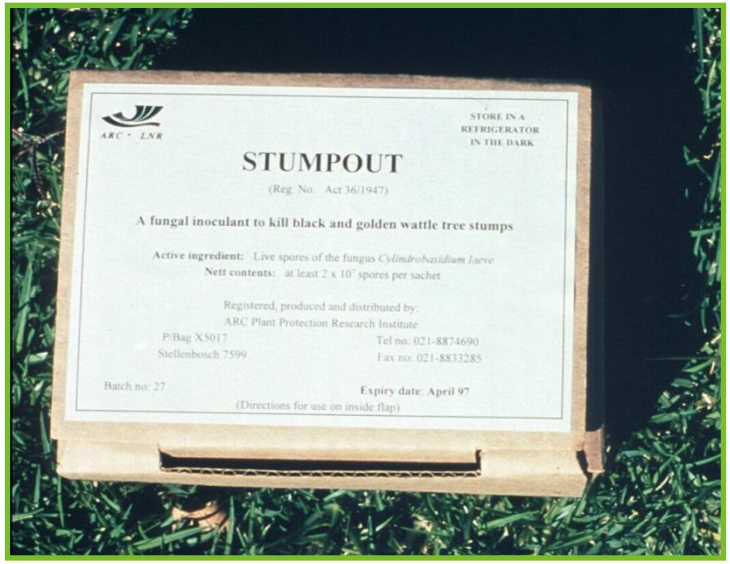
DeVine®

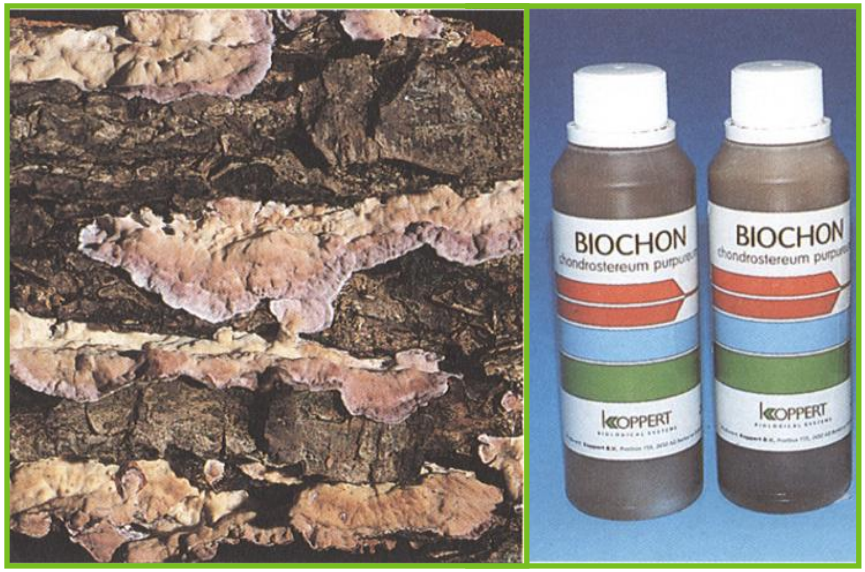
control of strangler vine in citrus groves in Florida



Stumpout™

control of Acacia species in native vegetation

South Africa



Biochon™

control of black cherry in plantation forests

Netherlands

Classical Biological Control

- Use of co-evolved, and highly specific natural enemies (insects, mites, pathogens) from the area of origin of the plant to provide self-sustaining control, often after a single release
- First insects were introduced against prickly pear in India nearly 200 years ago
- Some spectacular successes, returns on investment in research can be phenomenal
- International code of conduct, rigorous safety testing
- 12 examples of “non-target” effects – all but one predicted at the time or predictable by the science applied to day

- > 2000 releases globally, 224 weeds & 552 agents


Prickly pear with *Cactoblastis cactorum*

Rubber Vine with *Maravalia cryptostegiae*

Rail weeds as targets/Projects at CABI

- Japanese Knotweed
- Himalayan Balsam
- Rhododendron
- Buddleia

Japanese Knotweed

Fallopia japonica its native range in Japan


PRIVATE ROAD
NO PARKING
NO THROUGH

Biological control of Japanese Knotweed

- 12 year research programme
- Consortium funded
- Began with surveys in Japan which identified a number of potential candidates for biological control
- Test plant list >90spp
- Host specific psyllid - *Aphalara itadori*
- First phase field trials conducted in 2010
- 5 year monitoring and contingency programme - extended safety test with sub-optimal sites
- Regulatory pathway for UK/EU proven
- The suitability of the Mycosphaerella leaf-spot as biocontrol agent also being assessed

Aphalara itadori

Adult is 2mm

Nymphs do the damage

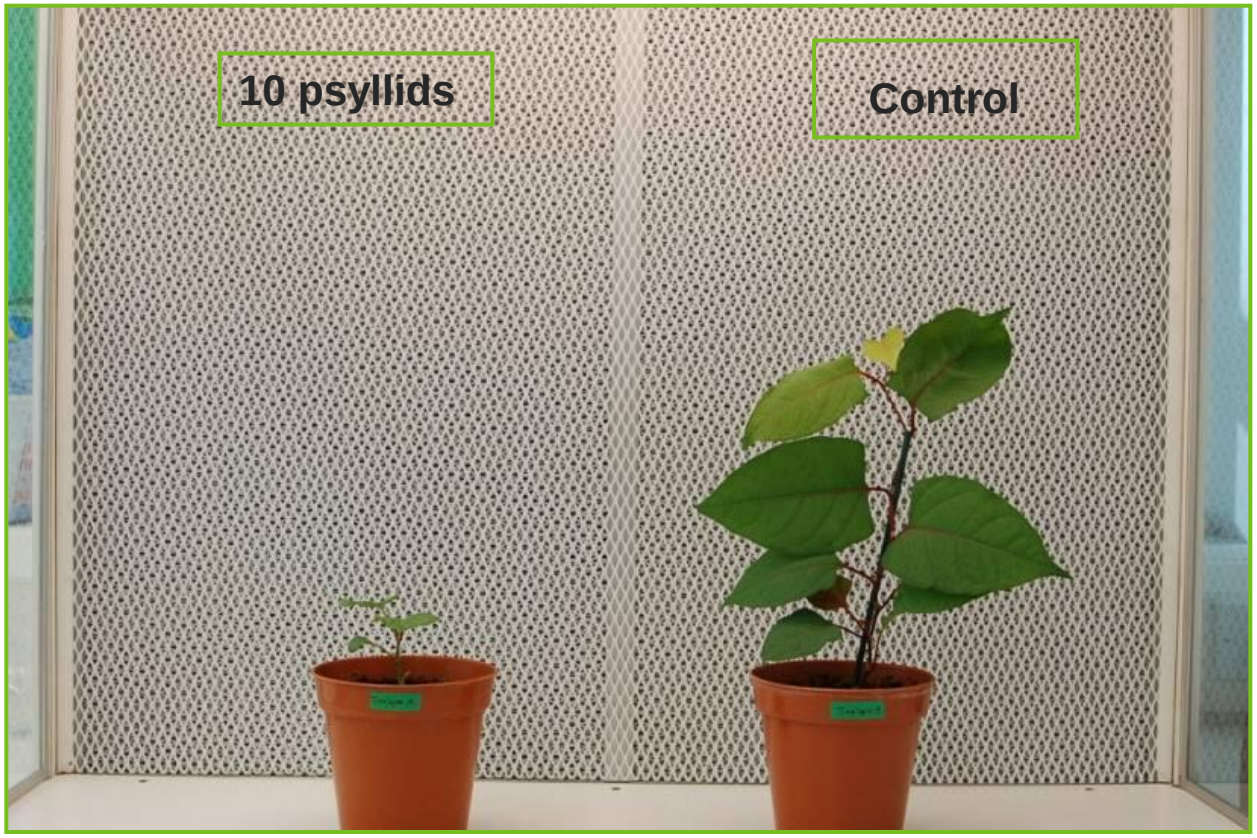

Aphalara itadori
nymphs

Impacts

High psyllid numbers can kill potted plants

Lower numbers limit growth

Should result in easier control/management



Mass Rearing

Insects reared and mass produced in cages before release

Monitoring plan for *A. itadori*

1. Determine whether the release of *A. itadori* has adverse impacts on the receiving environment:
   a. Non-target flora
   b. Invertebrate community
2. Identify overwintering habitat of *A. itadori*
3. Determine the efficacy of *A. itadori* as biocontrol agent for JK

5-year monitoring study initially very intense, later less so

Release & Monitoring

- **2014-**Studies to ensure no secondary impacts on native flora / fauna took place
- **2015/2016-**Releases made at humid riverine sites to aid establishment

Mycosphaerella polygoni-cuspidati

Leaf-spot infection,
CABI quarantine.

Japanese Knotweed Leaf Spot

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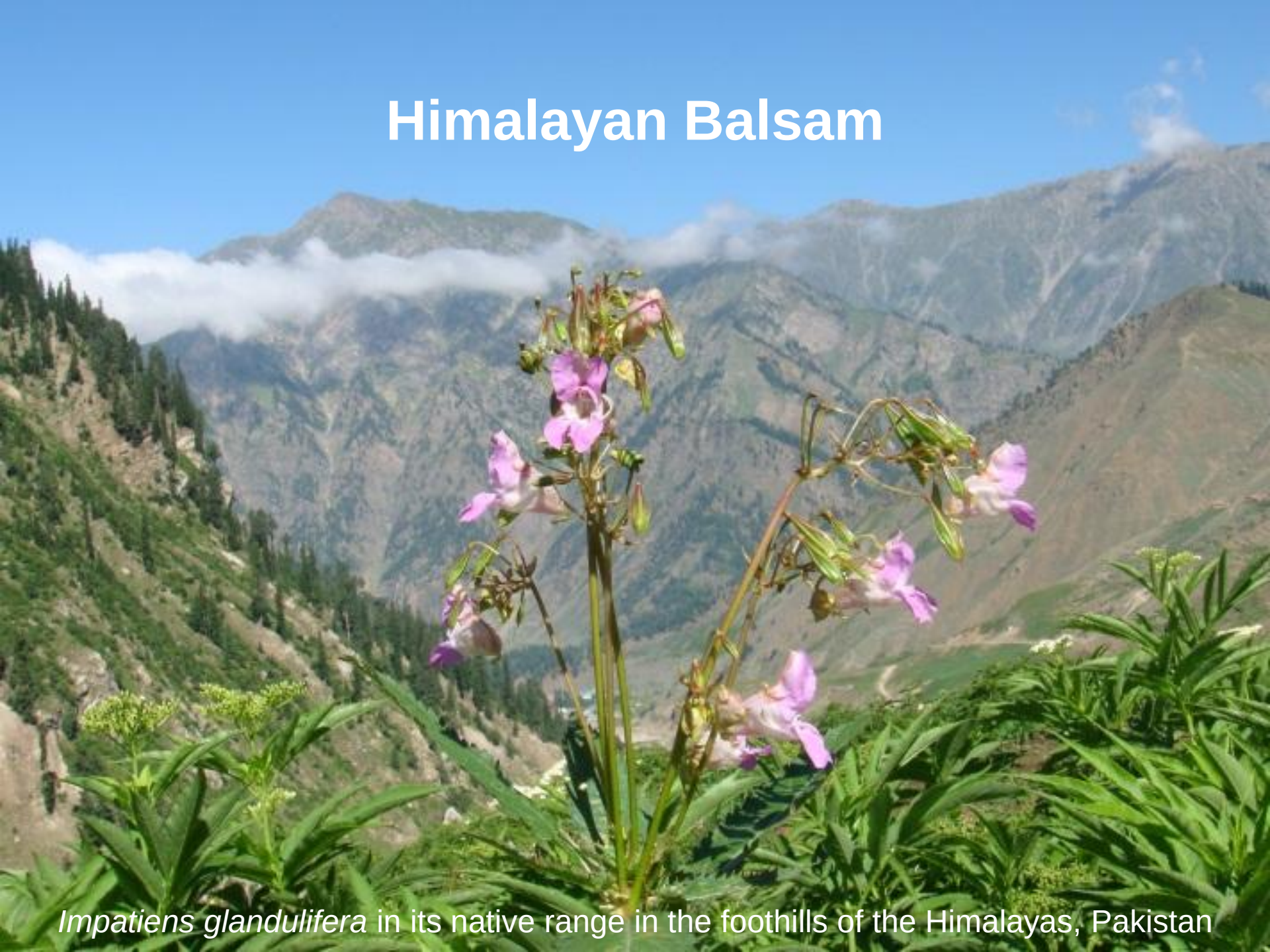
Research conducted in two phase

- First phase 2003-2010
- Second phase 2012-2014

- Infection parameters determined, biology studied
- Incidence/disease severity in the field documented
- 72 non-target species assessed in host-range testing
- PRA to be completed
- Possibility of using as a mycoherbicide
- Patent applied for, owned by Government in the name of the Secretary of State

Himalayan Balsam

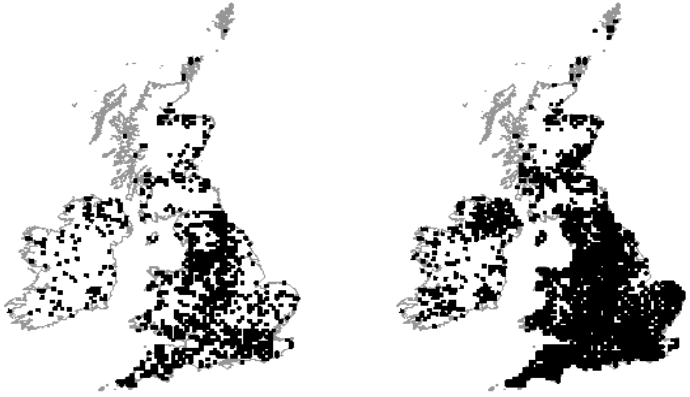


Impatiens glandulifera in its native range in the foothills of the Himalayas, Pakistan

Biocontrol of Himalayan balsam

Himalayan Balsam

- Native to foothillls of Himalayas (from north-west Pakistan to Northern India)
- First introduced into the UK in 1839
- Introduced into much of Europe, Canada, USA and New Zealand
- Predominantly a weed of riparian systems (also invades woodlands and meadows and disturbed site)

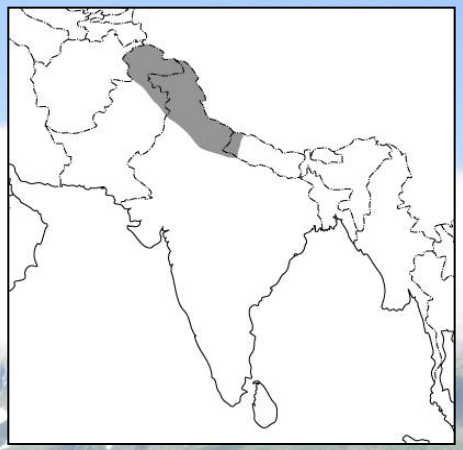


1950 2014

Impacts of Himalayan balsam

- Can reduce species richness by 25% (Hulme and Bremner, 2006)
- Himalayan balsam competes for space and light resources
- Reduces tree recruitment in wooded habitats
- Negative impact on pollination of native plants (Beans and Roach, 2015)
- Killed by winter frost which can lead to erosion of banks and can increase the amount of sediment in watercourses

Surveys for natural enemies



Biocontrol Candidates


Puccinia komarovii

Host Specificity Testing

Impatiens glandulifera

- Used to determine a biocontrol agent's host range
- Tested against 86 entries comprising 75 species
- Including: 25 natives, 42 ornamentals, 3 economically important, 3 introduced species.
- Economically important *Impatiens* species *Impatiens walleriana* and *Impatiens hawkeri* represented by additional cultivars
- *I. noli-tangere* represented by two distinct populations (Welsh plus Lake District)
- *Impatiens balsamina* susceptible to the rust

Impatiens glandulifera plants infected with *Puccinia komarovii* – pre-sporulation

Source of inoculum to be put out in the field

Rust release strategy

- The PRA was presented to the EC Standing Committee on Plant Health (SCPH) on the 26th June 2014 in Brussels – no objection to release of rust
- Accepted by FERA and DEFRA
- Defra Ministers approved the release
- The first fungal biocontrol agent released against a weed in Europe
- **Releases made in the UK in September 2014**
- Live Himalayan balsam plants pre-infected with urediniospores were planted in the ground at each release site and allowed to spread naturally by wind

Puccinia komarovii infection of *Impatiens glandulifera*

Brown powdery urediniospores bursting from the under surface of leaves

Rust release and establishment

- Limited releases in England in 2014/15:
- - confirm pathogenicity of the rust
  - develop release strategy
  - monitor establishment and spread
  - confirm overwintering capacity
- Limited spread so further research is ongoing to determine possible factors and releases are continuing at selected sites in 2016


Rhododendron ponticum

Rhododendron ponticum

- Rhododendron is invasive but also a source of inoculum of *Phytophthora ramorum and P. kernoviae* (Sudden Oak Death)
- CABI collaborated with Forest Research, UK and were involved in a field trial to compare the efficacy of a range of synthetic herbicides and a fungal biocontrol agent, *Chondrostereum purpureum* for preventing re-sprouting of *Rhododendron ponticum*
- Treatments were applied to cut rhododendron stumps in the summer and winter, and regrowth was evaluated 25 months after application.

Rhododendron ponticum

Table 1 Details of the experimental treatments

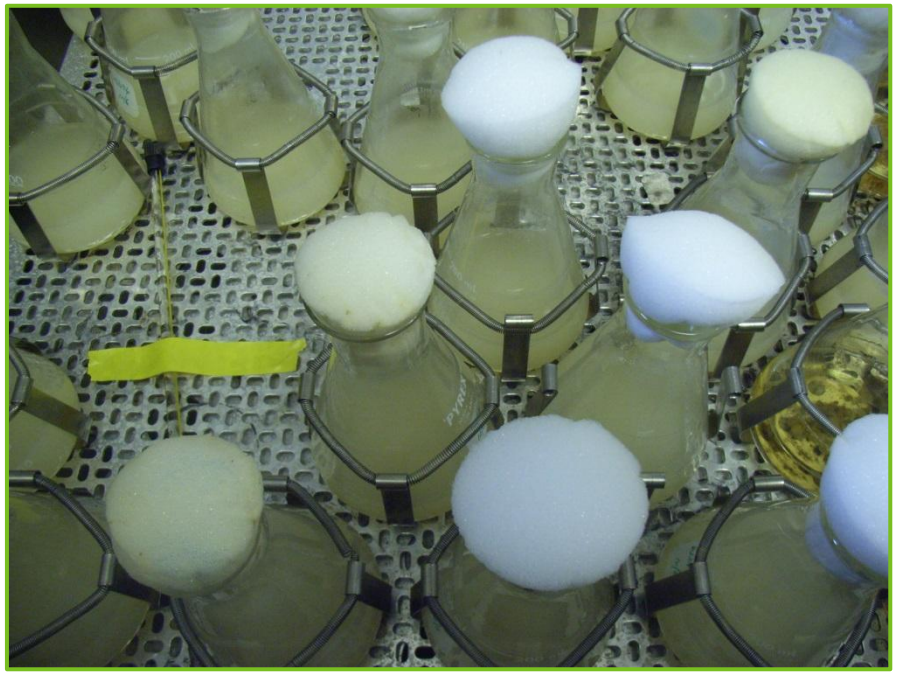
Treatment	Description
H0	Control (no treatment after cutting)
H1	Roundup Pro Biactive® (360 g l^{-1} glyphosate) as a 20% solution in water
H2	Tordon 22K® (240 g l^{-1} picloram) as a 2.5% solution in water
H3	Timbrel® (480 g l^{-1} triclopyr) as an 8% solution in water
H4	Timbrel® (480 g l^{-1} triclopyr) applied undiluted
H5	Roundup Pro Biactive® (360 g l^{-1} glyphosate) as a 20% solution plus growing medium only for experimental biocontrol agent (i.e. no *Chondrostereum purpureum* present)[a,b]
H6	Roundup Pro Biactive® (360 g l^{-1} glyphosate) as a 20% solution, plus experimental biocontrol agent (*C. purpureum* comprising mycelia concentration of 10^5 colony forming units (CFU) per ml of diluted growing medium/carrier)[a]
H7	Diluted growing medium only for experimental biocontrol agent (i.e. no *C. purpureum present*)[a,b]
H8	Experimental biocontrol agent (*C. purpureum* comprising mycelia concentration of 10^5 colony forming units (CFU) per ml of growing medium/carrier)[a]
H9	Roundup Pro Biactive® (360 g l^{-1} glyphosate) as a 20% solution, plus experimental biocontrol agent (*C. purpureum* comprising mycelia concentration of 10^5 colony forming units (CFU) per ml of growing medium/carrier)[a]. Applications were made immediately after cutting, to stumps cut from full size plants on the day of treatment

- Height of the tallest regrowth stem per plant
- The number of stools with live regrowth
- Fresh weight of the stem regrowth

Chondrostereum purpureum

Biological stump treatment using basidiomycete white-rot fungus

Fungus was mass produced in the laboratory and applied like a chemical in the field



Results

- Application of a 20% solution of Roundup Pro Biactive ® (360 g l^{-1} glyphosate; Monsanto) or an equivalent approved glyphosate product, immediately after cutting to rhododendron stumps is an effective and cheap means of preventing regrowth, and hence reduces the risk of subsequent re-infection from *P. ramorum* and *P. kernoviae*

- Foliar sprays are likely to be most effective when made from July to September

- The use of *C. purpureum* as a biocontrol agent was not effective in this study. However, it is possible that refinement of the pathogen application, by applying immediately after cutting, developing a suitable formulation and/or employing a more suitable application technique as well as improved isolate selection will result in improved results

Rhododendron ponticum

Willoughby, IH, Seier, MK, Stokes, VJ, Thomas, SE and Varia, S. (2015) Synthetic herbicides were more effective than a bioherbicide based on *Chondrostereum purpureum* in reducing resprouting of *Rhododendron ponticum*, a host of *Phytophthora ramorum* in the UK. Forestry, 88, 336–344.


Buddleja davidii

Biocontrol of Buddleia

- Conflict of interest – good source of nectar to butterflies and moths / structural problems for railways and buildings
- CBC used in NZ – leaf feeding weevil (*Cleopus japonicus*) not for UK
- Released in New Zealand in 2006 as a biological control agent for the weed

Buddleia pathogens- potential for use of native wood rotting fungus *Chondrostereum purpureum*

Geranium robertianum

Herb Robert

- Native annual/biennial plant
- Routinely sprayed with herbicides – resistance?
- No suitable native insects found
- Genus specific fungi present in the UK
  - *Ramularia geranii*
  - *Septoria geranii*
  - *Uromyces geranii*
  - *Venturia geranii*
  - *Coleroa robertiani*
  - *Plasmopara pusilla*
  - *Podosphaera* spp.

In Summary

- Biological control is a tried and tested approach to some of the worst weeds in the world
- It has a very good safety record and any non-target attack is predictable- social and political priorities play a role
- Efficacy is harder to predict- biotic and abiotic complexities
- The political, regulatory and consumer drivers mean that there should be a lot more classical biocontrol in Europe in future
- This tool cannot be ignored when considering species for inclusion in the list of spp of EU Concern re the Invasive Species Regulation*

***EU Regulation 1143/2014 on Invasive Alien Species**
Entered into force on 1 January 2015 and seeks to address the problem of invasive alien species in a comprehensive manner so as to protect native biodiversity and ecosystem services, as well as to minimize and mitigate the human health or economic impacts. Based on interventions; prevention, early detection and rapid eradication, and management.
A list of invasive alien species of Union concern will be drawn up and managed with Member States using risk assessments and scientific evidence.


waterwaysnet
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INTERREG IIIB
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FRANCE ESPACE ATLANTIQUE
IRELAND ATLANTIC AREA
PORTUGAL ESPAÇO ATLÂNTICO
U.K. ATLANTIC AREA


The Scottish Government
Riaghaltas na h-Alba


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Thank you


Forest Research


Royal Holloway
University of London


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