Proceedings of the XIV International Symposium on Biological Control of Weeds, pp 129-134. F.A.C. Impson, C.A. Kleinjan and J.H. Hoffmann (eds). 2-7 March 2014, Kruger National Park, South Africa.

Classical biocontrol of weeds in Europe - are we pushing against an open door?

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Abstract

In September 2013, the European Commission published a proposal for a Regulation on the prevention and management of the introduction and spread of invasive alien species. The proposal aims to address the threat of invasive alien species comprehensively, minimising and mitigating their impacts on human health and economies using three types of interventions: prevention; early warning and rapid response; and management. Importantly, the use of biological actions to achieve management is highlighted. There are currently over 12 000 alien species present in Europe and roughly 15% of these are invasive. The proposal draws on the European Union's (EU) 'Resource Efficiency Roadmap' and the EU 'Biodiversity Strategy to 2020' and centres around a black list of invasive alien species of EU concern and is drawn up with Member States using risk assessments and scientific evidence. Unlike some of its trading partners however, the EU currently lacks a comprehensive framework to address the threats posed by invasive alien species. To date there has only been one release of a biological control agent against a weed in Europe, although member countries have been the source for many agents used across the world. In this presentation we review weed biocontrol progress in Europe, the challenges faced and the new, exciting opportunities in the light of these recent regulatory changes, with an evaluation of the most suitable targets for future biocontrol efforts.

1. Introduction

Europe has been the source of many of the world's worst invasive plant species and consequently, the continent has also supplied many of the potential solutions in the form of over 500 weed biological control agents released worldwide. To date, the EU (excluding overseas territories) has been the official recipient of only one weed biocontrol agent, the Japanese knotweed psyllid *Aphalara itadori* Shinji (Hemiptera: Psyllidae) released in the UK in 2010 (Shaw *et al.*, 2011).

Despite the dramatic increase in scale and impacts of alien plant invasions across the continent in the last 200 years, as well as the associated and growing threat posed to native biodiversity, the severity of the impacts has only relatively recently come to be recognised in Europe. Ecological and economic costs of invasive alien species (IAS) are still poorly known in European States and only a few economic impact reviews have been published e.g. Germany (Reinhardt *et al*., 2003), Great Britain (Williams *et al.*, 2010), Ireland (Kelly *et al.,* 2013), the majority of which deal with direct costs (physical damage, management and restoration) incurred in the last twenty years. There have, however, been a number of large EU programmes aimed at tackling invasive species and all but a few Member States have some sort of national biodiversity or dedicated invasive species plan.

The actual costs of invasive plants in natural areas and their true environmental impacts -both direct and indirect - have only been crudely evaluated from a handful of known cases, and economic impacts are only available for about 10 percent of invasive species already in Europe (Vilà *et al.*, 2010). As a taxonomic group, plant species lead the way in terms of numbers invasive to some part of Europe, but crucially, almost half of these are native to some part of Europe.

Although it has taken ten years to develop a dedicated strategy on invasive species, there is now a groundswell of interest in the EU on the invasive species issue and, importantly, the winds of change are blowing, with classical biological control becoming more widely recognised as a viable and safe (Suckling and Sforza, 2014) management solution. This paper aims to briefly review the historical and current political drivers at play in the battle against invasive species in the EU, as well as reflect on the opportunities for biological control in the light of current research and the unintentional but successful cases in some Member States.

2. Political drivers

Various EU regulations and Directives cover plants, animals, diseases but few of these address IAS specifically or comprehensively. The impetus to tackle IAS in Europe began in the early 2000s with a proposed pan-European strategy which encouraged all member states to prepare draft and action plans. But while member states did begin taking a number of measures to tackle IAS, these remained predominantly reactive, fragmented and poorly coordinated, with relatively little attention paid to action. In 2003, the 'European Strategy on Invasive Alien Species' was adopted under the Bern Convention (Genovesi and Shine, 2004) The Strategy offered advice on measures to prevent unwanted introductions and tackle IAS. As signatories to the Convention on Biological Diversity, EU

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member states have an obligation to 'prevent the introduction of, to control, or eradicate, those alien species which threaten ecosystems, habitats and species' (Decision VI/23 in 1992). In 2006, further commitment was made to develop an EU wide strategy and from this point on, a vast number of communications between member states and stakeholders, technical support documents and consultations were instigated.

In addition, the EU has funded a raft of programmes through earmarked environmental funds (e.g. LIFE, Framework 6 & 7, etc.) and supported substantial research investments to improve and consolidate the IAS knowledge base (e.g. DAISIE[1]), as well as promoted European cooperation on research (e.g. COST[2]), various risk analysis and decision support schemes (e.g. ALARM[3], IMPASSE[4], PRATIQUE[5], BACCARA[6]). Invasive alien species continued to have low visibility in the EU outside specialist circles and it was recognised that, given the continental scale of the problems and Europe's numerous land borders and shared ecosystems, unilateral approaches would be largely inefficient and cost-ineffective.

Recognising the lack of joined up information, the European Commission's Joint Research Centre (JRC) launched the European Alien Species Information Network (EASIN) in 2012 with a stated aim to "facilitate the exploration of existing alien species information from distributed sources through a network of interoperable web services, and to assist the implementation of European policies on biological invasions" (Katsanevakis *et al.,* 2012).

Finally, after considerable expert consultation, in September 2013 a draft EU regulation on IAS was published by the European Commission. Since the beginning of 2014, the European Parliament and the Council have negotiated the details and after many months of often turbulent discussions, a compromise text was finally agreed and approved in March 2014 and subsequently endorsed by the Parliament and Council of Ministers in April of the same year. At the time of writing, the legislation still needs to be formally approved by the Council of Ministers but this should be a simple step. The Regulation, which should come into force in 2016, finally provides legislative substance for key intervention in the EU in the form of: prevention, early warning and rapid response and, more importantly, management of established invasive species, including biological control of any kind. The Regulation also provides crucial backing for member states to adopt national level measures (including new legislation) to complement the action at EU level and, as such, provides a much more pervasive and wide reaching framework for targeted IAS action than the benchmark prevention biosecurity systems employed in Australia and New Zealand, for instance (Fera, 2013).

The Regulation as it now stands is not without its challenges and the practicalities of implementation will need a great deal of fine-tuning. For example, details of the risk assessment procedure for the determination of the all-important list of IAS of EU concern have yet to be clarified. Perhaps more importantly, there has been no mention of associated financial support to MS.

A number of compromises were made during the negotiation period which served to weaken somewhat the impact of the originally proposed Regulation; these included the caveat of national derogations for certain species with socio-economic value. However, the identification of IAS of Union concern remains principally based on biodiversity and environmental considerations and any exemptions to EU level restriction must be accompanied by stringent contingency and eradication clauses, with a greater emphasis on the negative socio-economic impacts of species for any pest risk assessment (PRA) processes. Nevertheless, there were also some improvements, such as the removal of the arbitrary and scientifically-unjustifiable cap of 50 species which was central to earlier drafts. The Commission will also hold power to legislate and implement directly on species of regional concern and when large intractable weed problems come to be considered, classical biological control may offer the only viable solution.

In spite of the political and cultural differences across such a diverse continent - and after many amendments, compromises and negotiations - the final text for the Regulation provides an eagerly anticipated and much needed framework for coordinated policy against IAS at the EU level which, hopefully, should provide the opportunity for weed biocontrol to flourish. That being said, a general ignorance of the potential and in some cases of the existence of biocontrol, may mean that member states are persuaded to ignore the most difficult and infamous targets because they are deemed uncontrollable or prohibitively expensive to deal with.

3. Weed Biocontrol in Europe

Classical weed biocontrol in Europe is still in its infancy. The Japanese knotweed psyllid, *A. itadori*, released in 2010 against *Fallopia japonica* (Houtt.) Ronse Decr. (Polygonaceae) in the UK was the first official release of an exotic insect against a weed in continental Europe despite Europe's role as a donor of more than 500 agents worldwide (Suckling and Sforza, 2014).

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[1] Delivering Alien Invasive Species Inventories for Europe (http://www.europe-aliens.org/)

[2] European Cooperation in Science and Technology (http://www.cost.eu/)

[3] Assessing Large Scale Risks for biodiversity with tested Methods (http://www.alarmproject.net/alarm/)

[4] Environmental impacts of alien species in aquaculture (http://ec.europa.eu/research/fp6/ssp/impasse_en.htm)

[5] Enhancements of pest risk analysis techniques (https://secure.fera.defra.gov.uk/pratique/)

[6] Biodiversity and climate change, a risk analysis (http://www.baccara-project.eu/index.php)

Since then, and to satisfy the EU Water Framework Directive, funding has been provided by the UK Government to investigate the biological control of other priority aquatic/riparian weeds in the UK. In Portugal and Northern Ireland, international collaborative weed biocontrol programmes have been initiated to target intractable problems. Sheppard *et al.*, (2006) prioritised the top 20 exotic plant species for Western Europe for CBC based on a number of key acceptance criteria and, of these, 11 have been the subject of funded research, alongside the other nine still under consideration; the following section reviews the current status of weed biocontrol projects relevant to Europe.

3.1. Fallopia japonica – Japanese knotweed

This weed is probably the most notorious in Europe, particularly so in the UK where its ability to invade urban situations and to devalue properties is infamous. The CABI biocontrol project began in earnest in 2003 after previous surveys suggested a wide range of natural enemies were present in Japan. In the end, 186 arthropod and more than 40 fungal species were identified as damaging the plant in its native range and two agents, *Aphalara itadori* and *Mycosphaerella polygoni-cuspidati* Hara (Capnodiales: Mycosphaerellaceae) were selected for complete host range screening against a test plant list of 90 species (Shaw *et al.*, 2009). At the end of the project funding cycle, the psyllid was prioritised and a PRA based on the EPPO template was performed. This was to provide the evidence for the UK Plant Health authorities to free it from the Plant Health Quarantine Licence under which it was being held. In parallel, an application was made under the Wildlife and Countryside Act to actually gain permission to release the organism into the wild. A review by the Advisory Committee on Releases to the Environment, followed by an independent peer review and a public consultation as well as opinions from the Chief Scientist, were considered before Ministerial approval was granted in 2009.

The release licence requires a contingency plan, believed to be the first of its kind for a classical weed agent, which means no riparian sites can be considered. There are also limits to the number of sites permitted (8) and on the total number of psyllids that can be released per year (100,000). Despite these limitations, initial results were encouraging with successful adult overwintering being observed at more than one site. Nonetheless, populations have not taken off as hoped and the current focus is on improving the chances of establishment.

The *Mycosphaerella* leafspot research was suspended whilst the psyllid application progressed but was restarted in 2012 with the goal of completing the host range testing and the submission of a PRA. This work is on-going but concerns have been raised about the specificity of the fungus, at least under quarantine conditions.

3.2. Impatiens glandulifera Arn. (Balsaminaceae) – Himalayan balsam

This fast growing, annual riparian weed from the Western Himalayas is invasive across most of Europe and has been shown to have a negative impact on native invertebrate populations (Tanner, 2012), as well as reducing plant biodiversity (Hulme and Bremner 2006). Biocontrol research was initiated in the UK by CABI in 2006, funded by several UK stakeholders and subsequently, under the WFD initiative, by the UK Government. A rust fungus collected from Himalayan balsam in India was prioritised for study, and imported under quarantine into the UK in 2010 and identified as *Puccinia komarovii sensu lato*. Tranzschel ex P.Syd. & Syd. (Pucciniales: Pucciniaceae). By virtue of its specificity to *I. glandulifera* in cross inoculation studies, however, it was proposed that the rust be renamed as a new variety, *Puccinia komarovii* var *glanduliferae* (Tanner and Ellison, 2014). Following comprehensive host specificity testing against 75 plant species, and an additional 11 varieties of three widely grown ornamental *Impatiens* species in the UK, a PRA was compiled and assessed by the Food and Environment Research Agency (Fera), followed by an independent peer review process and finally presented to the EU Standing Committee on Plant Health; the PRA was eventually approved at every stage and permission to release has now been granted by Government ministers in the UK. This is a pioneering project and will deliver the first release of a fungal pathogen as a classical biological control agent against a weed in Europe (Tanner and Ellison, 2014).

3.3. Hydrocotyle ranunculoides L.f. (Araliaceae) – Floating pennywort

This floating aquatic perennial is native to the Americas, but has established in northern Europe, particularly in the UK, Netherlands, Germany and Belgium (EPPO, 2006).

Research into the potential for biocontrol was initiated in 2006 and the South American weevil, *Listronotus elongatus* (Hustache) (Coleoptera: Curculionidae) was identified as a potential candidate and showed promise in initial host range studies (Cordo *et al*., 1982; Cabrera *et al*., 2013). In 2010, as part of the Water Framework Directive, the UK Government funded further research into the biocontrol of floating pennywort by CABI and the weevil remains a strong contender as host range studies progress following Ministerial export approval in 2013. A rust pathogen, *Puccinia hydrocotyles* (Mont.) Cooke (Pucciniales: Pucciniaceae) and the stem mining fly, *Eugaurax* sp. (Diptera: Chloropidae) are also under evaluation. The project aims to finish the host range studies by 2015 and the next step would be the preparation of a PRA for *L. elongatus* should it continue to prove suitably specific for release in the UK/Europe.

3.4. Crassula helmsii A.Berger (Crassulaceae) - Australian swamp stonecrop

Another project in the suite of DEFRA-funded WFD initiatives at CABI, which was initiated in 2010, the research into the biocontrol of this Australian plant has highlighted a number of interesting agents; host specificity testing is ongoing with three potential agents: the stem mining fly, *Hydrellia perplexa* Bock (Diptera: Ephydridae);

a fungal pathogen, *Colletotrichum* sp. (Sordariales: Glomerellaceae) and a mite, *Aculus* sp. (Acari: Eriophyidae).

The recent permissions to release a pathogen and an insect in the UK, should herald a new dawn in biocontrol for Europe and these projects, in various stages of testing, not only maintain the momentum for this, but also hold the potential for piggy-backing by other members states for Europe wide release.

3.5. Acacia longifolia (Andr.) Willd. (Fabaceae) – Long-leaved wattle

Biocontrol initiatives often rely on the use of "off-the-shelf" agents which have been successfully used elsewhere and such a strategy has been developed in Portugal where Australian *Acacia* spp. are widespread invasives. In South Africa, a bud-galling wasp, *Trichilogaster acaciaelongifoliae* (Froggatt) (Hymenoptera: Pteromalidae) has successfully been used against *A. longifolia* (Dennill *et al*., 1999), and was subsequently trialled in Portugal through collaboration between the Centre for Studies of Natural Resources, Environment and Society, Coimbra, Portugal and the University of Cape Town (Marchante *et al*., 2011*)*. Despite excellent field safety in South Africa, and complementary laboratory and climate data from Portugal, the Standing Committee on Plant Health requested further analysis of the risks to plant health that the release could pose in the EU. The application for release of the gall wasp is still under review by the Plant Health Panel at EFSA (European Food Safety Authority) and a tentative decision date of 2015 has been given.

3.6. Lagarosiphon major (Ridl.) Moss (Hydrocharitaceae) – Curly waterweed

A collaborative project between University College Dublin (UCD), Inland Fisheries Ireland (IFI) and Rhodes University (South Africa) began in 2008 to investigate the prospects for biocontrol of this South African submerged macrophyte. A leaf-mining fly, *Hydrellia lagarosiphon* Deeming (Diptera: Ephydridae) (Mangan and Baars, 2012) and a shoot-tip mining midge *Polypedium* sp. (Diptera: Chironomidae) imported from South Africa into the quarantine facilities at UCD for evaluation and life tables suggest good colonisation success of *H. lagarosiphon* in response to the probable continued spread of *L. major* in Ireland (Mangan and Baars, 2013). Host specificity studies have been initiated and preliminary results indicate that *L. major* is the preferred host plant but some *Potamogeton* species may sustain damage under confined conditions. Further experiments will need to be run to verify the significance of this potential non-target damage, and also to assess the suitability of the *Polypedium* fly (Earle *et al.*, 2013).

3.7. Rhododendron ponticum L. (Ericaceae)

A potentially controversial classical target given its horticultural importance and native status in Southern Europe (Evans, 2003), *R. ponticum* has been the subject of an inundative biocontrol programme in the UK using a cut-stump treatment with the wood-rotting basidiomycete fungus *Chondrostereum purpureum* (Pers.) Pouzar (Agaricales: Cyphellaceae) as a bioherbicide. The research was facilitated by the DEFRA Phytophthora Disease Management Programme and the UK Government and carried out by CABI and the Forestry Commission. This pathogen has been successfully used in parts of Europe (De Jong and Scheepens, 1982) and Canada (Becker *et al*,. 1999) to control re-sprouting in various woody invasive species. Field trials were conducted at experimental sites in the southwest of England in 2010 using a selected native strain of *C. purpureum*, applied either on its own or in combination with herbicides. Final results showed that although the application of *C. purpureum* had no significant impact on the assessed regrowth parameters of *R. ponticum* stumps, infection and colonization of some cut stumps had taken place. Results also indicated a potential synergistic effect of *C. purpureum* with glyphosate (Willoughby *et al*, 2014).

Whilst these ongoing projects reflect investment in the biological control of weeds in Europe and great potential for further releases, there are also examples of successful, albeit unintentional, classical weed biocontrol in action in Europe:

3.8. Azolla filiculoides Lamark (Azollaceae) – floating fairy fern

Azolla filiculoides is widespread in many European countries and has been the target of a very successful biocontrol programme in South Africa using the frond feeding weevil, *Stenopelmus rufinasus* Gyllenhal (Coleoptera: Curculionidae) (McConnachie *et al.*, 2000). This weevil is also commonly associated with the weed wherever it is present in Europe and is likely to have been introduced either as a stowaway on *A. filiculoides* imported as an ornamental or by migratory waterfowl (Janson, 1921). In Great Britain, CABI has established a successful initiative (www.azollacontrol.com) rearing and redistributing the weevil to sites infested with *A. filiculoides*, with no restrictions on movement of the weevil due to its status as 'ordinarily resident' having been first identified in Britain in 1921 (Janson, 1921). The weevil has been shown to have a dramatic effect on Azolla, often resulting in local eradication of the weed. Between 2011 and 2012, The Netherlands Stichting Toegepast Onderzoek Waterbeheer (STOWA) funded a pilot project led by CABI to locate and identify *S. rufinasus* in The Netherlands and investigate the potential for its mass rearing and release in the country to control *A. filiculoides*. In addition, under a current European Commission Interreg 2 Seas-Programme funded project entitled 'Reducing the Impact of Non-native Species in Europe (RINSE)', CABI aims to conduct further demonstration trials of *S. rufinasus* on *A. filiculoides* in England, France, Belgium and The Netherlands to investigate the potential to rear and redistribute the weevil in mainland Europe for the treatment of Azolla infestations.

3.9. Ambrosia artemisiifolia L. (Asteraceae) – Common Ragweed

The North American ragweed leaf beetle, *Ophraella communa*, LeSage (Coleoptera: Chrysomelidae) was found causing extensive damage to the invasive alien plant *A. artemisiifolia* in Europe, south of the Alps, at more than 130 sites in southern Switzerland (Ticino) and northern Italy (Lombardia, Piemonte and Emilia-Romagna) (Müller-Schärer *et al.*, 2014). This oligophagous beetle has successfully been released against *A. artemisiifolia* in China, although the risk of attack and the level of damage to sunflower under field conditions remain unclear. Whether this unintentional introduction proves to have unwanted consequences, or whether it becomes the first case of a successful sustainable biological control of an invasive weed in continental Europe, is currently being investigated by the recently launched COST Action on 'Sustainable Management of *Ambrosia artemisiifolia* in Europe (SMARTER)' whose framework provides an ideal opportunity to assess any potential risks from the establishment of the beetle and to collect valuable data (Müller-Schärer *et al*., 2014).

4. Concluding remarks

Europe is a large continent with highly variable climates, landscapes and political drivers to tackle IAS but an enabling and overarching policy framework has been long overdue, in order to provide more coherent and collaborative EU wide protection against exponentially-rising IAS impacts, aggravated by the effects of climate change. As the licencing of the knotweed psyllid provided a case study for how to develop classical weed biocontrol with insects, the Himalayan balsam rust release should also open the door for fungal pathogens. The Invasive Species Regulation provides a great opportunity for classical biocontrol in Europe and, as the visibility of IAS as an EU-wide issue increases, so too should the use of biocontrol as a potential management solution. Serendipitous successes have been observed in Europe with the Ambrosia and Azolla beetles and some intentional successes in the near future, hopefully, should promote biocontrol further. In the meantime, more targets are under evaluation and waiting in the wings and through international collaborations and EU wide capitalisation, widespread weed CBC in Europe could become a distinct reality.

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