PNW 610

Knotweed shrubs:
identification, biology, and management

By Timothy S. Prather, Timothy W. Miller, & Sandra S. Robins

Figure 1. Japanese knotweed leaves tend to be very square across the base.

Figure 2. Giant knotweed plants may exceed 12 feet tall.

Figure 3. Himalayan knotweed has an impressive floral display.

THE PROBLEM WITH WOODY KNOTWEEDS

Michael Dirr's classic horticulture text, *Manual of Woody Landscape Plants*, has this to say about woody knotweeds: "Be leery and careful when considering the above for the garden. All are thugs."

All of the knotweeds discussed here are perennial species that sprout from a woody base each year. These knotweeds were brought to North America as ornamental plants. They now infest and dominate riparian areas (land near rivers and other watercourses) in many parts of North America. Their extensive rhizome system presents problems both in urban and riparian situations. In urban areas the stems that grow from rhizomes can push through asphalt and cause problems with sewer lines. In riparian environments, problems include the creation of near monocultures of Japanese knotweed, destabilization of stream banks (Child 1992), and changes in soil fertility which may affect native plant species (Vanderhoeven 2005).

Knotweeds also reduce the diversity of insects. In places dominated by knotweeds, scientists find fewer kinds of aquatic invertebrates (Dangles 2002) and fewer land-based insects which eat plants (Beerling and Dawah 1993). Frogs that are forced to feed in dense Japanese knotweed stands don't gain as much weight (Maerz 2005), which indicates that there are fewer insects to be eaten.

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WOODY KNOTWEED SPECIES

At least five knotweed species occur in the U.S.: Japanese (*Fallopia cuspidatum*) (figure 1), giant or Sakhalin (*Fallopia sachalinensis*) (figure 2), Himalayan (*Polygonum polystachyum*) (figure 3), Bohemian (*Fallopia* x *bohemicum*, a hybrid of Japanese and giant) (figure 4), and low Japanese fleeceflower (*Fallopia japonica* var. *compactum*). Other common names include Japanese bamboo, Mexican bamboo, false bamboo, and fleece flower. Latin names for this genus vary, and include *Polygonum, Reynoutria,* and *Fallopia*. *Fallopia* is becoming widely accepted as the genus name for Japanese knotweed, giant knotweed, and Bohemian knotweed.

All woody knotweeds are native to eastern Asia. As a group, the woody knotweeds grow from 5 feet to greater than 12 feet tall. Some species' hollow, jointed stems grow to 2 inches in diameter.

Japanese knotweed is the most widespread and was likely the first of these species introduced into the U.S., probably as an ornamental plant in the late 1800s; the other species probably arrived on our shores early in the 20th century. Japanese knotweed grows in New England, along the eastern seaboard south to Georgia, in most of the Southeast, throughout the Midwest and central Plains and into several Rocky Mountain states, and along the West Coast.

Bohemian knotweed often is mistaken for Japanese knotweed. For many years Idaho's knotweed was assumed to be Japanese knotweed. However, plant surveys conducted through the UI Erickson Diagnostic Laboratory in 2003 suggest that most populations in Idaho are actually Bohemian knotweed.

These species' impressive late-summer floral display, beautiful foliage, and unusual height (usually to 8 feet tall or more), belie their invasive natures. In fact, the plants are so vigorous, producing so much biomass in a single year, that Japanese knotweed has been considered for use as a fuel where 25 to 37 tons of dry matter per acre per year could be produced.

IDENTIFICATION

It can be useful to correctly identify knotweeds, because control strategies sometimes depend on the kind of knotweed that is causing the problem. For example Bohemian knotweed is the most vigorous and invasive, and may need control strategies that last longer than those needed for the others. Giant knotweed and low Japanese fleeceflower are not as invasive as the others.

Figure 4. Bohemian knotweed. Note the zig-zag stem, swollen nodes, sheathing stipules, and purple-spotted stem. Plants are often up to 8 feet tall.

At first glance, all these knotweeds closely resemble each other. In fact, the knotweeds are sometimes confused with bamboo, since they all bear medium to dark green, alternate leaves on a jointed stem that immediately reminds the viewer of a stalk of bamboo. However, the knotweed stalk has a membranous sheath that wraps around the stem like a sleeve. Look for this just above each node (the raised ring around the stem where the leaf petiole arises). This is called either a sheathing stipule or an ocrea. This sheathing stipule is absent from bamboo.

Leaves on these knotweeds, while similar to each other, provide a good way to differentiate between the species. Giant knotweed leaf blades are up to 18 inches long and about half that wide, and are "cordate" at the base, giving the leaf a distinctly heart-shaped outline (figure 5). Japanese knotweed leaves are shorter, up to about 8 inches long and almost the same wide. Japanese knotweed leaves tend to be very square across the base, without basal lobes (figure 1).

Since Bohemian knotweed is a hybrid of giant and Japanese knotweeds, its leaves are a blend of both species: they are slightly longer than wide, about midway between Japanese and giant in size, and are usually shallowly cordate at the base (figure 4).

Himalayan knotweed bears slender leaves up to about 10 inches long and 2 inches wide (figure 6).

Giant, Japanese, and bohemian knotweeds bear short, even-edged stipules above their leaf nodes. However, Himalayan knotweed stipules are long, pointed, and often curled at the tip (figure 7).

Figure 5. Giant knotweed leaves grow to a foot long and are more elongate in outline than those of Japanese and Bohemian knotweeds. Stems may exceed 12 feet tall and are usually thicker and less mottled than Japanese or Bohemian knotweed.

Figure 6. Himalayan knotweed has long, slender leaves.

Figure 7. The sheathing stipule on Himalayan knotweed is long, pointed, and often curled at the tip.

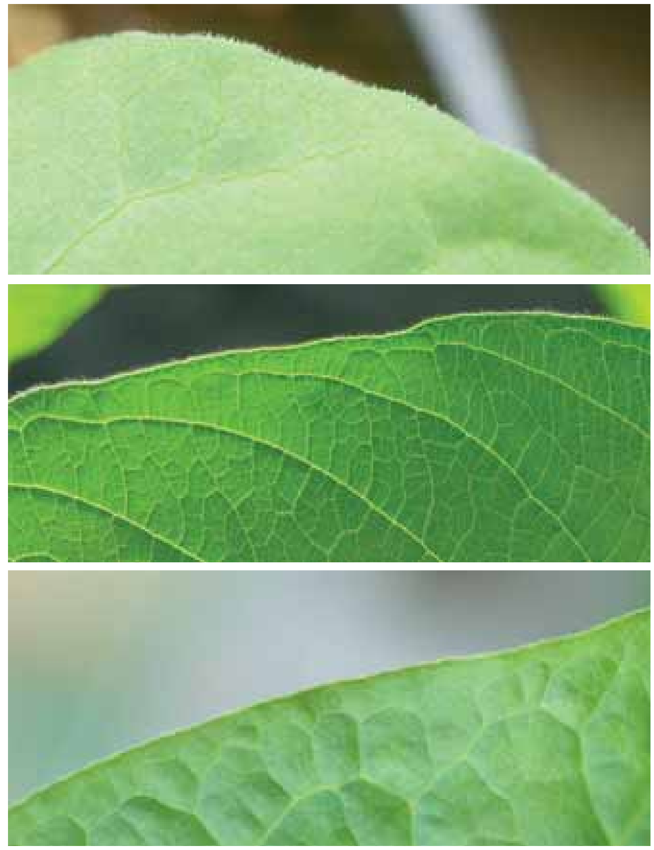

Figure 8. Giant knotweed (top) and Himalayan knotweed (center) may have hairs along the leaf margins. Japanese knotweed leaf margins (bottom) are hairless. Bohemian knotweed leaf margins are generally hairless as well.

Knotweed leaves differ in the type of hairs found on their surfaces. Giant and Himalayan knotweed leaves bear the longest hairs of all the knotweed species. These hairs occur along the veins on their undersides and along the margins. Japanese knotweed leaves, conversely, are nearly hairless, bearing only a few bump-like hairs along the veins on their undersides. Bohemian knotweed leaves have shorter and fewer hairs than giant, but longer and more numerous hairs than Japanese. Generally, Bohemian knotweed leaves have almost no hairs along the margins (figure 8). A 20-power magnifying lens is helpful when observing these hairs.

The University of Leicester Department of Biology has posted magnified photos of the hairs on knotweed leaves on their web site: http://www.le.ac.uk/bl/staff/jpb/ident.htm. These photos show that giant knotweed leaf hairs are composed of numerous cells, whereas Japanese knotweed leaf hairs are composed of only one cell each.

Table 1 lists characteristics of the various knotweeds to help you identify them.

Table 1. Knotweed characteristics

SPECIES	STEMS	LEAVES	FLOWERS
Japanese knotweed (*Fallopia cuspidatum*)	5 to 8 feet tall and branches profusely Zig-zag stem Swollen nodes Sheathing stipules	Leaves are 4 to 7 inches long Mid-stem leaves are less than 7 inches long Mid-stem leaves have squared base (not lobed) or are slightly wedge-shaped Leaf tip gradually tapers to a sharp point with concave sides Very few bump-like hairs on lower leaf surface	Female flower clusters appear as drooping panicles Greenish-white to white; inflorescence (flower cluster) has simple hairs calyx strongly winged; seeds $\frac{1}{16}$ inch long Inflorescence is longer than or of equal length to the leaf directly below (subtending leaf)
Giant knotweed (Sakhalin) (*Fallopia sachalinensis*)	8 to 12 feet tall and branches sparingly Stems are usually thicker and less mottled than Japanese or Bohemian knotweed Straight stem	Leaves are thin, 6 to 12 inches long, and two-thirds as wide Mid-stem leaves often greater than 12 inches long Leaves are more elongate in outline than Japanese or Bohemian knotweed Lower leaf shape deeply heart shaped Leaf tip evenly tapered to a blunt or short-acute tip Hairs on margin and multicelluar hairs on underside of leaf	Flowers are self-fertile Sepals are $\frac{1}{8}$ to $\frac{3}{8}$ inch long, greenish Inflorescence much shorter than subtending mid-branch leaf
Bohemian knotweed (*Fallopia* X *bohemicum*) Hybrid of giant and Japanese knotweeds	7 to 15 feet tall, intermediate in height between Japanese knotweed and giant knotweed Zig-zag stem Swollen nodes Sheathing stipules	Leaves are thicker and tougher than giant knotweed; length and size are between Japanese knotweed and giant knotweed Lower leaf shape variable; most are slightly cordate (heart-shaped) Leaf tip intermediate between Japanese knotweed and giant knotweed Few or no hairs on margin or on underside of leaf; hairs are broad-based, stout, and single-celled	Male flowers potentially fertile Inflorescence appears as erect panicle Inflorescence length variable between Japanese knotweed and giant knotweed, usually shorter than or as long as subtending leaf
Himalayan knotweed (*Polygonum polystachyum*)	6 feet tall	Leaves are oblong to lance shaped, 4 to 8 inches long Lower leaf slightly heart-shaped to tapered at the base Leaf tip tapered to a sharp point Hairs on lower leaf surface often with short simple hairs	Flowers are self-fertile Inflorescence large, spreading, no hairs Flowers are white to pink and occur in loose, branched clusters
Low Japanese fleeceflower (*Fallopia japonica* var. *compactum*)	1-2 feet tall	Leaves are leathery, short-oval to circular in shape, margins crimped, 3 to 6 inches long Lower leaf shape abrupt or truncate (squared off at the base) Leaf tip abruptly pointed	Small greenish white flowers and small reddish fruits

WHERE DOES KNOTWEED GROW?

It can be helpful to know under what conditions the different knotweeds grow. This can help you identify the knotweeds, since some knotweeds are found in only certain kinds of growing conditions. Japanese knotweed tends to like a soil on the acidic side, with a pH of 4 to 7.4 (Yoshioka 1974; Hirose and Tateno 1984) and soil textures from sand to silt loam (Locandro 1973). Plants will tend to be smaller in shady areas, since shading limits growth—Japanese knotweed needs at least 20% of full sunlight hitting the leaves (Beerling 1991). Annual precipitation requirements are more than 20 inches per year. They tend not to like summer drought (Beerling 1994). That said, some dry sites also have Japanese knotweed present (Locandro 1973). In Europe, the Japanese knotweed's northern distribution limit appears to correspond to a climatic zone with less than 120 frost-free days (Beerling 1994).

Giant knotweed is not as well studied, yet habitat requirements are considered similar to Japanese knotweed.

In India, Himalayan knotweed is relegated to disturbed areas at an altitudinal range of 9,900 to 10,500 feet (Kala 2004) and in Afghanistan to altitudes from 9,000 to 11,400 feet (Polunin and Stainton 1984). Environmental and soil characteristics of the Valley of Flowers National Park, India, where Himalayan knotweed occurs, include soil pH range of 3.8 to 6.2, soil nitrogen range of 0.3 to 4.5%, soil organic carbon 4 to 34%, and a growing season that spanned 3 to 4 months. Very little is known about habitat requirements of low Japanese fleeceflower, but it is considered naturalized in the British Isles (Beerling et al 1994).

Japanese knotweed and Bohemian knotweed are limited to riparian areas of drier inland environments of the Pacific Northwest (PNW). In Idaho, Bohemian knotweed is more commonly found than Japanese knotweed. Giant knotweed's distribution overlaps with Japanese and Bohemian knotweeds, but giant knotweed is not as prevalent. Himalayan knotweed is distributed primarily on the coast of Oregon and Washington, and it is not as prevalent as Japanese or Bohemian knotweeds. Low Japanese fleeceflower is the least prevalent in the wild, but it has escaped cultivation on at least one site in Idaho.

HOW DOES KNOTWEED REPRODUCE?

Knotweeds can reproduce by seed or by rhizomes. Japanese knotweed tends not to produce seed because most Japanese knotweed plants in North America and Great Britain bear female flowers. Bohemian knotweed flowers are often male. When Bohemian and Japanese knotweeds grow near each other, the Japanese knotweed will produce viable seed, as has been reported in Washington state. See figure 9 for a comparison of Japanese and Bohemian knotweed flowers.

Giant knotweed and Himalayan knotweed do reliably produce seeds (figure 10) because their flowers are "perfect"—each flower bears both male stamens and a female pistil. Low Japanese fleeceflower also has perfect flowers, although seed production is low.

Figure 9. Female flowers from Japanese knotweed (a) and male flowers from Bohemian knotweed (b).

Figure 10. Giant knotweed seed

Analysis of DNA in Bohemian knotweed in New England demonstrates complex hybridization that not only results in fertile seed production but could also potentially create hybrids that could require different strategies for management (Gammon 2007).

When knotweed plants produce seed, each is encased in a papery husk that seems made to order to float away and eventually begin new knotweed infestations far downstream. In Pennsylvania, seedling recruitment studies suggested seedling density ranged from 60 to 900 plants per square yard (Bram and McNair 2004).

Knotweed seedlings generally have low vigor and tend not to survive. Therefore, the primary means of reproduction for these knotweeds is apparently vegetative. Each plant produces a mass of ½- to 1-inch thick rhizomes. In addition, the stems are capable of producing new shoots and roots from their nodes. In greenhouse research conducted by Tim Miller at Washington State University with Bohemian and giant knotweeds in 2000 and 2001, rhizome sections produced about twice as many shoots as did stem sections of the same length. Over half of the 2-inch rhizome sections studied produced shoots within 6 weeks, while about half the studied stem sections shorter than 4 inches produced a new shoot. Significantly, all stem sections 16 inches long produced at least one shoot. Due to the sheer size of its root system, established knotweed is able to withstand most mechanical control efforts employed against it and to resprout vigorously.

While many knotweed species do not form arbuscular mycorrhizal associations, Japanese knotweed does form mycorrhizal relationships with fungi (Wu et al. 2004). This allows Japanese knotweed to capture additional soil resources, thus helping it to outcompete native plants. It is not known if the other knotweeds discussed here form mycorrhizal relationships.

MANAGEMENT

Cultural and Mechanical

Land managers are often interested in mechanical means of controlling knotweeds. However, we have found that mechanical means are impractical. For example, grazing with sheep or cows reduces shoot density by only 50% and will not eradicate these weeds. Hand pulling is not successful because it tends not to remove the woody root crown. In fact, hand pulling may increase spread (Beerling 1991). Mowing may be effective if shoots are removed as they form, but few people will want to invest the time and energy it takes to exhaust the carbohydrate reserves found in knotweed roots and rhizomes. While it is difficult to generalize, anecdotal evidence suggests that stems must be mowed or cut at least twice a month during the first growing season, and then monthly over the course of 3 years, to completely kill knotweed. In fact, one anecdotal report indicated that when knotweed stems were removed only once a month from April to October for three years, stem numbers actually increased.

Herbicides

Knotweeds can be controlled with herbicides. To date, efforts have centered on foliar applications of glyphosate, triclopyr, and imazapyr. There are aquatic labels for each of these materials. Remember that aquatic glyphosate products require the addition of surfactant prior to application. (*NOTE: if applying any herbicide to an aquatic site, additional licensing from state agencies will be necessary*.)

Unpublished studies from Washington State University used foliar-applied glyphosate, triclopyr, and imazapyr on Bohemian, giant, and Himalayan knotweed transplants in the greenhouse. The studies indicated that triclopyr results in quick symptom expression (usually within 48 hours) and defoliation within two weeks. Glyphosate and imazapyr did not produce symptoms until about one week following treatment, and defoliation had only progressed to about 50% three weeks after treatment.

At three weeks after treatment, plants were clipped and knotweed regrowth was monitored for the next eight weeks. In this study, imazapyr was the most active product on knotweed, as knotweed transplants did not regrow when treated with imazapyr, applied either alone or tank-mixed with glyphosate or triclopyr. Bohemian knotweed control 11 weeks after treatment of regrowth with glyphosate was 90% (compared to regrowth of untreated plants), while triclopyr gave 96% control. While knotweed in the field will likely require higher dosages of herbicide to achieve similar levels of control, it appears that all three of these herbicides alone or in combination will aid in the control of these species.

One problem with using herbicides is that they kill not only knotweeds but also nearby native plants. A new method of knotweed control recently evaluated in the Pacific Northwest involves injecting herbicide directly into the hollow knotweed stem. This method targets only knotweeds and can spare native plants. Formulations of glyphosate (Aquamaster [Monsanto] and Glypro [Dow]) for aquatic applications are currently registered for this application method on supplemental product labels in selected states. Up to 5 milliliters of undiluted product is injected into knotweed stems about 6 inches from the ground using a syringe. An awl may be used to first punch a hole into the stem just below a node, or a specially-designed injection gun may be purchased (www.jkinjectiontools.com) which performs both functions in a single operation. Note that herbicide labels stipulate the maximum number of stems which may be treated per acre using this method.

Results from Washington State University field tests with injection techniques on giant and Bohemian knotweeds showed that glyphosate provided 91 to 100% control of stems and crowns by 8 weeks after treatment. However, this method can be extremely labor-intensive. Other herbicides may also be effective when applied via stem injection, but currently may not be labeled for application by this method.

Another method of application which can spare native plants, and which is less labor-intensive than injection, involves wiping the lower 3 feet of knotweed stems with 33% herbicide solutions using a sponge paint-brush (Aquamaster, Garlon, or Arsenal Powerline). Wiping uncut stems resulted in 63 to 80% stem control by 8 weeks after treatment, while wiping stems whose tops had been cut off at a height of 3 feet resulted in 97 to 100% stem control. Knotweed control at one year after treatment was similar for all treatments, however. Often, knotweed stands are not accessible for herbicide applications given their large dense nature. Cutting the stands down can increase accessibility. If stands are cut to increase accessibility without immediate treatment of cut stems, then treatment with herbicides should be delayed until the crowns have sprouted new stems and leaves.

Yet another herbicide application method involves the use of imazapyr applied as an inverted emulsion to actively growing plants using special equipment. This technique has proven to be effective in the eastern U.S. The technique allows users to target imazapyr to knotweeds. The larger droplet size reduces drift to native plants, and the low volume of 3 to 5 gallons of inverted emulsion stays on the leaves rather than dripping to the ground. Aquatic labels for imazapyr and the inverted emulsion (ThinVert) allow for applications to be adjacent to waterways. (Note: ThinVert is not registered in the state of Washington).

Biological Control

No biological control agents have been approved for release in North America. However, several potential biocontrol agents are being evaluated both in the U.S. and at CABI Bioscience in England. The sap-sucker *Aphalara itadori* (Psyllidae) is a highly specific knotweed specialist whose nymphs are capable of killing plants in the laboratory. These insects can impact plant height and leaf production even at low insect density. The leafspot fungus *Mycosphaerella* spp. is a common knotweed pathogen that is highly damaging to knotweed in the field and laboratory. Additional agents being tested are the stem boring sawfly *Ametastegia polygoni*, the stem boring moth *Ostrinia ovalipennis*, and the leaf beetle *Gallerucida bifasciata*.

SUMMARY

Knotweeds continue to infest our riparian systems and decrease bank stability, limit terrestrial insect diversity, and reduce the diversity of food for plant-feeding aquatic insects. Because knotweeds can hybridize and in some cases produce seed, we need to effectively manage infestations of these plants before they get even further out of control. Currently the methods of control that have greatest effectiveness involve the use of herbicides. Techniques for applying these herbicides to reduce non-target effects are available and effective. Biological control is under investigation but organisms are not currently available.

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