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North-East, North-Central, Mid-Atlantic United States and Southern Canada: Japanese Hedgeparsley (*Torilis japonica*)—A New Invasive Species in the United States?

Antonio DiTommaso, Stephen J. Darbyshire, Caroline A. Marschner, and Kristine M. Averill*

Japanese hedgeparsley is an annual (or sometimes biennial) forb introduced from Eurasia and found throughout much of the eastern United States and parts of extreme southern Canada. In North America, Japanese hedgeparsley is commonly found in ruderal habitats, such as roadsides, railroad rights-of-way, forest edges, and urban waste spaces. This species has not yet been listed as a noxious invasive, but its expanding populations have caused concern in several Midwestern states. The primary threat from Japanese hedgeparsley is its vigorous growth habit, which creates dense patches, and its dispersal ability, facilitated by its clinging, burr-like fruits. Some confusion on identification exists within the *Torilis* genus, with similar species (particularly *T. arvensis*) frequently misidentified in herbaria and the literature. Here, we review aspects of the etymology, taxonomy, biology, distribution, and management of Japanese hedgeparsley with the objective of increasing awareness of the potential threat posed by this species and its closely related congeners.
Nomenclature: Japanese hedgeparsley, *Torilis japonica* (Houtt.) DC.; hedgeparsley, *Torilis arvensis* (Huds.) Link.
Key words: Apiaceae, *Torilis*, distribution, invasive species, ruderal, understory vegetation.

Japanese hedgeparsley [*Torilis japonica* (Houtt.) DC.] is an annual (or sometimes biennial) forb in the family Apiaceae (also known as Umbelliferae) (Zomlefer 1994), subfamily Apioideae, tribe Torilidinae (Downie 2000). Apiaceae is represented by about 94 genera and 440 species in the United States and Canada (Zomlefer 1994) and by more than 220 genera and about 3,500 species worldwide (Hiroe 1979). Despite the cosmopolitan distribution of the Apiaceae and its distinctive unifying characteristics, there is no widely accepted modern classification within the family. Classifications based on morphological characters have recently been challenged by the findings of molecular studies (Downie 1998, 2000).

The genus *Torilis* is estimated to include between 12 (Mabberley 1987) and 20 (Menglan and Watson 2005) annual, or sometimes biennial, species occurring through Europe, North Africa, and Asia. Five species have been introduced to North America (Kartesz 2013) including hedgeparsley, Japanese hedgeparsley, knotted hedgeparsley [*Torilis nodosa* (L.) Gaertn.], bristlefruit hedgeparsley [*Torilis leptophylla* (L.) Rchb. f.], and rough hedgeparsley (*Torilis henryi* C. Norman) [often reported as *Torilis scabra* (Thunb.) DC.], but only the first three have established as weeds.

Although the specific epithet *japonica* means "of Japan," the plant is naturally distributed from western Europe through central Asia to northern Japan and the Mediterranean parts of North Africa (Hultén and Fries 1986). Synonyms for Japanese hedgeparsley include *Tordylium anthriscus* L., *Caucalis anthriscus* (L.) Huds., *Anthriscus vulgaris* Bernh., *Torilis anthriscus* (L.) C. C. Gmel., *Caucalis japonica* Houtt., and *Torilis anthriscus* var. *japonica* (Houtt.) H. Boissieu [for additional synonyms see Hiroe (1979)]. Common names for this plant include Japanese hedgeparsley (Vandelook 2008), erect hedgeparsley (USDA 2007), upright hedgeparsley, and hemlock chervil (which can refer to either *T. japonica* or *T. arvensis*) (Steyermark 1963; Yatskievych 2006).

Description, Growth, and Development

Japanese hedgeparsley is a slender herbaceous plant that can grow to > 1 m (3.3 ft) in height (Gleason and Cronquist 1991). Its stout taproot can have multiple stems

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Figure 1. Species of *Torilis* established in North America. (A) *T. arvensis* (Curtis 1789 to 1798). (B) *T. japonica* (Thomé 1921). (C) *T. nodosa* (Syme 1873): (1) (cross-section) and (2) (lateral view), central schizocarp with both mericarps tuberculate and lacking spines; (3) (cross-section) and (4) (lateral view), outer schizocarp with one spiny mericarp; (5) detail of barbed mericarp spine.

emerging, and the ridged stems have a branching habit. The alternate leaves are deltoid or lance-ovate in outline and two to three times pinnately divided (Gleason and Cronquist 1991), with the leaves toward the base of the plant more heavily divided. Each leaf has three (to five) deltoid and pinnate or lance-shaped and toothed leaflets, with the center (terminal) leaflet being the largest (Czarapata 2005) (Figure 1B). The plant produces both axillary and terminal compound umbels that are loose and open (Figure 1B). The inflorescence is similar in *T. arvensis* (Figure 1A), but in *T. nodosa*, the short peduncle ($<$ 1 cm long [0.4 in]), and rays result in a compact, globose inflorescence close to the stem (Figures 1C and 2C). Each umbel of *T. japonica* is subtended by five to six, more or less, lanceolate bracts, whereas in *T. arvensis*, there are only zero to one (to three) bracts. Flowers have five pinkish-white petals that are unequal and free, the largest up to 2 mm (0.08 in) long and broad. Flowers are bisexual at the center and staminate at the margin of each umbel. Five stamens alternate with the petals and there are two styles. The ovary is inferior. The stylopodium (enlarged style bases) is broadly conic (Gleason and Cronquist 1991). Fruits are schizocarps (dry indehiscent fruits with two locules), which split into two, more or less cylindrical, one-seeded segments called mericarps (Figures 1C, 2B, and 2C); the mericarps are five-ribbed (three prominent dorsal ribs and two, more or less obscure, lateral ribs) (Figure 2A), about 4 mm long with curved spines (Figure 2D), which make them highly effective burrs (Couvreur et al. 2004; Grime 1988; Tutin et al. 1968). In *T. japonica*, both mericarps of all schizocarps are beset with forward-curved spines, most of which are tipped with a single, straight spicule (Figure 2D). The schizocarps of *T. arvensis* mostly have both mericarps spiny, although sometimes in fruits at the outer part of the umbel one of the mericarps (the inner one) has only stubby bristles or tubercles (Figure 2B). The mericarp spines are more or less straight and have zero to two, backward-pointing apical spicules (Figure 2E), which act as barbs (glochidiate). In *T. nodosa*, the presence and characteristics of the spines are similar to *T. arvensis* (Figures 1C3–5), except that none of the schizocarps have both mericarps spiny, and the one to three schizocarps in the center of the umbel entirely lack spines, with both the mericarps bearing only tubercles (Figures 1C1 and 2 and 2C). As well as the terminal spicule(s), mericarp spines of all three species have smaller spicules along their length.

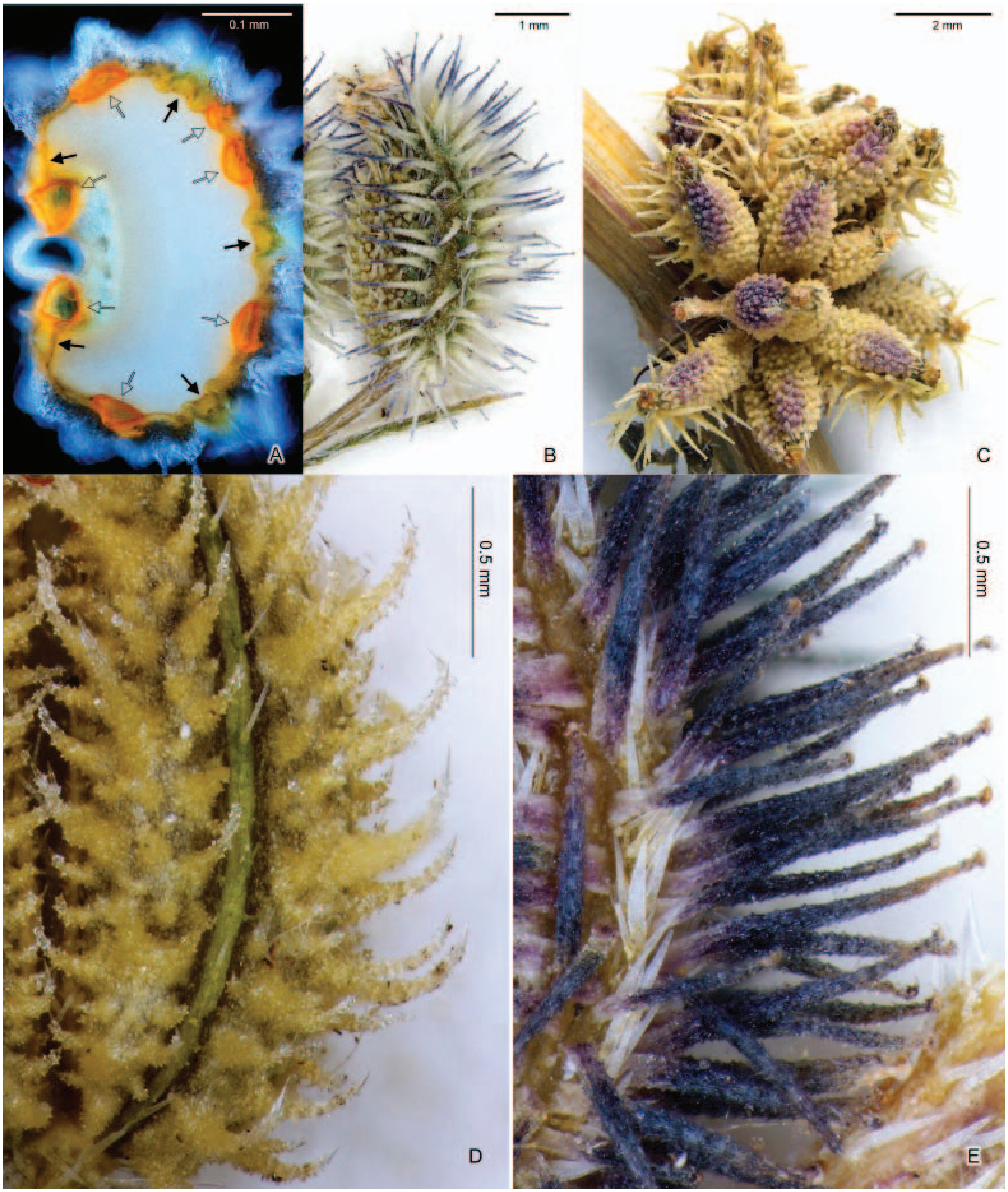

Figure 2. Fruits of *Torilis* species. (A) *T. japonica* cross-section of mericarp showing ribs (solid arrows) and oil tubes (outline arrows). (B) *T. arvensis* schizocarp, mericarp to right, with long, barbed spines; mericarp to the left with tubercles. (C) *T. nodosa* sessile lateral umbel (with two umbellets), both mericarps of central schizocarps tuberculate and lacking long spines, outer mericarps of the outer schizocarps with long spines. (D) *T. japonica* mericarp with scattered, fine hairs on rib and erect spicules at the apex of curved spines. (E) *T. arvensis* mericarp with stout, white hairs obscuring rib and backward-pointing spicules at the apex of straight spines.

Table 1. Key to *Torilis* species established in North America.

1. Umbels usually in leaf axils, very compact, peduncles short and not exceeding 1 cm (Figures 1C and 2C); the central schizocarps in each umbellet with both mericarps tuberculate and peripheral schizocarps with only the outer mericarp spiny (Figures 1C and 2C)	*Torilis nodosa*
1. Umbels mostly terminal, open with conspicuous rays and peduncles, peduncles 2–12 cm (Figures 1A and 1B); schizocarps with both mericarps spiny or sometimes with 1 mericarp tuberculate (Figures 2B, 2D, 2E).	
2. Involucre of umbel with five to six bracts; schizocarps with strongly forward-curved spines, the apices acute with a single erect spicule, elsewhere on the spines spicules smaller and erect or forward-pointing; mericarps with more or less conspicuous green dorsal ribs, the ribs glabrous or with a few scattered hairs not obscuring the ribs (Figure 2D)	*Torilis japonica*
2. Involucre of umbel with zero to three bracts; schizocarps more or less straight to slightly forward-curved spines, the apices barbed with one to two backward-pointing spicules, elsewhere on the spines spicules smaller and erect to backward-pointing; mature mericarp with inconspicuous dorsal ribs, which are obscured by lines of white hairs similar to those on pedicels (Figure 2E)	*Torilis arvensis*

These spicules are erect in *T. japonica* but tend to be slightly backward curved in *T. arvensis* and *T. nodosa*. For further clarification, see the key (Table 1).

Two other species of *Torilis* have been collected in North America, but they have probably not persisted. They resemble *T. arvensis*. The European *T. leptophylla* can be distinguished by the axillary umbels on peduncles that are 2 to 5 cm long and with two to three rays; it has been collected in Massachusetts and Pennsylvania. The east Asian *T. henryi* [often reported as *T. scabra*] has umbels with about three rays and schizocarps that are 5 to 6 mm long (schizocarps are ≤ 5 mm in the three established species); it has been collected in Oregon.

There are many white-flowered, umbelliferous plants with pinnately compound leaves; several of which are also weedy exotics. Wild carrot (*Daucus carota* L.) has similar, finely divided leaves, but the underside of its leaves and stems are pubescent with spreading hairs (both sides of leaves and stems are pubescent with adpressed hairs in Japanese hedgeparsley), the umbel is much larger and denser, with about eight, deeply divided, involucral bracts (the involucral bracts of *T. japonica* and *T. arvensis* are linear and not divided), and when crushed, it smells like carrots. Other weedy exotic look-alikes for Japanese hedgeparsley include wild chervil [*Anthriscus sylvestris* (L.) Hoffmann], common caraway (*Carum carvi* L.), poison-hemlock (*Conium maculatum* L.), eastern hemlockparsley [*Conioselinum chinense* (L.) Britton, Sterns & Poggenb.], and the native Clayton's sweetroot [*Osmorhiza claytonii* (Michx.) C.B. Clarke] (WDNR 2013b).

Like most species in the Apiaceae, Japanese hedgeparsley flowers are self-fertile and unspecialized, attracting generalist pollinators. Japanese hedgeparsley mericarps are beset with the spines that attach readily to animal fur (or human clothing) and have the capacity to be dispersed over large distances by zoochory (Couvreur et al. 2004).

Japanese hedgeparsley is reported variously as a summer annual, a biennial, or a winter annual; throughout most of its range, it is either a spring-germinating annual or a biennial, whereas in Japan, it is reported as a winter annual (Masuda and Washitani 1990a,b; Renz 2012; Roberts 1979; Vandelook 2008). Its seeds are governed by morphophysiological dormancy (MPD); i.e., both physiological (PD) and morphological (MD) dormancy. The PD part of MPD is broken by cold stratification, and MD is broken when the embryo matures. The PD part of MPD can undergo cycles in response to temperature and light (Vandelook 2008). In central England, it is an annual or biennial (Tutin 1980; Tutin et al. 1968); most plants germinate January to May, with $< 1\%$ of annual germination occurring in the fall; the plant flowers in July and August, and seeds remain viable in the soil for 3 to 5 yr (Roberts 1979; Tutin 1980). In Europe, it is considered a summer annual or biennial, with seeds dispersed in September and October (Hegi 1975; Vandelook 2008). In Wisconsin, it is considered a biennial that flowers in July and sets seed in August and September (Renz 2012). In Japan, Japanese hedgeparsley was found to emerge primarily in the fall, with some secondary emergence in spring; the cause of this difference in the life cycle is not known (Masuda and Washitani 1990; Vandelook 2008).

Voucher Specimens

Citation of a few voucher specimens is provided for the three *Torilis* species common in North America. Most collections cited will also be represented by duplicate specimens at herbaria other than those cited.

Torilis arvensis (Huds.) Link

CANADA. BRITISH COLUMBIA. Kootenay Boundary Regional District: *Lomer 6271*, 17 Jun 2007 (UBC)

UNITED STATES. CALIFORNIA. Humboldt Co.: *Tracy 17557*, 15 Jun 1946 (DAO). **INDIANA. Switzerland Co.:** *Friesner 23639*, 22 Jul 1950 (DAO). **KANSAS. Douglas Co.:** *Horr E90*, 14 Jul 1935 (DAO). **KEN-**

TUCKY. Boyle Co.: *Welch 9113*, 14 Jul 1947 [1937?] (DAO-2 sheets). **LOUISIANA. Lafayette Parish:** *Thieret 29003*, 10 Jun 1968 (DAO). **MISSOURI. Ralls Co.:** *Hinterthuer 450*, 28 Jun 1973 (DAO). **MISSISSIPPI. Oktibbeha Co.:** *Leidolf 1502*, 21 May 1995 (DAO). **NORTH CAROLINA. Madison Co.:** *Radford 45405*, 27 Jun 1967 (DAO, UBC). **OKLAHOMA. Marshall Co.:** *Goodman 6894*, 2 Jul 1959 (DAO). **OREGON: Benton Co.:** *Dennis & Johnson s.n.*, 27 Jun 1960 (DAO, UBC); **Coos Co.:** *Constance 3453*, 30 Jul 1953 (UBC). **TEXAS. McLennan Co.:** *Burkett 44*, 30 Oct 1971 (DAO). **WASHINGTON. Klickitat Co.:** *Hitchcock & Muhlick 22364*, 19 Jun 1962 (DAO, UBC).

Torilis japonica (Houtt.) DC.

CANADA. BRITISH COLUMBIA. Fraser Valley Regional Dist.: *Glendenning s.n.*, Jul 1950 (UBC). **ONTARIO. Haldimand–Norfolk Regional Municipality:** *Cusick & Oldham 32117*, 20 Sep 1994 (DAO). **QUEBEC. Gatineau Co.:** *Bassett & Mulligan 3212*, 19 Aug 1954 (DAO).

UNITED STATES. INDIANA. Montgomery Co.: *McCoy 5214*, 25 Aug 1940 (DAO). **NEW JERSEY. Cap May Co.:** *Killip 2363*, 15–16 Jul 1917 (DAO). **WASHINGTON. King Co.:** *Zika & Jacobson 17707*, 28 Aug 2002 (DAO).

Torilis nodosa (L.) Gaertn.

CANADA. NEW BRUNSWICK. Charlotte Co.: *Vroom s.n.*, 1882 (DAO).

UNITED STATES. CALIFORNIA. Butte Co.: *Brown 192*, 1–15 Apr 1897 (DAO); **Humboldt Co.:** *Tracy 8183*, 18 Jun 1927 (DAO). **TEXAS. Travis Co.:** *Warnock 46123A*, 13 Apr 1946 (DAO).

Importance

Detrimental Impacts. Japanese hedgeparsley is considered a weedy plant worldwide because of its ability to spread rapidly and form dense populations (Eagan 2006). It is listed as prohibited in northwestern Wisconsin and restricted through the rest of the state (WDNR 2013b). In Wisconsin, natural areas stewards at the Aldo Leopold Foundation and the Department of Natural Resources have found Japanese hedgeparsley establishing in rights-of-way, roadsides, and other edge habitats, and then, spreading into adjoining forests, grasslands, or savannahs (Panke and Renz 2012; Renz 2012; WDNR 2013a).

Although the most common species of *Torilis* in North America, Japanese hedgeparsley is not the only problematic species in the genus. The similar hedgeparsley (*T. arvensis*) is a class B noxious weed with a noxious plant seed and plant quarantine in Washington state (USDA, NRCS 2007 2007). A less-common species, knotted hedgeparsley has also become established as a weed in North America. These three species are also considered agricultural weeds in parts of their native European distribution (Jauzein 1995; Salisbury 1961).

Beneficial Impacts. Japanese hedgeparsley has a long history of use by humans in its native range. Its numerous secondary compounds have a variety of medicinal uses in the traditional medicine of China and eastern Asia, where it is used as treatment for dysentery, fever, hemorrhoids, spasm, and uterine tumors (Duke and Ayensu 1985). Recent medical studies have shown that compounds isolated from Japanese hedgeparsley have a number of potentially cancer-combating effects (Kim et al. 2000; Park et al. 2003, 2006). The terpene torilin has been shown to have cytotoxic effects on human tumors (Park et al. 2006). Additionally, torilin has an inhibitory effect on angiogenesis or the growth of blood vessels, which is a critical phase in the change of tumors from benign to malignant (Kim et al. 2000). Torilin also inhibits the transformation of testosterone into a more potent androgen, which may be useful in the treatment of androgen-dependent cancers, such as prostate cancer and androgen alopecia (Park et al. 2003). These studies were conducted using a variety of methods, including chicken embryonic cells, human and bovine tissue cultures, and live mice. The medical applicability of Japanese hedgeparsley is beyond the scope of this article; for more information, see Park et al. (2003, 2006) and Kim et al. (2000).

Geographical Distribution

The native range of Japanese hedgeparsley extends from Europe to Asia and is somewhat discontinuous between the European continent, Great Britain, southern Norway, and the Caucasus (~35°N to ~65°N) and China, Eastern Russia, Korea, and Japan (~25°N to ~45°N). There are occurrence records across the Eurasian continent around the 30th parallel and a scattering in India, Indonesia, the far northern regions of Africa, and on the Arabic peninsula (Global Biodiversity Information Facility 2014; Hultén and Fries 1986; Meusel et al. 1978). The plant's range is now circumpolar, with North American records from Texas to southern Canada and across the continent (~25°N to ~50°N; Figure 3). Japanese hedgeparsley was recorded in North America at least as early as 1917 in New Jersey (*Killip 2363*). In the Midwest, Japanese hedgeparsley is now considered invasive (Eagan 2006; Panke and Renz 2012). The distribution of the three species of *Torilis* established in North America is shown by state and province in Figure 3 (USDA, NRCS 2007; herbarium specimens).

Figure 3. Distribution of *Torilis* species established in North America by state. (A) *T. japonica*. (B). *T. arvensis*. (C) *T. nodosa*. The distribution in southern Canada is indicated by dots.

Habitat

Climatic Requirements. Japanese hedgeparsley seeds require a period of cold to break the PD part of MPD (Vandelook et al. 2008). In the north-central United States, it is often found in partial to full shade areas, but it can withstand a wide range of light availabilities (Panke and Renz 2012). Its natural distribution is more northerly than hedgeparsley, which is more adapted to Mediterranean climates and is a fall-germinating, winter annual (Baskin and Baskin 1975; Hegi 1975).

Communities in Which the Species Occurs. In Great Britain, Japanese hedgeparsley is among the most-common, July-flowering umbellifers and is widespread in roadsides, hedges, and grassy places (Clapham et al. 1987; Tutin 1980). Common habitats are rock outcrops, disturbed soil, woodland margins, hedgerows, pastures, and rights-of-way. It prefers areas with, at most, a moderate slope and more-calcareous soils but does not grow well in wetlands or cut and grazed habitats. It occurs at low densities, in species-rich, sunny habitats and in less-diverse, low-light plant communities (Grime et al. 1988).

In North America, its habitat includes disturbed upland sites, such as roadsides, urban areas, railroad rights-of-way, thickets, and woodlands (Panke and Renz 2012). Typically, Japanese hedgeparsley establishment begins on a roadside, trail, or forest edge, then spreads into adjacent grasslands and forests (Panke and Renz 2012). Mowing after seed set can facilitate the spread of the species (Panke and Renz 2014).

Management Options

Cultural and Mechanical Control. Although Japanese hedgeparsley is generally not considered an ornamental, it is recommended as a potential medicinal plant for cultivation and may be sold as such (Duke and Ayensu 1985; Plants For A Future 2014). Given its invasive nature, sale of the plant should be discouraged. Once plants are established, pulling or mowing are both recommended for control. For small populations, hand-pulling or cutting the plant at 2.5 to 5 cm below the surface is the recommended control method. If pulled before the plants have visible brown seed, pulled plants may be left on site; after that point, plants have viable seed and should, therefore, be bagged and removed for burning or proper disposal (Renz and Heflin 2014). For larger populations or where hand-pulling is impractical, mowing plants is effective if performed before plants set seed (Renz and Heflin 2014). Renz and Helflin (2014) mowed at several dates from early July through mid-August and found all mowing dates from flowering through green fruit stage to be effective; $< 5\%$ of the 450 mowed plants resprouted in the fall, and none returned the following spring. Plants may reflower, although Renz and Heflin (2014) reported that those flowers did not set germinable seed. Mowing once the plants have set seed, however, will spread the seed instead of controlling the population. Prescribed burning or burning with a propane torch can kill germinating seedlings, but established plants resprout vigorously; burning alone will not control an established population (Panke and Renz 2012).

Biological Control. No effort has yet been made to control Japanese hedgeparsley via biological means. In 1984, a leaf gall-forming fungus was reported on Japanese hedgeparsley in Arkansas, which was tested as a biocontrol agent on Japanese hedgeparsley and 11 other Umbelliferae species. It formed galls on Japanese hedgeparsley and dill (*Anethum graveolens* L.) (Valverde 1984). To our knowledge, no further research on this fungus has been reported.

Chemical Control. The reported herbicides for Japanese hedgeparsley control are glyphosate, triclopyr, and metsulfuron (Panke and Renz 2012; WDNR 2013a). All three are applied to rosettes in the late fall or early spring and to bolting plants.

The University of Wisconsin Extension compiled results for trials of glyphosate applied to rosettes in fall or spring or to bolting plants at 1.7 to 3.36 kg ae ha^{-1} (1.5 to 3 lb ae ac^{-1}) broadcast or 1 to 2% solution for spot application. They reported 70 to 90% control in the year of application, but $< 50\%$ control in the year following application (Panke and Renz 2012). A 1.5% glyphosate application was effective on spring and fall rosettes but not on second-year plants (Aldo Leopold Foundation 2014). A metsulfuron broadcast application at 0.34 to 1.12 kg ha^{-1} and 0.29 g L^{-1} (0.04 oz gal^{-1}) spot application was reported to provide 90 to 100% control in the season of application and 70 to 90% control in the season after application (Panke and Renz 2012). Triclopyr applied at 2.2 to 4.45 kg ha^{-1} broadcast or 1 to 2% solution for spot application was reported to provide 79 to 90% control in the season of application and 50 to 70% in the following season (Panke and Renz 2012). In 2013, the Wisconsin Department of Natural Resources recommended 2,4-D, metsulfuron, or triclopyr, but not glyphosate, for control of this species (WDNR 2013a).

Discussion

Japanese hedgeparsley was introduced to North America from Eurasia by 1917 and has become a problem weed particularly in the north-central United States. Misidentification of this species with closely related species has confused our understanding of its geographic range, life history, and aggressiveness. In this article, we attempted to clarify diagnostic differences between *T. japonica*, *T. arvensis*, and *T. nodosa*, as well as the closely related *T. leptophylla* and *T. henryi*. Careful observation of the spines on the fruit and the number of umbel involucre bracts can distinguish between the established species, as can the spring-germinating habit of *T. japonica* in Europe and North America.

Where Japanese hedgeparsley is spreading, control through hand-pulling or mowing before brown seeds develop can be an effective means of control. The systemic herbicides 2,4-D and triclopyr have also proven effective, although applicators need to be aware of the restrictions on use of both pesticides near water. Glyphosate applications provided more-variable results.

Many questions remain regarding the life history, impact, control, and likely invasiveness of Japanese hedgeparsley. Management studies have mainly been conducted in Wisconsin, with efficacy of control in other climates less well understood. Why Japanese hedgeparsley is invasive in natural areas in North America, whereas it is considered an agricultural weed in Europe and is a minor component of natural area vegetation, is unknown. Similarly, why this species is particularly invasive in the upper Midwest, whereas *T. arvensis* is more of a problem in the Pacific Northwest, is unclear. The effects of Japanese hedgeparsley on native plant communities are undocumented, and the plant's potential response to changing climate has not been studied. All of this information would help clarify our understanding of the effects and appropriate management options of this increasingly common, invasive weed in many regions of North America.

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