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Asian knotweeds - an example of a raising threat?

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**Introduced tree species
in European forests:
*opportunities and challenges***

Frank Krumm and Lucie Vítková (eds.)



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in European forests:**
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3.8 Asian knotweeds – an example of a raising threat?

Fanny Dommaget, Paul Cavallé, André Evette and François-Marie Martin

Asian knotweeds (*Fallopia* spp.) are herbaceous plants originating from south-eastern Asia that were introduced to Europe at the end of the 19th century for ornamental purposes. They are now widespread across Europe and North America, and are currently considered to be one of the worst invasive species in the world (IUCN 2011). The Asian knotweed complex is mainly composed of three taxa:

1. Japanese knotweed (*Fallopia japonica* (Houtt.) Ronse Decr.);
2. Giant knotweed (*F. sachalinensis* (F. Schmidt) Ronse Decr.);
3. Hybrid knotweed (*F. x bohemica* (Chrtek & Chrtková) J.P. Bailey).

F. japonica has also been designated as *Reynoutria japonica* Houtt. and *Polygonum cuspidatum* Sieb. & Zucc. in the scientific literature, *F. sachalinensis* as *R. sachalinensis* (F. Schmidt) Nakai and *P. sachalinense* F. Schmidt, and *F. x bohemica* as *R. x bohemica* Chrtek & Chrtková or *P. x bohemicum* (Chrtek & Chrtková) Zika & Jacobson.

Asian knotweeds are highly productive rhizomatous species that quickly spread through various habitats.

Asian knotweeds develop a dense network of rhizomes that can laterally spread over distances such as 20 m (Beerling et al. 1994) with the underground biomass representing up to two thirds of the total biomass (Figure 52) (Price et al. 2001). Ramets (i.e. individual members of a clone) from the same individual are interconnected through the rhizomes and seem to share resources through clonal integration (Aguilera et al. 2010). This mechanism enables individual ramets in less favourable microenvironments to benefit from resources acquired by ramets in more favourable microenvironments (De Kroon and Hutchings 1995). Asian knotweeds are characterised by a high growth rate that can be up to 15 cm a day (Urgenson et al. 2009) allowing them to rapidly dominate the areas where they become established. The segmented and ramified ramets (Figure 52) of Japanese knotweed can reach a height of 3 m, with giant knotweed growing to 5 m, and hybrid knotweed having an intermediate morphology (Bailey and Wisskirchen 2006).



Figure 52. Underground system [a], flowers [b] and growing ramets [c] of *Fallopia japonica* (photos: F. Dommanget).

If sexual reproduction also occurs in the wild (Forman and Kesseli 2003), Asian knotweeds' reproduction is mostly vegetative, especially in Japanese knotweed for which only one male-sterile clone has been identified in Europe (Krebs et al. 2010) and only four in the USA (Gammon and Kesseli 2010). Giant knotweed and hybrid knotweed have a more complex genetic variability (Hollingsworth et al. 1999) as sexual reproduction exists between Japanese and giant knotweeds and between the hybrid and its two parents (Tiébré et al. 2007). But vegetative reproduction is very efficient as it only takes a small fragment of a rhizome (Sásik and Eliáš Jr 2006) or stem to produce a new individual (Bímová et al. 2003). Small white flowers appearing in summer from July to September (Figure 52) are situated in terminal and axillary panicles and are pollinated by insects (Beerling et al. 1994). Asian knotweeds produce achenes of variable viability depending on the clone (e.g. Buhk and Thielsch 2015) that spread along rivers thanks to their good buoyancy and ability to germinate after immersion (Rouifed et al. 2011). The propagules disperse via e.g. watercourses (Bímová et al. 2004) or through construction vehicles (Rouifed et al. 2014) or backfill materials (Beerling 1991).

Asian knotweeds have a broad environmental range (e.g. Rouifed et al. 2012) and they can therefore be found in a diverse variety of habitats; they are able to grow on old mine spoil, alluvial soils, quarries and waste zones, but also in open woodlands (Beerling et al. 1994). However, they are more frequently found on disturbed habitats along riverbanks or along roads and railways (Tiébré et al. 2008). Hybrid knotweed has also been found around Mediterranean Basin where extreme weather events such as summer droughts do not seem to be limiting for the hybrid (Bailey and Wisskirchen 2006). Hybrid knotweeds have also colonised southern Scandinavia and mountainous areas (Bailey and Wisskirchen 2006). Moreover, with climate change causing increases in temperatures and a decrease in the number of early frost days (e.g. Groeneveld et al. 2014), Asian knotweeds are expected to spread to higher altitudes and latitudes.

▶ *Invasive Asian knotweeds impact ecosystem functioning as they negatively affect species diversity and the growth and abundance of other species, in particular tree regeneration and modify biogeochemical processes.*

In areas where they invade, Asian knotweeds displace native plant species, affect fauna and modify soil functioning. Their high growth rate and high biomass production allow them to dominate open spaces, forming a dense layer that prevents light reaching the ground layer, and thereby reducing both richness and abundance of other plant species (Siemens and Blossey 2007). However, light obstruction is not the only mechanism explaining their dominance; Asian knotweed litter has been shown to reduce seed germination of other species (Beerling et al. 1994). Moreover, they produce phytotoxic compounds negatively affecting seed germination (e.g. Vrchotová and Šerá 2008) and growth of neighbouring species (e.g. Dommaget et al. 2014).

Asian knotweeds have also been reported to affect fauna as it changes the composition of soil macroorganisms. Gerber et al. (2008) found that total biomass of invertebrates in grassland and shrub-dominated habitats was almost twice as high than that in habitats invaded by Asian knotweeds, and that species richness was also negatively affected in areas infested by Asian knotweed. Kappes et al. (2007) investigated the effect of Asian knotweed infestation on different groups of soil and litter-dwelling fauna: herbivore generalists (slugs and snails), detritivores (Isopoda; e.g. woodlice, Diplopoda, millipedes) and predators (Opiliones; harvestmen). Snails were generally found to be more negatively affected than slugs by knotweed infestation, the abundance of Isopoda was decreased, whereas Diplopoda were not affected, and abundance, species diversity and diversity of predatory Opiliones were greater in knotweed infested stands. Kappes et al. (2007) conclude that knotweed infested habitats are characterised by a shift to a detritus based food chain. Such modifications to the composition and the abundance of invertebrate communities affect higher trophic levels. Maerz et al. (2005) observed a decline of green frog (*Rana clamitans* Latreille) in areas invaded by Asian knotweeds and hypothesised that knotweed degrades habitat quality for frogs by reducing arthropod abundance. Hajzlerová and Reif (2014) found that understory birds species richness in riparian communities was reduced in areas invaded by Asian knotweeds in the Czech Republic.

The litter of Asian knotweeds has a low nutritional value when compared with other plants. Knotweeds are able to transfer nitrogen from the aerial parts to rhizomes for storage before the leaf fall; resorption of nitrogen from knotweed leaves into the rhizomes was more than 75 % whereas in red alder (*Alnus rubra* Bong.) it was only 5 % (Urgenson et al. 2009). This results in soils under knotweed cover containing less organic matter and with slower mineralisation rates (Koutika et al. 2007), which in turn can lead to the replacement of key tree species (e.g. *Alnus*) (Urgenson et al. 2009). Asian knotweeds induce changes in soil microbial communities, which leads to the reduction in the potential denitrification enzyme activity (Dassonville et al. 2007). It is important to note that the impacts of Asian knotweeds on nutrient concentrations depend on the site initial conditions (Dassonville et al. 2008). However, the presence of Asian knotweeds may lead to edaphic conditions becoming rather homogeneous.

In riparian environments Asian knotweeds can, after reaching a certain threshold of spread, alter the physical and chemical quality of stream water (Claeson et al. 2014) and modify stream macroinvertebrate assemblages (Lecerf et al. 2007). Finally, by reducing

the regeneration of native woody species, knotweed can have lasting effects on the structure of riparian forests and the amount of large woody debris; this is of the utmost importance for sediment dynamics and stream morphology and, consequently, for plant development along river banks (Urgenson et al. 2009).

Control methods to eradicate or impede further spread of Asian knotweeds are usually expensive and often insufficient.

Various methods to control Asian knotweeds have been tested but they are often largely inefficient and expensive. However, one of the most efficient methods is the early uprooting and disposal requiring a constant monitoring of areas at risk. Other mechanical solutions were developed to locally eliminate Asian knotweeds; i.e. rhizome extraction and their deep burial, rhizomes removal and their elimination or their crushing and covering with tarpaulin to accelerate their decomposition (Boyer 2003). Cutting and mowing are commonly used solutions to eradicate or at least reduce Asian knotweeds' vigour in conservation and protected areas. However, they are labour-intensive requiring repeated treatment, and are therefore expensive (Delbart et al. 2012).

Biological control has also been investigated as a means to control Asian knotweeds. Trials by Shaw et al. (2009) and Grevstad et al. (2013) indicated that the psyllid (*Aphalara itadori* Shinji) has potential as a biocontrol agent in Great Britain and in North America; the psyllid greatly reduced knotweed growth, and was observed to be a specialist feeder on knotweed, with a low occurrence of development on other plant species.

Another method is the use of chemical herbicides. Bashtanova et al. (2009) reviewed various methods to eradicate Japanese knotweed using a variety of herbicides and found that none of them resulted in eradication. Delbart et al. (2012) found consistent results, testing the efficiency of different active substances, concentrations and application methods (injected and sprayed). In some cases, where Asian knotweeds have invaded, the use of chemical herbicides is not recommended (e.g. along roads) or is forbidden (e.g. along rivers) as the herbicides could leach into the groundwater table or into the stream (cf. Directive 2009/128/EC of the European Parliament and of the Council of 21st October 2009). The herbicides are also non-specific, and depending on the method of application can result in loss of other vegetation. This can cause destabilisation of the ground, for example, along streams and rivers (Green 2003).

Restoring invaded habitats by stimulating successional processes through direct seeding and/or by transplanting native species can also be a solution for both the conservation of native communities and the control of invasive species (Sheley and Smith 2012). Such alternative strategies have already been successfully tested against various herbaceous invasive plants including Asian knotweeds. In their experimental tests, Dommanget et al. (2015) planted cuttings of fast-growing willow species on previously mowed knotweed patches in order to stimulate the regeneration of a competitive canopy. After two or three years with repeated cuts, Asian knotweeds were dominated by willows and their biomass had significantly decreased. Similarly, Delbart et al. (2012) showed that mowing associated with native trees transplanting was the most efficient mechanical control method. However, these techniques require a repeated and long-term application (Barták et al. 2010).

Asian knotweeds are very persistent, and effective control measures require thorough monitoring and follow-up treatments. It is also important to note that these measures are often very expensive; in Great Britain, the annual cost of infestation (including costs of research; costs to control knotweed along rivers, railways and roads; costs to control knotweed on development sites; devaluation of housing; and costs to local authorities for dealing with infestations) by Japanese knotweed was estimated to be about €230 million (Williams et al. 2010). In the whole of Europe, the total annual economic cost of Japanese knotweed infestations was estimated to be about €2.3 billion (Kettunen et al. 2008).

▶ *Asian knotweed invasions of forests is driven by forest disturbances, climate change and the effective dispersal by seeds of hybrids.*

The presence of Asian knotweeds in the forests is a growing concern for many forest managers; the French National Forest Office, for instance, is concerned about Asian knotweed infestations developing along forest edges because of the risk they represent if a clearing or a disturbance occurs thus reducing competitive pressure.

Although knotweeds are considered to be pioneers with a broad environmental range (Figure 53), it is generally recognised that some habitats are more susceptible to invasion than others; this may be attributed to differences in propagule pressure, climatic constraints and intrinsic biotic resistance (Chytrý et al. 2008). Concerning forest ecosystems, the most susceptible to invasion by Asian knotweed are frequently disturbed forests, riparian woodlands and deciduous forests (e.g. poplar plantations). Coniferous mountain forests and shrublands are not as susceptible to invasion.

Many examples of forests invaded by Asian knotweeds can be found in the literature (e.g. Beerling et al. 1994, Schnitzler and Muller 1998, Bímová et al. 2004, Dommanget et al. 2013, Gerber and Schaffner 2014). However, it is important to note that mature forests are rarely invaded by knotweeds except along their margins (Beerling et al. 1994). In a study carried out in southern Poland, Asian knotweeds were reported to be less common in forests, than in gardens, railways, wetlands or wasteland (Chmura et al. 2013).

Asian knotweeds affect the growth and germination of ground vegetation and tree species. This can cause changes in composition of plant communities, which can consequently impact forest management and timber production. At sites in Massachusetts (USA), Aguilera et al. (2010), for instance, found that natural regeneration of tree species – including sugar maple (*Acer saccharum* Marsh.), silver maple (*Acer saccharinum* L.), and hickory (*Carya ovata* (Mill.) K.Koch) – was lower in stands that had been invaded by Asian knotweeds. Similarly, Siemens et al. (2007) reported that growth of silver maple saplings was significantly reduced under hybrid knotweed, mainly due to the reduced light level.



Figure 53. Asian knotweeds thrive in a broad range of environments: (a) along rivers; (b) in urban areas; (c) along forest edges; and (d) in wild garden waste (photos: F. Dommanget).

Dommanget et al. (2014) demonstrated that the growth of three species with potential for restoration – e.g. black poplar (*Populus nigra* L.), grey willow (*Salix atrocinerea* Brot.) and osier (*Salix viminalis* L.) – was noticeably reduced when watered with leachates from soil in which Japanese knotweed was growing.

▶ *In forests, observation and prevention are the most efficient management method for Asian knotweed.*

Removal of Asian knotweeds helps the spontaneous re-establishment of native species. Following local application of herbicides, coniferous species such as western red cedar (*Thuja plicata* Donn), Sitka spruce (*Picea sitchensis* (Bong.) Carr.) and western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) and broadleaved trees such as red alder (*Alnus rubra* Bong.) or black cottonwood (*Populus trichocarpa* Torr. & A.Gray ex.Hook.) were able to recolonise the areas that had been invaded by Asian knotweeds in Washington State (USA) (Urgenson et al. 2014). Cutting back Asian knotweed also benefitted the establishment and growth of planted oak (*Quercus* spp.) saplings along the Bronx River in New York City (Haight et al. 2014) as well as common ash (*Fraxinus excelsior* L.) and sycamore (*Acer pseudoplatanus* L.) saplings in the Czech Republic (Barták et al. 2010). Barták et al. (2010) report that there was frequent re-sprouting of Asian knotweeds in forest stands in spite of the application of herbicides. The plants were however, relatively small and weak. It is preferable to prevent establishment of Asian knotweeds rather than rely on post-establishment control and eradication (Simberloff et al. 2013).

On sites infested by Asian knotweeds, a frequent and repeated effort to control knotweeds should be maintained in order to allow native species to successfully re-establish until canopy closure occurs (Dommanget et al. 2015). Regular and selective cuttings for at least four consecutive years help the cover and the diversity of native species to increase in invaded patches (Gerber et al. 2010). The active restoration of a native plant community can also be used as a control tool against Asian knotweeds but knotweed shoots must be mowed specifically for a minimum of two or three years depending on the site and on native species growth (Dommanget et al. 2015). Attention must be then paid to forest clearings in close proximity to sites infested by Asian knotweeds; it is important to minimise disturbance within kilometres around infestations of Asian knotweed. Following cutting or pulling, knotweed remnants such as stems, rhizomes or seedlings should be removed from the site and disposed of safely (Miller et al. 2015). Similarly, forest managers should be aware of the dispersion risk through the use of machinery along the trails. Having been used in infested areas (i.e. for wood harvesting, knotweed management, etc.), all machinery should be carefully cleaned to remove knotweed fragments and prevent infestation of new sites (Cottet et al. 2015). Child and Wade (2000) provide suggestions for increasing public awareness and provision of information about good practice for knotweed management and prevention of its spread into unaffected areas.

▶ *Some habitats are more susceptible to invasion than others mainly due to differences in propagule pressure, climatic constraints and intrinsic biotic resistance.*

Recent research shows that hybrid knotweed seems to disperse efficiently by seed in Europe (Buhk and Thielsch 2015), which is especially promoted by the presence of forest clearings and favourable light conditions in freshly disturbed sites. Sexual reproduction also represents opportunities to adapt to changing environmental conditions. As seedling

establishment can be reduced by summer drought and late frost (Funkenberg et al. 2012), the predicted climate change scenarios may favour the establishment of hybrid knotweed in forests, which might provide some respite from the hottest of the summer temperatures. The effects of climate warming have already been observed within the northern part of its distribution in North America, with the further northward spread of viable seeds (Groeneveld et al. 2014). Even if warmer summer temperatures could limit seedling survival (Funkenberg et al. 2012), climatic changes are likely to reduce late-spring frosts and favour extreme wind events (Christensen et al. 2007), which could provide favourable conditions for knotweeds to colonise forests.

It is important to understand the risk presented by Asian knotweeds in order to prevent their further expansion. Control of knotweed is expensive and better results are achieved when the invasion risks are considered prior to the possible invasion or, at least, as early as possible once an infestation has been identified (Child and Wade 2000).

Competition is an effective way to control Asian knotweed infestations and to prevent their spread into neighbouring areas. In infested areas, forestry practices should be adapted to minimise the disturbance in areas adjacent to knotweed infestations and to reduce light availability for the knotweeds on the forest floor. In disturbed areas close to Asian knotweed infestations, knotweed growth should be kept under control (in non-riparian forest areas this could involve application of herbicides, in riparian areas other methods should be considered), until natural regeneration of desired species has become established. The spread of Asian knotweed should be kept under careful observation.

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