

# Could *Fallopia japonica* be the first target for classical weed biocontrol in Europe?

D.H. Djeddour,<sup>1</sup> R.H. Shaw,<sup>1</sup> H.C. Evans,<sup>1</sup> R.A. Tanner,<sup>1</sup> D. Kurose,<sup>2</sup>  
N. Takahashi<sup>2</sup> and M. Seier<sup>1</sup>

## Summary

Japanese knotweed, *Fallopia japonica* (Houtt.) Ronse Decr., (Polygonaceae), is a serious environmental and economic weed in its adventive range of Europe and much of North America. Such is the scale of the problem in the UK that a pioneering biocontrol programme began in 2003 which would possibly make it the first target of a full classical biological control of weeds programme in Europe. This paper summarizes the current status of the plant, reviews the literature associated with its natural enemies and reports the progress with the programme for UK sponsors, as well as referring to North American interests. We conclude that, should appropriate permissions be made available, the prospects for biological control of this high profile weed, using arthropod and fungal agents, are good.

**Keywords:** Japanese knotweed, classical biological control, *Fallopia japonica*.

## Introduction

In December 2003, the European Strategy on Invasive Alien Species (ESIAS) came into being (Genovesi and Shine, 2004), supporting the Convention on Biological Diversity (CBD), calling for a regional approach to the invasive alien species problem, and highlighting the need for cost/benefit analyses of long-term control measures. Any country intending to control those invasive alien species that threaten ecosystems, habitats or species are encouraged by the Convention to consider classical biological control for environmental weeds.

There have been over a thousand releases of biological control agents against weeds worldwide. Despite European countries being the source for 381 releases of classical biological control agents for alien plants around the world (Julien and Griffiths, 1998), no full classical weed biocontrol programme has yet been carried out for the benefit of an EU country. The reasons for this are manifold and a source of frustration for many weed biocontrol experts working in Europe, particularly in light of the long list of potential targets (Shaw, 2003; Sheppard *et al.*, 2006). *Fallopia japonica*

(Houtt.) Ronse Decr., Japanese knotweed (Polygonaceae), is one such target whose profile is so high that many of the usual hurdles have been easier to overcome than for previous potential targets.

## Nomenclature

Japanese knotweed was independently classified as *Reynoutria japonica* by Houttuyn in 1777 and as *Polygonum cuspidatum* by Siebold in 1846. It was not until the early part of the 20th century that these were discovered to be the same plant (Bailey, 1990). Generally referred to as *Polygonum cuspidatum* by Japanese and American authors, recent evidence vindicates Meissner's 1856 classification as *Fallopia japonica* var. *japonica* (Bailey, 1990). The closely related giant knotweed, *Fallopia sachalinensis* (F. Schmidt ex Maxim.) Ronse Decraene can hybridise with *F. japonica* to form *Fallopia x bohemica* (Chrtek and Chrtková) J. Bailey, first described in 1983, and is rapidly proving to be more difficult to manage than either of its parents (Bímová *et al.*, 2001; Mandák *et al.*, 2004).

Common names include Japanese/Mexican bamboo, pea-shooter plant, Sally/donkey/gypsy/wild rhubarb, Hancock's curse, Japanese fleece-flower and horse buckwheat. The Cornish name, 'Ladir Tir', is a rare example of the democratic addition to the lexicon since the Cornwall Knotweed Forum, voted for this translation of their preferred English descriptor, 'land thief'. Itadori, the Japanese name for the plant, translates as

<sup>1</sup> CABI E-UK Centre, Bakeham Lane, Egham, Surrey TW20 9TY.

<sup>2</sup> Kyushu University, Faculty of Agriculture, Fukuoka, 812-8581, Japan.  
Corresponding author: D.H. <d.djeddour@cabi.org>.

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'take away pain', presumably reflecting its medicinal properties. The subject of this paper will be referred to as Japanese knotweed.

## Reproduction

In its native range, the plant is functionally dioecious but in its introduced range it has spread solely by vegetative means from a very small number of initial introductions. Consequently, much of the invasive knotweed in the world may be clonal, as is the case in the UK (Hollingsworth and Bailey, 2000). However, recent research in the USA has shown that wild *F. japonica* can produce large quantities of viable seed and seedlings have been found in the field (Forman and Kesseli, 2003).

## Morphology

Detailed descriptions of Japanese knotweed's morphology are available (Beerling *et al.*, 1994; Lousely and Kent, 1981). It is a vigorous, herbaceous perennial, with annual, glabrous, tubular stems which ascend from an often extensive rhizome system, to reach heights of over 3 m in 3 months (Beerling *et al.*, 1994).

## Spread

The history of alien *Polygonum* and *Reynoutria* species in the UK has been well reported (Bailey and Conolly, 2000; Bailey, 2005; Conolly, 1977). The most likely date of introduction of Japanese knotweed to Europe is 1849, received at the nursery of Philipp von Siebold in the Netherlands. This was also the first year that the *japonica* variety was made available to the public as a much-prized ornamental. In the UK, the plant had become naturalized by the late 1880s, having been first recorded in the wild in Maesteg, South Wales, in 1886 (Conolly, 1977). Its status as a weed was soon recognized, and today it is one of only two terrestrial plants which are 'illegal to cause to grow in the wild' under the UK 1981 Wildlife and Countryside Act, as well as being classed as a 'controlled waste', meaning that a licence is required for its disposal.

## Damage

The costs of Japanese knotweed can be considered as both economic and environmental. To control Japanese knotweed on a national scale in the UK would cost an estimated £1.56 billion, as noted by a review team reporting to the UK Department of Environment, Food and Rural Affairs in its recent non-native species policy review (Defra UK, 2003). An accepted estimate of control costs is £10,000 per hectare for a three-year spraying regime with two sprays per year, although this is probably an underestimate if revegetation costs are taken into account. With fragments as small as 0.6g

capable of generating new plants, the presence of Japanese knotweed can add around 10% to the costs of a development project, especially if soil is considered contaminated and subject to removal fees. A worst-case scenario could see a 1m<sup>2</sup> patch costing up to £46,000 to eradicate (M. Wade, 2006, personal communication). Its reputation as a 'concrete-cracking super-weed' is justified; seven designs of reinforced channel revetment blocks were specifically tested against penetration and displacement by Japanese knotweed (Beerling, 1991), and all seven failed. In East London, work has begun to clear four hectares of knotweed infesting the 2012 Olympics site, an activity which is gleefully reported by the press to have added £65 million to the expanding development budget.

Though harder to quantify, the impact the weed has on ecosystem function and biodiversity are considerable. Its early emergence and great height combine to shade out other vegetation and prohibit regeneration of other species (Sukopp and Sukopp, 1988). Dead knotweed stems can persist for two to three years producing large quantities of debris and slowly decomposing litter, which also leads to low floristic diversity (Child and Wade, 2000). Observations on knotweed in the UK revealed that invertebrate species' richness was lower on *F. japonica* than on sympatrically occurring native plant species (Beerling and Dawah, 1993). More recent work in Switzerland, Germany and France, comparing the diversity of plants and invertebrates in invaded and non-invaded habitats, showed a reduced diversity on both taxa, as well as a halving of invertebrate biomass under knotweed (E. Gerber, unpublished data). Impacts on fish and other vertebrates further up the food chain are likely and knotweed-invaded sites appear to be less suitable habitats for foraging frogs (Maerz *et al.*, 2005).

Dense knotweed stands can also exacerbate flooding, damage riverbank protection works and impede flow, whilst dead stems can cause blockages downstream when swept away. Knotweed's influence on riparian systems is particularly pertinent in the light of the EU Water Framework Directive, which demands that member nation's waterways achieve 'good status' by 2015.

## Current control measures

The effectiveness of control and eradication interventions has recently been thoroughly reviewed by Kabat *et al.* (2006), who included 65 articles in their meta-analyses. Six control interventions were considered, none of which could eradicate Japanese knotweed or its hybrid in the short term. Cutting treatments alone were not found to result in significant decreases of knotweed abundance. However, they found that statistically significant reductions in abundance could be achieved through limited application of: a) glyphosate,

imazapyr, or imazapyr plus glyphosate, b) cutting followed by filling stems with glyphosate, or c) cutting followed by spraying with glyphosate. These authors were unable to conclude any clear long-term efficacy.

As a general rule of thumb, based on discussions with numerous experts in the UK and the United States, a late-season application of glyphosate, when the plant is at maximum height, is the most cost-effective control measure.

## Literature and field observations

### Methods and materials

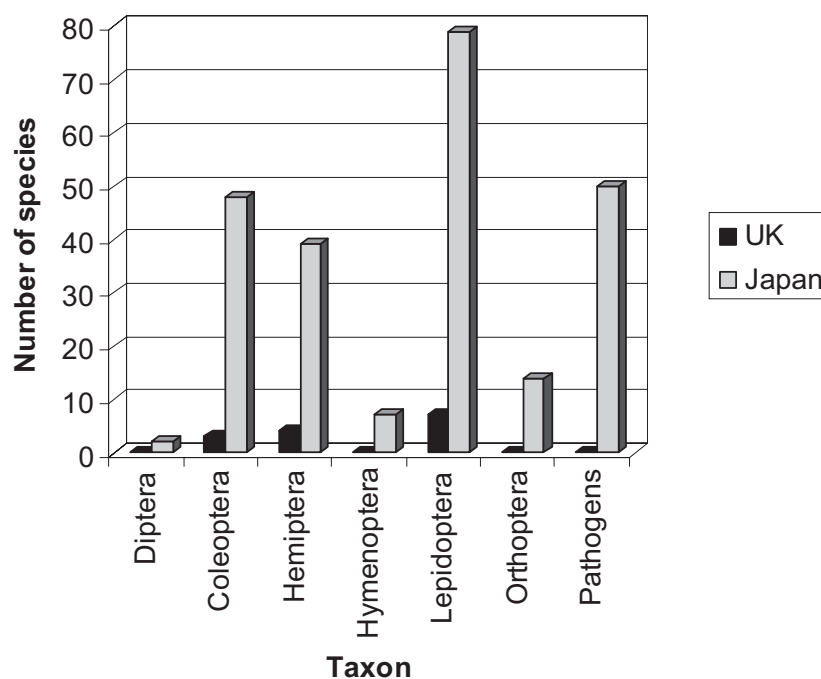
The phytophagous arthropods and fungi recorded from Japanese knotweed were collated from the printed and electronic literature in both the English and Japanese language and, for arthropods, their feeding habits were categorized. Surveys were carried out across the growing season of the plant each year from 2003 to 2006. Early surveys covered the complete range of the plant from Northern Honshu to Southern Kyushu islands, whilst later collections focussed on Kyushu Island. The focus on Kyushu Island was a consequence of molecular studies carried out at Leicester University, that showed the closest match to the UK clone was to be found in the Nagasaki Prefecture of Kyushu. At each site, knotweed plants were first visually assessed for natural enemies, their activity and/or damage inflicted, before using a beating tray to collect any natural enemies that had been missed. A subset of the plants had

their stems and rhizomes split open to reveal any endophagous species. Simultaneous assessments were carried out on other members of the Polygonaceae family growing in the vicinity to provide data on field host range.

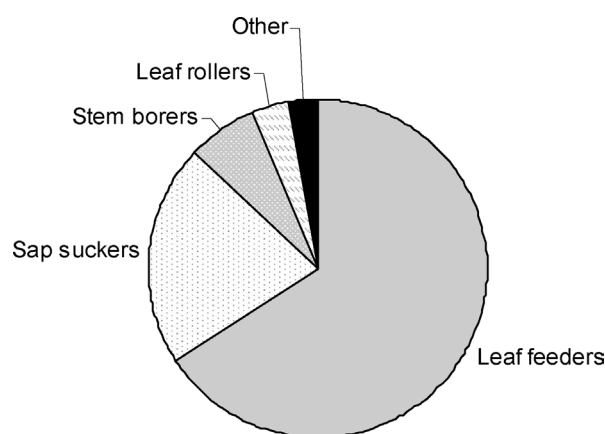
### Results

The literature review of natural enemies revealed 186 arthropod species and over 30 fungal plant pathogens to be associated with *F. japonica* in Japan. This is in stark contrast with the situation in the UK where only 14 arthropods and no fungal plant pathogens have been recorded on the plant (Figure 1). In Japan, leaf feeders and sap suckers together made up over 87% of the arthropod species recorded (Figure 2). The dearth of rhizome feeders was notable and this surprising observation was supported by subsequent field surveys, which revealed this large resource to be almost solely exploited by the polyphagous hepialid moth *Endoclyta excrescens* (Butler).

Surveys revealed that knotweed was subject to significant—and in many cases, severe—natural enemy damage. In undisturbed areas, this led to it being out-competed by the many large forbs characteristic of the Japanese flora. Observations on sympatric Polygonaceae revealed that a handful of these natural enemies had a very narrow host range. It should be noted that at sites where the natural enemy cycles had been disrupted by cutting, Japanese knotweed revealed its potential as a dominant species.



**Figure 1.** A comparison of phytophagous natural enemies recorded on *Fallopia japonica* in Japan and the UK by order (fungal pathogens are presented collectively).



**Figure 2.** Arthropod natural enemies found on *Fallopia japonica* in Japan, grouped by feeding habit.

## Potential biological control agents

The status of the more interesting potential biocontrol agents is presented below including a summary of any host-range testing that has been undertaken. Despite the sound arguments for shorter and more tailored host-range test plant lists (Briese, 2005), the approach taken here was the more traditional one including apparently irrelevant species. This decision was taken because any consideration of the use of a classical biological control agent in the UK would be novel and the authorities are likely to be most interested in economic and crop plants. The list includes 74 species from 23 families, consisting of 33 plants native to the UK, 15 introduced species, three native to Europe, 13 ornamentals and ten economically important crop species.

## Arthropods

***Ostrinia ovalipennis* Ohno (Lepidoptera: Crambidae)** is a recently identified (Ohno *et al.*, 2003; Ohno, 2003) close relative of *O. latipennis* (Warren), a well-known and widely distributed knotweed borer feeding on other species in the field in Japan. *Ostrinia ovalipennis* appears to be univoltine and restricted to two distinct populations; one from Hokkaido Island and the other from highland areas in the Nagano Prefecture of central Japan (Ohno *et al.*, 2006). It has only been recorded from Japanese and giant knotweed. Identification and likely rearing difficulties meant that this potential agent was not prioritized for the UK but remains of interest for North America where giant knotweed is more of an issue.

***Macchiatella itadori* (Shinji) (Hemiptera: Aphididae)** is a very common aphid which causes severe damage to both *F. japonica* and *F. sachalinensis* from June to September, often in association with leafspot and various ant species that tend it. Unfortunately, its

primary winter hosts are recorded as *Rhamnus japonica* Maxim and *R. purshiana* De Candolle and, as such, it was dismissed for the UK due to the likely attack of native *Rhamnus* spp. It is also unlikely to be of interest to North America, unless the latter host has been recorded erroneously.

***Ametastegia polygona* Takeuchi (Hymenoptera: Tenthredinidae)**. This stem-mining sawfly has been collected from both Japanese and giant knotweeds in the field, although the Japanese literature only reports Japanese knotweed as a host plant. Attempts to establish a culture for host-range testing have failed so far but this sawfly has not been rejected.

***Gallerucida bifasciata* (Motchulsky) syn. *Gallerucida nigromaculata* (Baly) (Coleoptera: Chrysomelidae)**. Originally two species, these have recently been synonymized to *G. bifasciata*. Some doubt remains, however, since our collections revealed considerable differences in both morphology and behaviour in populations from different regions of Japan. A more southerly population was used for preliminary larval no-choice testing and when presented with both cut plant and live plant material, larvae fed significantly within the Polygonaceae family. Subsequent field observations in Kyushu revealed larvae feeding on *Rumex acetosa* L. leaves and consequently, this beetle was not prioritized. A more northerly population has been collected and is undergoing testing in the United States.

***Lixus impressiventris* Roelofs (Coleoptera: Curculionidae)** is a very common stem-boring weevil which has only ever been collected from Japanese and giant knotweeds in the field even when suitably sized stems of *Rumex* spp. were present, at a site where almost every internode section of the knotweed stems contained a *Lixus* larva. Nonetheless, adult no-choice and choice tests showed a physiological host range that included many members of the Polygonaceae. Despite a Japanese paper reporting the weevil as a pest of a

very minor crop, *Polygonum tinctoria* Lour. (Sekiguchi and Wakiya, 1988), every attempt to rear the weevil on this plant has failed. No-choice oviposition and development tests showed that one native UK plant, *Polygonum hydropiper* (L.), was able to support development of the weevil, albeit producing significantly smaller adults in the process. The possibility of adults feeding on non-targets and the risk of development on a native plant species have meant that this weevil is no longer a prioritized agent for the UK. Further studies, perhaps in the native range, may well prove this weevil to be highly specific.

***Aphalara itadori* Shinji (Hemiptera: Psyllidae)** is found from southern Kyushu to as far north as Nagano Prefecture on Honshu Island and was observed feeding on Japanese knotweed from sea level to 2150 m a.s.l. Adults were collected from late April to mid-August and although widespread, were rarely present in high numbers. One unidentified eulophid parasitoid has been reared out from a late nymph. Adults lay eggs on the leaves or under the papery sheath surrounding the petiole and once hatched, the nymphs pass through five instars feeding on the phloem of the plant. In the laboratory, at 22°C, the mean development time was 32.9 days ( $\pm 0.8 = \text{SE}$ ,  $n=21$ ) and reproductive females laid a mean of 637 eggs each ( $\pm 121 = \text{SE}$ ,  $n=11$ ). Impact studies are ongoing but early signs indicate that the presence of feeding nymphs restricts plant height and increases leaf production.

Host-range tests have focussed on multiple-choice oviposition studies since the nymphs are not very mobile and adult feeding was hard to observe and quantify. Host-absent multiple-choice tests were used to test the validity of host-present tests and no significant difference was found when very closely related plants were used. Over a 20-month period, the location and fate of just under 125,000 eggs have been recorded during tests on 83 test plant species. So far, only 700 eggs (0.6%) have been laid on non-knotweed or knotweed hybrid hosts and not one of these has developed through to adult. Although more replication is required on some non-target species, these results are extremely encouraging. The question of what happens when above-ground knotweed dies off at the first frost remains. Adult *Aphalara* are presumed to shelter in the bark of trees such as *Cryptomeria* spp. (N. Takahashi, 2007, personal communication). This is currently being investigated.

## Pathogens

***Puccinia polygoni-amphibii* var. *tovariae* Arthur (Basidiomycota: Pucciniaceae)**. Several strains of this rust have been found in the field on *F. japonica* in Honshu and Kyushu Islands, from sea level to 1550 m a.s.l. Collected all year round, either as cinnamon brown-coloured uredinia or as the over-wintering, brownish-black, telial stage, it was also recorded on

*F. sachalinensis*, *F. japonica* var. *compacta* and the somewhat hairy-leaved *F. japonica* var. *uzenensis*. The uredinial spore stage was tested against more than 40 non-target plants. It showed a great deal of potential by infecting all stages of the target plant, causing severe defoliation in the lab. Unfortunately, infective symptoms and subsequent sporulation to produce viable spores were consistently recorded on the native *Rumex longifolius* DC, and *Fallopia baldschuanica* (Regel) Holub, an ornamental. Furthermore, its life cycle could not be resolved in quarantine since telial dormancy could not be broken under these artificial conditions. These facts, coupled with reports in the Japanese literature of closely related *Puccinia* varieties being heteroecious, with *Geranium* spp. as alternative hosts, meant that this damaging rust was no longer prioritized for the UK.

***Aecidium polygoni-cuspidati* Dietel (Basidiomycota: *Incertae sedis*)**. This conspicuous rust was found on *F. japonica* var. *compacta* and *F. japonica* var. *japonica* in the field and has been recorded from *F. sachalinensis* in the Japanese literature. It is found from late April to September at altitudes of up to 1270 m, but occurring more frequently in the lower, warmer areas of both Honshu and Kyushu islands, commonly in humid riparian and woodland habitats. Failure to infect knotweed plants with aeciospores in the lab reinforced suspicions that this rust may in fact be heteroecious and synonymous with *Puccinia phragmitis* (Schum.) Körn., using *Phragmites communis* Trin. as its alternative host. This was confirmed in the Japanese literature (Harada, 1978) where it was identified that the rust had many specialized biologic forms or strains, one of which infected *F. japonica* and *F. sachalinensis* in its aecial stage. This agent has therefore been dismissed.

***Mycosphaerella polygoni-cuspidati* Hara (Ascomycota: Mycosphaerellaceae)**. This hemibiotrophic pathogen which cycles through the sexual ascospores and causes a highly damaging and ubiquitous leafspot is found on Kyushu, Honshu and Shikoku islands, from sea level to altitudes over 900 m. Displaying a high degree of polymorphism, the lesions may appear as large, dark-tan coalescing forms, or as circular or irregular, chestnut-brown lesions, or as more discrete spotting. This, and considerable variation shown in cultured isolates, suggests that there is a range of morphotypes and/or pathotypes. The leafspot appears to be restricted to *F. japonica* var. *japonica* in the field, and coincides with knotweed stem emergence in late April through to its senescence in October/November. After considerable investigation, this slow-growing ascomycete has now been confirmed as the causal agent, following Koch's postulates. Host-range testing has been carried out, using ascospore inoculum for closely related species and mycelial inoculum for the entire host-test list since the availability of the former is limited. To date, over 50 plant species have been tested, and results confirm the extremely narrow host range shown in the field. Genetic characterization of the

various strains is being carried out to ascertain their relatedness.

## Discussion

The short answer to the question posed by the title of this paper is 'no', this will not be the first target for classical biocontrol of weeds in Europe. This is not because an eventual agent release is unlikely but rather because it would not actually be novel for Europe. Closer examination of a biological control study against creeping thistle (*Cirsium arvens*) in the UK in 1969 (Baker *et al.*, 1972) revealed that, although the initial releases of hundreds of adult beetles (*Haltica carduorum* Guerin) from France were made into field cages, these cages were removed later in the study. The eventual results were similar to those encountered in Canada, with no successful survival over winter (Peschken *et al.*, 1970).

Despite this, the completion of a full, official classical biological control programme for a weed in Europe is effectively a new concept and would be expected to face various challenges from the outset (Shaw, 2003; Sheppard *et al.*, 2006). A team at the University of Coimbra in Portugal is currently studying the safety and efficiency of the gall wasp, *Trichilogaster acaciaelongifoliae* Froggatt, against *Acacia longifolia* (Andr.) Willd. in quarantine. This agent was successfully released in South Africa (Julien and Griffiths, 1998). This is part of a larger project, but it could be that this excellent agent will be the first classical agent released in Europe against a weed.

Regulatory challenges are likely to be the most difficult to overcome especially when it comes to fungal agents, although proposed arthropod releases for weeds have not been welcomed as much as those for insect pests. At this stage, the psyllid *Aphalara itadori* and the leafspot *Mycosphaerella* sp. seem likely to pass the host-range testing process, but whether the prospect of an actual release into the environment becomes a reality is likely to depend on individuals within the appropriate UK government and EU department(s) taking a pragmatic approach to often inappropriate or absent legislation. If the eventual goal of release is achieved, then this programme will indeed have laid the groundwork, helped establish the rules and opened the door to classical biological control of weeds in Europe (Kurose *et al.*, 2006).

## Acknowledgements

Much of the work outlined in this paper would not have been possible without the help of the Japanese knotweed team at Kyushu University, in particular Professor Masami Takagi, as well as technical support in the UK from Sarah Bryner, Valerie Coudrain and Lynn Hill. We would like to thank Defra, the UK Environment Agency, Network Rail, The Welsh and South West Regional

Development Agencies, British Waterways, Cornwall County Council and the USDA Forest Service for their funding, and the Royal Entomological Society and the European Weed Research Society for the travel grants that were used to attend this symposium.

## References

- Bailey, J. (2005) The history of Japanese knotweed. *Ecos—British Association of Nature Conservationists* 26, 55–62.
- Bailey, J.P. (1990) Breeding behaviour and seed production in alien giant knotweed in the British Isles; Biology and control of invasive plants. In: Richards, Moorehead & Laing Ltd. (eds) *Biology and Control of Invasive Plants. BES Industrial Ecology Group Symposium*, pp.110–120.
- Bailey, J.P. and Conolly, A.P. (2000) Prize-winners to pariahs—a history of Japanese knotweed s.l. (Polygonaceae) in the British Isles. *Watsonia* 23, 93–110.
- Baker, C.R.B., Blackman, R.L. and Claridge, M.F. (1972) Studies on *Haltica carduorum* Guerin (Coleoptera: Chrysomelidae) an alien beetle released in Britain as a contribution to the biological control of creeping thistle, *Cirsium arvense* (L.) Scop. *Journal of Applied Ecology* 9, 819–830.
- Bimová, K., Mandák, B. and Pyšek, P. (2001) Experimental control of *Reynoutria* congeners: a comparative study of a hybrid and its parents. In: Brundu, G., Brock, J., Camarda, I., Child L. and Wade, M. (eds) *Plant Invasion: Species Ecology and Ecosystem Management*. Backuys, Leiden, Netherlands, pp. 283–290.
- Berling, D. (1991) The testing of cellular concrete revetment blocks resistant to growths of *Reynoutria japonica* Houtt. (Japanese knotweed). *Water Research (Oxford)* 25, 495–498.
- Berling, D.J. and Dawah, H.A. (1993) Abundance and diversity of invertebrates associated with *Fallopia japonica* (Houtt. Ronse Decraene) and *Impatiens glandulifera* (Royle): two alien plant species in the British Isles. *Entomologist* 112, 127–139.
- Berling, D.J., Bailey, J.P. and Conolly, A.P. (1994) *Fallopia japonica* (Houtt.); Ronse Decraene (*Reynoutria japonica* Houtt.; *Polygonum cuspidatum* Sieb. & Zucc.), *Journal of Ecology* 82, 959–979.
- Briese, D.T. (2005) Translating host-specificity test results into the real world: the need to harmonize the yin and yang of current testing procedures. *Biological Control* 35, 208–214.
- Child, L. and Wade, M. (2000) *The Japanese Knotweed Manual: the Management and Control of an Invasive Alien Weed*. Packard Publishing Limited, Chichester, UK 123p.
- Conolly, A.P. (1977) The distribution and history in the British Isles of some alien species of *Polygonum* and *Reynoutria*. *Watsonia* 11, 291–311.
- Defra, UK (2003) Review of Non-native Species Policy—Report of the Working Group [www.defra.gov.uk/wildlife-countryside/resprog/findings/non-native/report.pdf](http://www.defra.gov.uk/wildlife-countryside/resprog/findings/non-native/report.pdf)
- Forman, J. and Kesseli, R.V. (2003) Sexual reproduction in the invasive species *Fallopia japonica* (Polygonaceae). *American Journal of Botany* 90, 586–592.
- Genovesi, P. and Shine, C. (2004) European Strategy on Invasive Alien Species. Nature and Environment, n. 137, t-pv (2003)7. Council of Europe Publishing, Strasbourg.

- Harada, Y. (1978) New hosts and biologic specialization in the aecial state of *Puccinia phragmitis* in Japan. *Transactions of the Mycological Society of Japan* 19, 433–438.
- Hollingsworth, M.L. and Bailey, J.P. (2000) Evidence for massive clonal growth in the invasive weed *Fallopia japonica* (Japanese Knotweed). *Botanical Journal of the Linnean Society* 133, 463–472.
- Julien, M.H. and Griffiths, M.H. (1998) *Biological Control of Weeds. A World Catalogue of Agents and their Target Weeds. Fourth edition.* CABI Publishing, Wallingford, UK. 223 p.
- Kabat, T.J., Stewart, G.B. and Pullin, A.S. (2006) Are Japanese knotweed (*Fallopia japonica*) control and eradication interventions effective? In: *Centre for Evidence Based Conservation Internal Report, Systematic Review no. 21.* Birmingham, UK.
- Kurose, D., Renals, T., Shaw, R., Furuya, N., Takagi, M. and Evans, H. (2006) *Fallopia japonica*, an increasingly intractable weed problem in the UK: Can fungi help cut through this Gordian knot? *Mycologist* 20, 126–129.
- Lousely, J.E. and Kent, D.H. (1981) *Docks and Knotweeds of the British Isles.* BSBI, London, UK. 205p.
- Maerz, J.C., Blossey, B. and Nuzzo, V. (2005) Green frogs show reduced foraging success in habitats invaded by Japanese knotweed. *Biodiversity and Conservation* 14, 2901–2911.
- Mandák, B., Pyšek, P. and Bímová, K. (2004) History of the invasion and distribution of *Reynoutria* taxa in the Czech Republic: a hybrid spreading faster than its parents. *Preslia* 76, 15–64.
- Ohno, S. (2003) A new knotweed-boring species of the genus *Ostrinia* Hübner (Lepidoptera: Crambidae) from Japan. *Entomological Science* 6, 77–83.
- Ohno, S., Hoshizaki, S., Tatsuki, S. and Ishikawa, Y. (2003) New records of *Ostrinia ovalipennis* (Lepidoptera: Crambidae) from Hokkaido, and morphometric analyses for species identification and geographic variation. *Applied Entomology and Zoology* 38, 529–535.
- Ohno, S., Ishikawa, Y., Tatsuki, S. and Hoshizaki, S. (2006) Variation in mitochondrial COII gene sequences among two species of Japanese knotweed-boring moths, *Ostrinia latipennis* and *O. ovalipennis* (Lepidoptera: Crambidae). *Bulletin of Entomological Research* 96, 243–249.
- Peschken, D., Friesen, H.A., Tonks, N.V. and Banham, F.L. (1970) Releases of *Altica carduorum* (Chrysomelidae: Coleoptera) against the weed Canada thistle (*Cirsium arvense*) in Canada. *Canadian Entomologist* 102, 264–271.
- Sekiguchi, T. and Wakiya, H. (1988) Ecology and chemical control of a *Lixus impressiventris* Roelofs infesting *Polygonum tinctorium* Lour. *Tokushima Agricultural Experimental Station Reports* 25, 52–57.
- Shaw, R.H. (2003) Biological control of invasive weeds in the UK: opportunities and challenges. In: Child, L., Brock, J.H., Brundu, G., Prach, K., Pyšek, K., Wade, P.M. and Williamson, M. (eds) *Plant Invasions: Ecological Threats and Management Solutions.* Backhuys, Leiden Publishers, pp.337–354.
- Sheppard, A.W., Shaw, R.H. and Sforza, R. (2006) Top 20 environmental weeds for classical biological control in Europe: a review of opportunities, regulations and other barriers to adoption. *Weed Research* 46, 1–25.
- Sukopp, H. and Sukopp, U. (1988) *Reynoutria japonica* Houtt. in Japan and in Europe. *Veröffentlichungen Geobotanisches Institut, Zurich* 98, 354–372.