



United States Department of Agriculture

United States
Department of
Agriculture

Animal and
Plant Health
Inspection
Service

April 9, 2019

Version 1

Weed Risk Assessment for *Thesium ramosum* Hayne (Thesiaceae) – Thesium



Left: *Thesium ramosum* growing on a southwest-facing slope in Montana, USA (thesium is the rusty-yellow fine-stemmed cover with a spreading growth habit). Top right: Plants. Bottom right: flowers. Source: Matt Lavin, Wikimedia Commons and Flickr.com, licensed by Creative Commons.

AGENCY CONTACT

Plant Epidemiology and Risk Analysis Laboratory
Science and Technology
Plant Protection and Quarantine
Animal and Plant Health Inspection Service
United States Department of Agriculture
1730 Varsity Drive, Suite 300
Raleigh, NC 2760

Executive Summary

The result of the weed risk assessment for *Thesium ramosum* is High Risk of becoming weedy or invasive in the United States. *Thesium ramosum* is a parasitic herb that is found in a variety of open habitats, including natural, agricultural, and anthropogenic systems. In the United States, it is naturalized in ten counties across Idaho, Montana, and North Dakota. In Canada, it was first reported in Fish Creek Provincial Park near Calgary in 2001, and has since spread to many other sites in the park and other areas along the Bow River. All *Thesium* spp. are regulated by the United States Department of Agriculture (USDA) because they are parasitic plants. *Thesium ramosum* has spread outside its native range to other parts of Europe and to North America, likely as a contaminant of grain or hay. This species has been recorded on about a dozen hosts from several plant families, and on grasses and trees. Because it is a generalist parasite, it has the potential to impact a wide range of hosts and is primarily a concern in natural areas. Some Canadian populations of *T. ramosum* are supposedly quite dense and appear to be replacing other species. In Europe, it is reported as a weed of crop fields and of cereals, but no additional information is available as to its impacts. Approximately 80 percent of the United States is climatically suitable for the species to establish. The most likely pathways for entry or further spread in the United States are movement as a contaminant in trade and possibly as a hitchhiker of human foot or vehicular traffic.

1. Plant Information and Background

SPECIES: *Thesium ramosum* Hayne (Brouillet et al., 2010; Nickrent, 2016).

FAMILY: Thesiaceae (sometimes placed in Santalaceae)

SYNONYMS: *Thesium arvense* Horvátovszky (Brouillet et al., 2010); *T. linophyllum* L. var. *ramosum* (Hayne) Fiori; *T. bulgaricum* Velen. (Hendrych, 1964; Xia and Gilbert, 2003).

COMMON NAMES: Field thesium, thesium (Brouillet et al., 2010).

BOTANICAL DESCRIPTION: *Thesium ramosum* is a slender, yellowish-colored, perennial herb, 50-70 cm tall, with small flowers (Moore et al., 2010). It is a hemi-parasite, which means it can absorb nutrients from host plants through specialized root structures (Xia and Gilbert, 2003; AISC, 2014) and photosynthesize its own food. In North America, it is found in riparian areas; on dry, rocky slopes; along roadsides; and in pastureland and open fields (AISC, 2014; Nickrent, 2016; CPNWH, 2019). Members of the family Thesiaceae are host generalists, parasitizing a wide range of plants including monocots, dicots, and occasionally conifers and ferns (Hendrych, 1972; McClay, 2011; Musselman and Hayes, 1996; McLean, 2015). In Montana, *T. ramosum* was reported on **Fabaceae:** *Astragalus miser*, *Thermopsis montana*, and *Trifolium pretense*; **Poaceae:** *Bromus inermis*, *Koeleria macrantha*, *Poa pratensis*, and *P. secunda*; **Equisetaceae:** *Equisetum* spp.; **Iridaceae:** *Iris missouriensis*; **Rosaceae:** *Rosa acicularis*; **Salicaceae:** *Salix* spp.; **Caprifoliaceae:** *Symphoricarpos* sp.; and **Asteraceae:** *Tragopogon dubius* (Musselman and Hayes, 1996).

INITIATION: Due to mutual concern about *T. ramosum* in Canada and the United States, the Plant Health Risk Assessment Unit of the Plant Health Science Division of the Canadian Food Inspection Agency (CFIA) prepared this WRA in collaboration with the Plant Epidemiology and Risk Analysis Laboratory of the United States Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS), Plant Protection and Quarantine (PPQ).

WRA AREA¹: United States and Territories.

FOREIGN DISTRIBUTION: *Thesium ramosum* is native to southeastern Europe and central Asia (Hendrych, 1964; Hendrych, 1968), including Russia and China (Xinjiang) (Xia and Gilbert, 2003). It is introduced north of its native range in Europe (e.g., Belarus, Latvia, Lithuania, and Poland; also casual in the British Isles) (Kalinowski, 2014; Gudžinskas and Žalneravičius, 2017; Kaplan et al., 2017; Randall, 2017; DAISIE, 2019; NOBANIS, 2019) and in North America, where naturalized populations are reported from Canada (Alberta) (Brouillet et al., 2010; McClay, 2011; ANPC, 2013; McClay, 2012;

¹ The “WRA area” is the area in relation to which the weed risk assessment is conducted (definition modified from that for “PRA area”) (IPPC, 2017).

AISC, 2014; Nickrent, 2016; GBIF Secretariat, 2019). All *Thesium* species are regulated as pests by the Republic of Korea (PCIT, 2019).

U.S. DISTRIBUTION AND STATUS: *Thesium ramosum* has been reported from North Dakota, Idaho, and Montana (van Bruggen, 1986; Musselman and Hayes, 1996; CPNWH, 2019; Mincemoyer, 2013; Kartesz, 2015; Nickrent, 2016; Shipunov, 2017; NRCS, 2019). It is not regulated as a Federal Noxious Weed, nor is it regulated in any U.S. state (USDA, 2010; NRCS, 2019); however, all *Thesium* spp. are regulated by the USDA because they are parasitic plants (APHIS, 2018). Figure 1 shows the current distribution of *T. ramosum* in the United States and Canada. It is not known to be cultivated for any purpose (e.g. Bailey and Bailey, 1976; Wiersema and León, 1999; IPK Gatersleben, 2019; University of Minnesota, 2019). We found no evidence of this species is being controlled in the field.

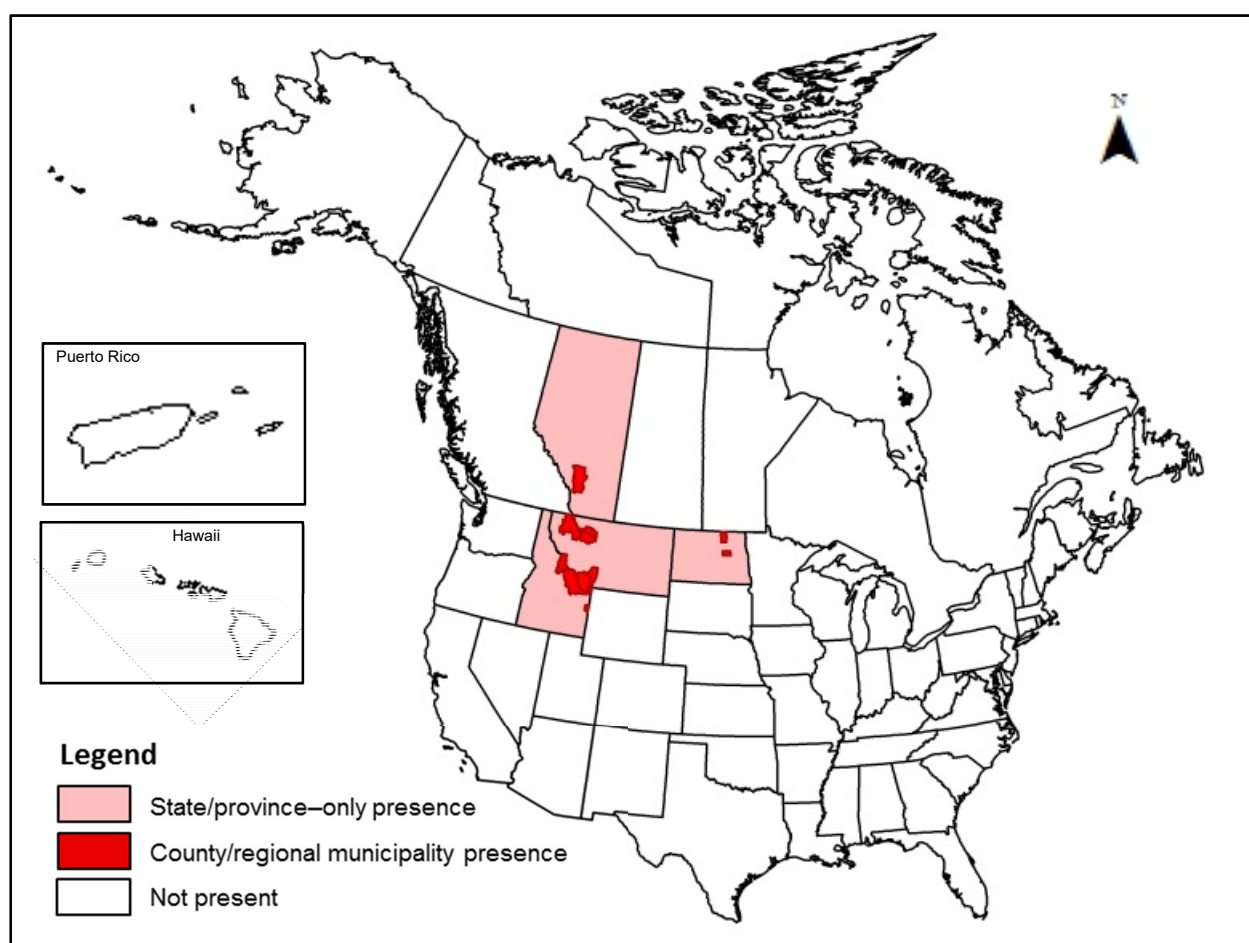


Figure 1. Known naturalized distribution of *Thesium ramosum* in the United States and Canada. The records shown here were obtained primarily from other species distribution databases (CPNWH, 2019; Kartesz, 2015; Nickrent, 2016; Shipunov, 2017; NRCS, 2019) and were not independently verified by PERAL. Map insets for Hawaii and Puerto Rico are not to scale

2. Analysis

ESTABLISHMENT/SPREAD POTENTIAL

Thesium ramosum has naturalized beyond its native range in Europe and North America (Musselman and Hayes, 1996; McLean, 2015; Gudžinskas and Žalneravičius, 2017; Nickrent, 2016). It reproduces by seed, and a single plant can produce 500 to 1500 seeds in a season, flowering early and continuing to produce flowers and seeds until frost (Hendrych, 1972; McLean, 2015; Gudžinskas and Žalneravičius, 2017). Flowers are thought to be pollinated by small bees and flies, and seeds are dispersed by gravity and ants (Hendrych, 1972; Moore et al., 2010; Nickrent, 2016). Seeds may also be dispersed through contaminated seed, grain, hay, or other commodities and possibly in soil or through foot or vehicular traffic (Stevens, 1944; Musselman and Hayes, 1996; McClay, 2011; AISC, 2014; Kalinowski, 2014; Gudžinskas and Žalneravičius, 2017; Kaplan et al., 2017). In the United States, *T. ramosum* is described as common or abundant in several widely separated locations in the three affected U.S. states, while in Canada it has spread to hundreds of sites in Fish Creek Provincial Park near Calgary, Alberta since it was first reported in 2001 (CPNWH, 2019; McClay, 2011; 2012; AISC, 2014; Nickrent, 2016). We had very high uncertainty for this risk element, as specific information was lacking on breeding systems, minimum generation time, seed production and viability, and seed banking, particularly in the introduced range in North America. Information on both natural and human-mediated seed dispersal was mostly speculative or anecdotal.

Risk score = 9.0

Uncertainty index = 0.26

IMPACT POTENTIAL

Thesium ramosum is primarily a concern in natural areas, and it occurs in national and provincial parks in its introduced ranges in Europe and North America (ANPC, 2013; Gudžinskas and Žalneravičius, 2017; Nickrent, 2016). However, relatively little published information about its impacts is available. A recent study in Lithuania indicates that although it is established in Trakai Historical National Park, it is not invasive and “further spread without new introductions is unlikely” (Gudžinskas and Žalneravičius, 2017). In the United States, it was previously noted that it “may prove to be a benign addition to the weed flora” (Musselman and Hayes, 1996); however, concern is now increasing as it spreads further into native prairie systems (McLean, 2018b). In Fish Creek Provincial Park and the adjacent Cross Conservancy in Canada, it occurs in hundreds of open, sunny areas (ANPC, 2013). A researcher from St. Mary’s University in Calgary has observed that some dense populations of *T. ramosum* appear to be replacing other species (McLean, 2018b). Although specific impacts have not been documented, its ability to parasitize a wide range of hosts suggests that it could have an impact on natural plant communities. In Canada, detector dogs have been used in survey efforts (Government of Alberta, 2017) and researchers are testing control methods in experimental plots (St. Mary’s University, 2019).

Thesium ramosum is also reported as an alien plant in a variety of anthropogenic habitats, such as roadsides and railways, in its introduced range in Europe (Kalinowski, 2014; Gudžinskas and Žalneravičius, 2017; Kaplan et al., 2017); however, no evidence of impacts or control efforts was found. It has been reported as a minor weed of agricultural systems in eastern Europe (Williams and Hunyadi, 1987; Kaplan et al., 2017), and it has been reported as a weed of cereals in Estonia, although the details of its introduction are unknown (Gudžinskas and Žalneravičius, 2017). All *Thesium* spp. are

regulated as pests by the Republic of Korea (PCIT, 2019), thus the presence of this weed in agricultural commodities could affect trade. We had very high uncertainty for this risk element due to the fact that impacts of this species in its native range are not well documented.

Risk score = 2.4

Uncertainty index = 0.41

GEOGRAPHIC POTENTIAL

Based on three climatic variables, we estimate that about 80 percent of the United States is suitable for the establishment of *T. ramosum* (Fig. 2). This predicted distribution is based on its known distribution elsewhere in the world, using evidence from both point-referenced localities and general areas of occurrence. The map for *T. ramosum* represents the joint distribution of Plant Hardiness Zones 3 to 9, areas with 0 to 70 inches of annual precipitation, and the following Köppen-Geiger climate classes: steppe, desert, Mediterranean, humid subtropical, marine west coast, humid continental warm summers and humid continental cool summers.

The area of the United States shown to be climatically suitable (Fig. 2) for species establishment considered only three climatic variables. Other variables, such as soil and habitat type, novel climatic conditions, or plant genotypes, may alter the areas in which this species is likely to establish. *Thesium ramosum* is generally described as a "light demanding species of sandy, calcareous dry soils" (Kaplan et al., 2017). In its native range, it is found in meadows, pastures, shady grasslands, dry sunny steppes, saline deserts, and sandy areas and on stony slopes (Hendrych, 1968; Xia and Gilbert, 2003; Bojňanský and Fargašová, 2007). Hendrych (1968) describes it as a plant of low elevations, suggesting that a report from about 6400 feet above sea level may be a misidentification, but Xia and Gilbert (2003) list its elevation range as 5200 to 7500 feet. In North America, it is found in riparian areas, pastureland, and open fields; on dry, rocky slopes; and along roadsides (ANPC, 2013).

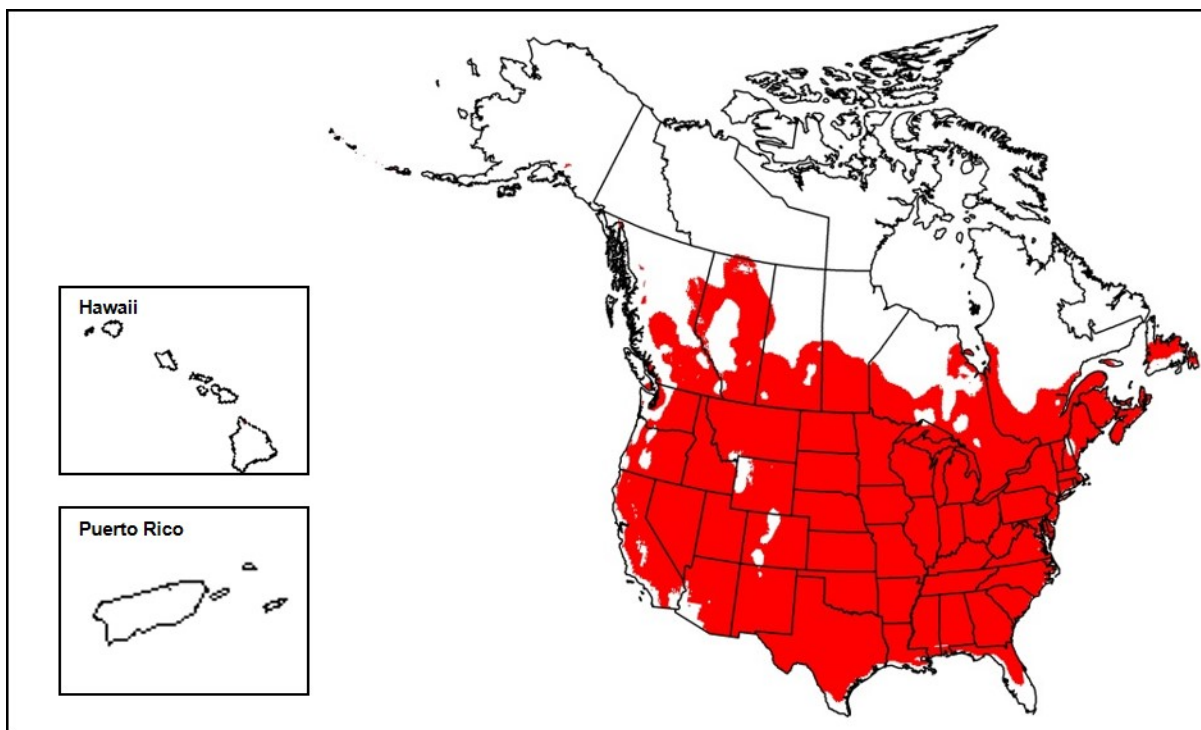


Figure 2. Potential geographic distribution of *Thesium ramosum* in the United States and Canada. Map insets for Hawaii and Puerto Rico are not to scale. For additional on PPQ's climate-matching process see Magarey et al. (2017)

ENTRY POTENTIAL

Thesium ramosum is already present in the United States in Idaho, Montana, and North Dakota. This risk element was evaluated, however, in order to determine how additional material may enter the country. Overall, the most likely pathway by which this species would enter the United States is as a contaminant of seed (Stevens, 1944), grain (Gudžinskas and Žalneravičius, 2017), hay, or straw (McClay, 2011; Musselman and Hayes, 1996). If the species is also dispersed by water or with soil or foot or vehicular traffic (AISC, 2014; Duckworth, 2014), populations near the border may expand into the United States.

Risk score = 0.2

Uncertainty index = 0.08

3. Predictive Risk Model Results

Model Probabilities: P(Major Invader) = 36.1%
P(Minor Invader) = 58.8%
P(Non-Invader) = 5.1%

Risk Result = Evaluate Further

Risk Result after Secondary Screening = High Risk

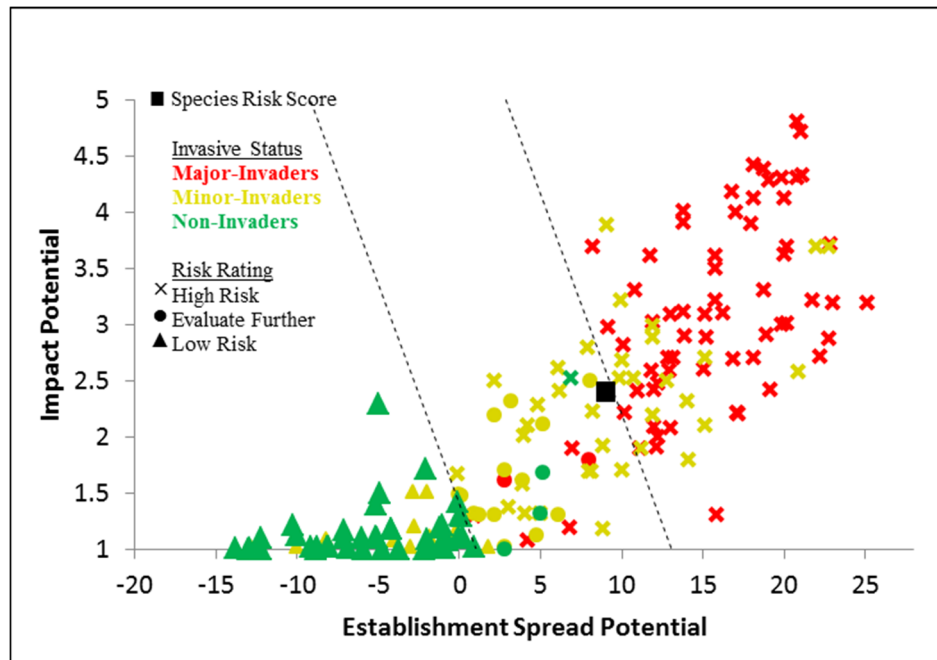


Figure 3. Risk score for *Thesium ramosum*. The risk score for this species (solid black symbol) is plotted relative to the risk scores of the species used to develop and validate the PPQ WRA model (Koop et al., 2011).

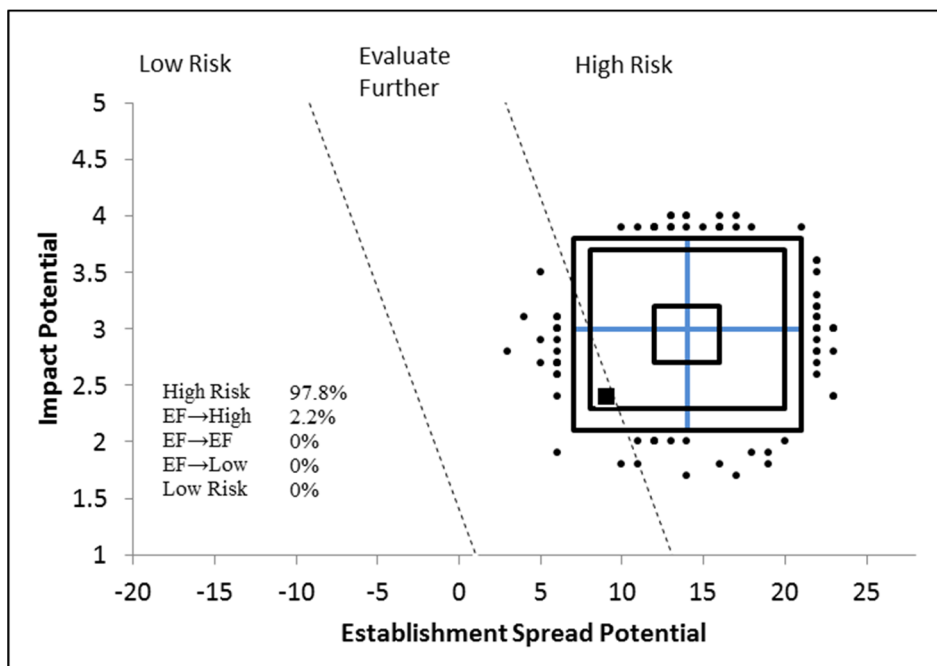


Figure 4. Uncertainty results for *Thesium ramosum*. The results from the uncertainty analysis are plotted around the risk score for thesium. The smallest, black box contains 50 percent of the simulated risk scores, the second box 95 percent, and the largest 99 percent. The black vertical and horizontal lines in the middle of the boxes represent the medians of the simulated risk scores (N=5000). For additional information on the uncertainty analysis used, see Caton et al. (2018).

4. Discussion

The result of the weed risk assessment for *Thesium ramosum* is High Risk of becoming weedy or invasive in the United States. The literature available on this species was limited, leading to a very high level of uncertainty for the establishment/spread risk element and the impact risk element. *Thesium ramosum* is a small, herbaceous, hemiparasitic plant with a wide host range. It can spread via several human-mediated pathways, including contaminated seed, grain, or hay. It has been introduced outside its natural range in Europe and North America, where it grows in natural, anthropogenic, and agricultural habitats. Although the impacts and mechanisms of introduction in these systems are not reported, research is underway in Canada to address these questions as well as on potential control measures and the use of detector dogs for surveys. All *Thesium* spp. are regulated as pests by the Republic of Korea, so the presence of *T. ramosum* in agricultural commodities could affect trade.

We estimate that about 80 percent of the United States is suitable for the establishment of *T. ramosum*, including almost all of the contiguous states (Figure 2). Environmental variables such as soil and habitat type may limit further spread; however, the wide range of habitats from which *T. ramosum* is reported is likely to be well-represented in the area at risk. Based on its High Risk score, *T. ramosum* could establish in the area at risk, although the impact of that establishment is largely unknown.

5. Acknowledgements

AUTHOR

Claire Wilson, Plant Health Risk Assessor, Botany^a
Kimberly Israel, Editor^b

REVIEWERS

Robert Favrin, National Manager^a
Andrea Sissons, Senior Risk Assessor, Botany^a
Karen Castro, Plant Health Risk Assessor, Botany^a
Mary Ann McLean, Associate Professor^c
Anthony L. Koop, Risk Analyst^d

^a Canadian Food Inspection Agency, Plant Health Risk Assessment Unit, Ottawa, Ontario

^b North Carolina State University, Department of Plant Pathology, Raleigh, NC

^c St. Mary's University, Department of Biology, Calgary, Alberta

^d USDA APHIS PPQ CPHST Plant Epidemiology and Risk Analysis Laboratory, Raleigh, NC

SUGGESTED CITATION

PPQ. 2019. Weed risk assessment for *Thesium ramosum* Hayne (Thesiaceae) – Thesium. United States Department of Agriculture, Animal and Plant Health Inspection Service, Plant Protection and Quarantine (PPQ), Raleigh, NC. 24 pp.

DOCUMENT HISTORY

April 9, 2019: Version 1.

6. Literature Cited

- Adams, G. 2018. Review of draft *Thesium ramosum* Weed Risk Assessment 2017-055. Personal communication to C. Wilson on October 29, 2018, from G. Adams (USDA, APHIS, PPQ). Notes archived with the Plant Health Risk Assessment Unit, Canadian Food Inspection Agency, Ottawa.
- AISC. 2014. *Thesium arvense*. Alberta Invasive Species Council. 2 pp.
- ANPC. 2013. Rogues Gallery. Alberta Native Plant Council.
https://www.anpc.ab.ca/wiki/index.php?title=Thesium_arvense. (Archived at PERAL).
- APHIS. 2018. Plants for Planting Manual. United States Department of Agriculture, Animal and Plant Health Inspection Service, Plant Protection and Quarantine, Riverdale, MD. 1366 pp.
- Bailey, L. H., and E. Z. Bailey. 1976. Hortus Third: A Concise Dictionary of Plants Cultivated in the United States and Canada. Macmillan, New York. 1,290 pp.
- Baranova, O. G., and A. N. Puzirjev. 1998. Floristic records in the Udmurt Region. *Botanicheskii zhurnal* 83(5):114-115.
- Bojňanský, V., and A. Fargašová. 2007. Atlas of Seeds and Fruits of Central and East-European flora: The Carpathian Mountains region. Springer, Dordrecht, The Netherlands. 1046 pp.
- Brouillet, L., F. Coursol, S. J. Meades, M. Favreau, M. Anions, P. Belisle, and P. Desmet. 2010. *Thesium ramosum* Hayne: VASCAN, the Database of Vascular Plants of Canada.
<http://data.canadensys.net/vascan/taxon/30188?lang=en>. (Archived at PERAL).
- Caballero, I., J. M. Olano, J. Loidi, and A. Escudero. 2003. Seed bank structure along a semi-arid gypsum gradient in Central Spain. *Journal of Arid Environments* 55:287-299.
- Caton, B. P., A. L. Koop, L. Fowler, L. Newton, and L. Kohl. 2018. Quantitative uncertainty analysis for a weed risk assessment model. *Risk Analysis* DOI:10.1111/risa.12979.
- Cerabolini, B., R. M. Ceriani, M. Caccianiga, R. D. Andreis, and B. Raimondi. 2003. Seed size, shape and persistence in soil: a test on Italian flora from Alps to Mediterranean coasts. *Seed Science Research* 13:75-85.
- Clause, J., S. Barot, and E. Forey. 2016. Earthworms promote greater richness and abundance in the emergence of plant species across a grassland-forest ecotone. *Journal of Plant Ecology* 9(6):703-711.
- CPNWH. 2019. Consortium of Pacific Northwest Herbaria. University of Washington Herbarium.
<http://www.pnwherbaria.org/data/results.php?DisplayAs=WebPage&ExcludeCultivated=Y&GroupBy=ungrouped&SortBy=Year&SortOrder=DESC&SearchAllHerbaria=Y&QueryCount=1&IncludeSynonyms1=Y&Genus1=Thesium&Species1=ramosum&Zoom=4&Lat=55&Lng=-135&PolygonCount=0>. (Archived at PERAL).
- DAISIE. 2019. *Thesium arvense*. DAISIE European Invasive Alien Species Gateway. <http://www.europe-alien.org/speciesFactsheet.do?speciesId=8692#>. (Archived at PERAL).
- Directorate of Plant Protection. 2003. The Plant Quarantine Order, 2003. Directorate of Plant Protection, Quarantine & Storage, Faridabad, India. 302 pp.
- Duckworth, B. 2014. New invader in Alta. soil. *The Western Producer*. Last accessed 2/21/2019,
<https://www.producer.com/2014/06/new-invader-in-alta-soil/>.
- Environment Canada. 2014. Species at Risk: A guide to Canada's species at risk in the Prairie Provinces. Environment Canada, Canadian Wildlife Service, Edmonton, AB. 43 pp.

- Fer, A., N. Russo, P. Simier, M. C. Arnaud, and P. Thalouarn. 1994. Physiological changes in a root hemiparasitic angiosperm, *Thesium humile* (Santalaceae) before and after attachment to the host plant (*Triticum vulgare*). *Journal of Plant Physiology* 423(6):704-710.
- Fer, A., P. Simier, M. C. Arnaud, L. Rey, and S. Renaudin. 1993. Carbon Acquisition and Metabolism in a Root Hemiparasitic Angiosperm, *Thesium humile* (Santalaceae) Growing on Wheat (*Triticum vulgare*). *Australian Journal of Plant Physiology* 20(1):15-24.
- GBIF Secretariat. 2019. GBIF Backbone Taxonomy. <https://www.gbif.org/species/7460783>. (Archived at PERAL).
- Government of Alberta. 2017. Conservation K-9s to detect invasive plant *Thesium arvense* in Fish Creek Provincial Park. 2016-2017 Innovation Fund Project Report, Calgary, AB. 14 pp.
- Gudžinskis, Z., and E. Žalneravičius. 2017. Notes on the enigmatic *Thesium linophyllon* and report on *Thesium ramosum* in Lithuania. *Botanica Lithuanica* 23(2):111-122.
- Heap, I. 2019. The International Survey of Herbicide Resistant Weeds. <http://www.weedscience.com/Summary/Species.aspx>. (Archived at PERAL).
- Hendrych, R. 1964. *Thesium* L. Pages 70-72 in T. G. Tutin, V. H. Heywood, N. A. Burges, D. H. Valentine, S. M. Walters, and D. A. Webb, (eds.). *Flora Europaea*, Volume 1: Lycopodiaceae to Platanaceae. Cambridge University Press, Cambridge, UK.
- Hendrych, R. 1968. A treatise of *Thesium arvense*. *Acta Universitatis Carolinae (Biologica)* 1968:243-262.
- Hendrych, R. 1972. The natural history and systematics of the genus *Thesium* L. *Acta Universitatis Carolinae (Biologica)* 1970:293-358.
- Holm, L. G., J. V. Pancho, J. P. Herberger, and D. L. Plucknett. 1991. *A Geographical Atlas of World Weeds*. Krieger Publishing Company, Malabar, FL. 391 pp.
- Hughes, G., and D. Steindl. 1977. Special issue, sugar-cane diseases. *Cane Growers' Quarterly Bulletin* 41(1):1-24.
- IPK Gatersleben. 2019. Mansfeld's World Database of Agricultural and Horticultural Crops. http://mansfeld.ipk-gatersleben.de/apex/f?p=185:145::NO::P3_BOTNAME:Thesium. (Archived at PERAL).
- IPPC. 2017. International Standards for Phytosanitary Measures No. 5: Glossary of Phytosanitary Terms. Food and Agriculture Organization of the United Nations, Secretariat of the International Plant Protection Convention (IPPC), Rome, Italy. 34 pp.
- Kalinowski, P. 2014. Rzadkie rośliny naczyniowe Podlasia Nadbużańskiego – cz. 3. Gatunki siedlisk antropogenicznych [Rare vascular plants of the Podlasie Nadbużańskie region (eastern Poland) – part 3. Synanthropic plants]. *Fragmenta Floristica et Geobotanica Polonica* 21:253-273.
- Kaplan, Z., J. Danihelka, P. Koutecký, K. Šumberová, L. Ekrt, V. Grulich, R. Řepka, Z. Hroudová, J. Štěpánková, V. Dvořák, M. Dančák, P. Dřevojan, and J. Wild. 2017. Distributions of vascular plants in the Czech Republic. Part 4. *Preslia* 89:115-201.
- Kartesz, J. T. 2015. Taxonomic Data Center. The Biota of North America Program (BONAP). <http://bonap.net/tdc>. (Archived at PERAL).
- Koop, A., L. Fowler, L. Newton, and B. Caton. 2012. Development and validation of a weed screening tool for the United States. *Biological Invasions* 14(2):273-294.
- Kraaij, T., and B. W. van Wilgen. 2014. Drivers, ecology, and management of fire in fynbos. Pages 47-72 in N. Allsopp, J. F. Colville, and G. A. Berboom, (eds.). *Fynbos: ecology, evolution and conservation of a megadiverse region*. Oxford University Press, Oxford, UK.
- Luo, F.-L., and Q.-S. Guo. 2007. Study on endogenesis inhibitory substances in seed of *Thesium chinense* [abstract]. *Zhongguo zhongyao zazhi* 32(17):1737-1739.
- Magarey, R., L. Newton, S. C. Hong, Y. Takeuchi, D. Christie, C. S. Jarnevich, L. Kohl, M. Damus, S. I. Higgins, L. Millar, K. Castro, A. West, J. Hastings, G. Cook, J. Kartesz, and A. L. Koop. 2017. Comparison of four modeling tools for the prediction of potential distribution for non-indigenous weeds in the United States. *Biological Invasions* DOI:10.1007/s10530-10017-11567-10531.
- McClay, A. S. 2011. Weed species assessments for the Alberta Weed Regulation Advisory Committee (AWRAC). McClay Ecoscience, Sherwood Park, AB. 8 pp.

- McClay, A. S. 2012. Revising Alberta's Provincial Weeds List: Experiences and Lessons Learned. 2012 Weeds Across Borders Conference, Meeting the Challenges of the Future, Cancún, Mexico. April 24-27, 2012.
- McLean, M. A. 2015. Parasitism of weeds and native species by a potential weed, the introduced exotic *Thesium ramosum*. Canadian Weed Science Society 69th Annual Meeting, Edmonton, AB. November 23-26, 2015.
- McLean, M. A. 2018a. Comments on draft *Thesium ramosum* Weed Risk Assessment 2017-055. Personal communication to C. Wilson on October 29, 2018, from M.A. McLean (St. Mary's University, Calgary).
- McLean, M. A. 2018b. Questions on the biology and ecology of *Thesium ramosum* in Fish Creek Provincial Park. Personal communication to C. Wilson on February 19, 2018, from M.A. McLean (St. Mary's University, Calgary). Notes archived with the Plant Health Risk Assessment Unit, Canadian Food Inspection Agency, Ottawa, ON.
- Miller, A. G. 1982. *Thesium*. Pages 536-544 in P. H. Davis, (ed.). Flora of Turkey and the East Aegean Islands, Volume 7. Edinburgh University Press, Edinburgh, UK.
- Mincemoyer, S. 2013. Checklist of Montana Vascular Plants. Montana Natuarl Heritage Program, Helena, MT. 97 pp.
- Moore, T. E., G. A. Verboom, and F. Forest. 2010. Phylogenetics and biogeography of the parasitic genus *Thesium* L. (Santalaceae), with an emphasis on the Cape of South Africa. Botanical Journal of the Linnean Society 162:435-452.
- Musselman, L. J. 1982. Parasitic weeds of arable land. Pages 175-185 in W. Holzner and M. Numata, (eds.). Biology and ecology of weeds. Dr. W. Junk, The Hague.
- Musselman, L. J., and S. C. Hayes. 1996. Santalaceae with weed potential in the United States. Pages 521-527 in M. T. Moreno, J. I. Cubero, D. Berner, D. Joel, L. J. Musselman, and C. Parker, (eds.). Advances in Parasitic Plant Research. Junta de Andalucia, Dirección General de Investigación, Cordoba, Spain.
- Nickrent, D. L. 2016. *Thesium ramosum*. Page 415 in Flora of North America North of Mexico, Volume 12. Flora of North America Editorial Committee, New York.
- NOBANIS. 2019. *Thesium arvense* (Santalaceae, Angiosperms). European Network on Invasive Alien Species. <https://www.nobanis.org/species-info/?taxald=1555>. (Archived at PERAL).
- NRCS. 2019. The PLANTS Database. United States Department of Agriculture, Natural Resources Conservation Service. <https://plants.sc.egov.usda.gov/core/profile?symbol=THAR10>. (Archived at PERAL).
- Parker, C., and C. R. Riches. 1993. Other Root Parasites. Pages 165-182 in Parasitic Weeds of the World: Biology and Control. CAB International, Kettering, UK.
- PCIT. 2019. Phytosanitary Export Database (PExD). United States Department of Agriculture, Animal and Plant Health Inspection Service, Phytosanitary Certificate Issuance & Tracking System (PCIT). https://pcit.aphis.usda.gov/PExD/faces/_ADFv_?_afPfm=-13ov94lkqr&t=fred&_vir=/getReportPdf.jsp&loc=en&_minWidth=700&_minHeight=550&_rtrnId=3. (Archived at PERAL).
- PROTA4U. 2019. Plant Resources of Tropical Africa. <https://www.prota4u.org/database/searchresults.asp>. (Archived at PERAL).
- Randall, R. P. 2017. A Global Compendium of Weeds. R.P. Randall, Perth, Australia. 3654 pp.
- Real Jardín Botánico. 2019. Flora iberica: Plantas vasculares de la Península Ibérica e Islas Baleares. Consejo Superior de Investigaciones Científicas, Real Jardín Botánico. http://www.floraiberica.es/eng/PHP/cientificos_.php?gen=Thesium. (Archived at PERAL).
- Reed, C. F. 1977. Economically imporant foreign weeds: Potential problems in the United States (Agriculture Handbook No. 498). United States Department of Agriculture, Animal and Plant Health Inspection Service, Agricultural Research Service, Washington, DC. 746 pp.
- Ricketts, T. H., E. Dinerstein, D. M. Olson, C. J. Loucks, W. Eichbaum, D. Della-Sala, K. Kavanagh, P. Hedae, P. T. Hurley, K. M. Carney, R. Abell, and S. Walters. 1999. Terrestrial ecoregions of North America: a conservation assessment. Island Press, Washington, DC.
- Romo, A., Y. Didukh, and A. Boratynski. 2004. *Thesium* (Santalaceae) in Crimea, Ukraine. Annales botanici fennici 41(4):273-281.
- Shipunov, A. 2017. Flora of North Dakota: Illustrated checklist. Minot State University, Minot, ND. 945 pp.

- Simier, P., A. Fer, and S. Renaudin. 1993. Identification of the Main Osmotically Active Solutes in the Unstressed and Water-stressed Root-hemiparasitic Angiosperm *Thesium humile* and its Host *Triticum vulgare*. *Australian Journal of Plant Physiology* 20(2):223-230.
- St. Mary's University. 2019. Dr. Mary Ann McLean Studies an Invasive Parasitic Plant. St. Mary's University, Biology, Calgary, AB. Last accessed 2/20/2019, <https://www.stmu.ca/scientific-research/>.
- Stevens, O. A. 1944. *Thesium linophyllon* in North Dakota, a first record for North America. *Rhodora* 46:490.
- Suetsugu, K. 2015. Seed dispersal of the hemiparasitic plant *Thesium chinense* by *Tetramorium tsushimae* and *Pristomyrmex punctatus*. *Entomological Science* 18:523-526.
- University of Minnesota. 2019. Plant Information Online. <https://plantinfo.umn.edu/node/1430465>. (Archived at PERAL).
- USDA. 2010. Federal Noxious Weed List. United States Department of Agriculture, Washington, DC. 5 pp.
- USFWS. 2019. Endangered Species. United States Fish and Wildlife Service. <https://www.fws.gov/endangered/?ref=topbar>. (Archived at PERAL).
- van Bruggen, T. 1986. Santalaceae. Pages 531-532 in R. L. McGregor, T. M. Barkley, R. E. Brooks, and E. K. Schofield, (eds.). *Flora of the Great Plains*. University Press of Kansas, Lawrence, KS.
- van Wilgen, B. W., and G. G. Forsyth. 1992. Regeneration strategies in fynbos plants and their influence on the stability of community boundaries after fire. Pages 54-80 in B. W. van Wilgen, D. M. Richardson, F. J. Kruger, and H. J. v. Hensbergen, (eds.). *Fire in South African mountain fynbos: ecosystem, community and species response at Swartboskloof*. Springer-Verlag, Berlin.
- Wiersema, J. H., and B. León. 1999. *World economic plants - A standard reference*. CRC Press, New York. 749 pp.
- Williams, G., and K. Hunyadi. 1987. *Dictionary of Weeds of Eastern Europe*. Elsevier New York. 479 pp.
- Xia, N., and M. G. Gilbert. 2003. Santalaceae. Pages 208-219 in Z. Wu, P. H. Raven, and D. Y. Hong, (eds.). *Flora of China*, Volume 5: Ulmaceae through Basellaceae. Science Press, Beijing.

Appendix A. Weed risk assessment for *Thesium ramosum* Hayes (Thesiaceae)

The following table includes the evidence and associated references used to evaluate the risk potential of this taxon. We also include the answer, uncertainty rating, and score for each question. The Excel file in which this assessment was conducted, is available upon request.

Question ID	Answer - Uncertainty	Score	Notes (and references)
ESTABLISHMENT/SPREAD POTENTIAL			
ES-1 [What is the taxon's establishment and spread status outside its native range? (a) Introduced elsewhere =>75 years ago but not escaped; (b) Introduced <75 years ago but not escaped; (c) Never moved beyond its native range; (d) Escaped/Casual; (e) Naturalized; (f) Invasive; (?) Unknown]	f - negl	5	<i>Thesium ramosum</i> is native to Eurasia, occurring primarily in southeastern Europe and central Asia (Hendrych, 1968; Hendrych, 1964) as well as in China (Xinjiang) (Xia and Gilbert, 2003). It is introduced north of its native range in Europe (e.g., Belarus, Latvia, Lithuania, and Poland), where it is spreading along roadsides and railways (Gudžinskas and Žalneravičius, 2017; Kaplan et al., 2017; Randall, 2017; DAISIE, 2019; NOBANIS, 2019), and in North America, where it is reported from the United States (Idaho, Montana, and North Dakota) and Canada (Alberta) (Brouillet et al., 2010; Nickrent, 2016; NRCS, 2019). In the United States, it was first reported in 1943 in Towner County, ND and was naturalized in that location by 1974. A second population was reported in non-adjacent Eddy County by the mid-1990s, and both are still present (van Bruggen, 1986; Musselman and Hayes, 1996; Nickrent, 2016; Shipunov, 2017). It was reported from Madison County, MT in 1992; from Teton County, ID in 1993; and in several other widely separated locations in Montana between 2003 and 2008, where it is variously described as "common", "locally common", "abundant", and in one case, "growing abundantly and spreading in pasture/hay ground" (CPNWH, 2019; McClay, 2011; Nickrent, 2016). In Canada, it was first reported in Fish Creek Provincial Park near Calgary, Alberta in 2001 and has since spread to "hundreds of sites" in the park (AISC, 2014; McClay, 2011; McClay, 2012; Nickrent, 2016). In 2013, it was also reported in the Cross Conservancy southwest of Calgary, on the other side of the Bow River from previous detections (ANPC, 2013), and since 2016 it has been reported from two other locations along the Bow River: Bowmont Park and Beaverdam Flats (McLean, 2018a). The alternate answers for the uncertainty simulation were both "e".
ES-2 (Is the species highly domesticated)	n - negl	0	<i>Thesium ramosum</i> is not known to be cultivated for any purpose (Bailey and Bailey, 1976; Wiersema and León, 1999; IPK Gatersleben, 2019; University of Minnesota, 2019). Some other <i>Thesium</i> spp. have medicinal uses and may be cultivated on a small scale or collected from the wild (Xia and Gilbert, 2003; PROTA4U, 2019; ANPC, 2013). <i>Thesium</i> spp. are not used as ornamentals because they have a yellowish color, no leaves, and small flowers (Moore et al., 2010). We found no evidence that <i>T.</i>

Weed Risk Assessment for *Thesium ramosum* (thesium)

Question ID	Answer - Uncertainty	Score	Notes (and references)
ES-3 (Significant weedy congeners)	y - negl	1	<p><i>ramosum</i> has been bred for traits that would result in reduced weed potential.</p> <p>A few <i>Thesium</i> spp. are known to parasitize crops. <i>Thesium humile</i> occurs in the western Mediterranean and parasitizes barley, wheat, and other cereals (Musselman, 1982; Fer et al., 1993; Parker and Riches, 1993; Simier et al., 1993; Fer et al., 1994). It is listed as a principal weed in Tunisia and a common weed in Morocco by Holm et al. (1991) and causes yield reductions of 10 to 15 percent in barley in Libya (Parker and Riches, 1993). <i>Thesium resedoides</i> occurs in southern Africa, where it causes serious damage to sugarcane (Musselman, 1982; Parker and Riches, 1993). <i>Thesium australe</i> causes damage to sugarcane in Australia, and young shoots are reportedly killed by 2,4-D, which indicates an attempt to control the weed (Hughes and Steindl, 1977; Musselman, 1982; Holm et al., 1991; Parker and Riches, 1993). It was also noted as an economically important foreign weed of potential concern to the United States by Reed (1977). <i>Thesium humile</i> and <i>T. australe</i> are regulated as quarantine weeds in India (Directorate of Plant Protection, 2003; Randall, 2017).</p>
ES-4 (Shade tolerant at some stage of its life cycle)	n - mod	0	<p><i>Thesium ramosum</i> is generally described as a "light demanding species of sandy, calcareous dry soils" (Kaplan et al., 2017). In Europe, it is found in meadows, pastures, dry sunny steppes, and saline deserts; on stony slopes; and in sandy areas (Hendrych, 1968). In China, it is reported from shady grasslands between 5200 and 7500 feet in elevation (Xia and Gilbert, 2003), but this was the only reference we found to a shady habitat. In North America, it is found in riparian areas; on dry, rocky slopes; along roadsides; and in pastureland and open fields (Nickrent, 2016); and in Fish Creek Provincial Park in Calgary, Canada, it is reported from "open, sunny sites" (ANPC, 2013). Since most habitat descriptions refer to open, sunny conditions, we answered "no" with moderate uncertainty.</p>
ES-5 (Plant a vine or scrambling plant, or forms tightly appressed basal rosettes)	n - negl	0	<p><i>Thesium ramosum</i> is neither a vine nor an herb with a basal rosette. It is a slender, perennial herb, 15-40 cm tall with erect to ascending, highly branched stems (Hendrych, 1964; Xia and Gilbert, 2003; Nickrent, 2016).</p>
ES-6 (Forms dense thickets, patches, or populations)	? - max	0	<p><i>Thesium ramosum</i> is described as low-growing and difficult to detect in surrounding vegetation. Detection dogs have been used to monitor populations in Fish Creek Provincial Park near Calgary, Canada (Government of Alberta, 2017). Some populations in the park are also described as "quite dense" and as appearing to replace other species, although this has not been quantified (McLean, 2018b). Reports from Montana suggest that it is "abundant" in some locations (CPNWH, 2019; McClay, 2011; Nickrent, 2016) (see cover photograph). Population densities measured in Lithuania averaged between 0.35 and 1.05 plants per m² (Gudžinskas and Žalneravičius, 2017). We answered "unknown" due to unclear and conflicting information.</p>

Weed Risk Assessment for *Thesium ramosum* (thesium)

Question ID	Answer - Uncertainty	Score	Notes (and references)
ES-7 (Aquatic)	n - negl	0	<i>Thesium ramosum</i> is a terrestrial species (Hendrych, 1964; 1968; Xia and Gilbert, 2003; Bojňanský and Fargašová, 2007; Kaplan et al., 2017; Nickrent, 2016).
ES-8 (Grass)	n - negl	0	<i>Thesium ramosum</i> is not a grass. It is in the Thesiaceae family (sometimes placed in Santalaceae) (Brouillet et al., 2010; Nickrent, 2016).
ES-9 (Nitrogen-fixing woody plant)	n - negl	0	<i>Thesium ramosum</i> is a slender, perennial, parasitic herb in the Thesiaceae family (Brouillet et al., 2010; Nickrent, 2016). It is not a woody plant and is not known to fix nitrogen.
ES-10 (Does it produce viable seeds or spores)	y - negl	1	<i>Thesium ramosum</i> reproduces by seed (Hendrych, 1972; McLean, 2015; Gudžinskas and Žalneravičius, 2017). North American herbaria collections include plants with flowers and fruits (CPNWH, 2019). Populations studied in Lithuania show evidence of recruitment (Gudžinskas and Žalneravičius, 2017). Populations in Canada include seedlings and young plants in a reproductive state. Roots are "wimpy" and show no evidence of vegetative reproduction (McLean, 2018b); however, seeds have been difficult to germinate (St. Mary's University, 2019). Since we found several sources describing seed reproduction and no indication of vegetative reproduction, we answered "yes" with negligible uncertainty.
ES-11 (Self-compatible or apomictic)	? - max	0	Flowers are small and hermaphroditic, with four or five lobes (Musselman and Hayes, 1996). Autogamy has been described for some <i>Thesium</i> spp. but is considered rare (Hendrych, 1972). We found no evidence of autogamy in <i>T. ramosum</i> .
ES-12 (Requires specialist pollinators)	n - low	0	Most <i>Thesium</i> spp. are probably pollinated by small bees and flies (Hendrych, 1972; Moore et al., 2010). References refer to the genus only, but populations of the species are established and spreading in the PRA area, suggesting they do not need specialist pollinators, so we answered "no" with low uncertainty.
ES-13 [What is the taxon's minimum generation time? (a) less than a year with multiple generations per year; (b) 1 year, usually annuals; (c) 2 or 3 years; (d) more than 3 years; or (?) unknown]	c - high	0	We found no specific evidence about how long it takes <i>T. ramosum</i> to germinate, grow, and produce seed. It is reported as a perennial, rarely a biennial (Hendrych, 1968). Observations in Canada suggest that small plants can flower early in the season and keep producing flowers and seeds until frost (McLean, 2018b). We found no further information on generation time for <i>T. ramosum</i> or its perennial congeners. One species, <i>T. humile</i> , is an annual (Fer et al., 1994). Since <i>T. ramosum</i> is sometimes a biennial, we answered "c". Alternate answers for the uncertainty simulation were b and d.
ES-14 (Prolific seed producer)	n - high	-1	The fruit is a single-seeded nut with a dry perianth; a single plant can produce many fruits (Musselman and Hayes, 1996). Data from Canada suggest that a single plant can produce 500 to 1500 seeds but the source does not report the number of plants per m ² (McLean, 2015), and we found no information on seed viability. Based on the densities of

Weed Risk Assessment for *Thesium ramosum* (thesium)

Question ID	Answer - Uncertainty	Score	Notes (and references)
ES-15 (Propagules likely to be dispersed unintentionally by people)	y - negl	1	0.35 to 1.05 plants per m ² observed in Lithuania (Gudžinskas and Žalneravičius, 2017), it seems unlikely that <i>T. ramosum</i> would produce over 5000 viable seeds/m ² . <i>Thesium ramosum</i> has recently been reported in Lithuania, Belarus, and Poland, where it is spreading along roadsides and railways (Kalinowski, 2014; Gudžinskas and Žalneravičius, 2017; Kaplan et al., 2017). In the Czech Republic, it has spread along railways to central Moravia and Bohemia (Kaplan et al., 2017). It occurs in anthropogenic habitats outside its natural habitat in Europe (Kalinowski, 2014) and in the United States, where it is common along trails and roads in many developments near Bozeman, MT (McClay, 2011). It has been introduced through unknown means into Fish Creek Provincial Park near Calgary, Canada (McClay, 2011; McClay, 2012; Nickrent, 2016), and it is speculated that "seeds would be easily spread in soil and attached to foot or vehicular traffic" (AISC, 2014). Seeds are 2-3 mm long with a persistent perianth; no specific dispersal adaptations such as burrs or stickiness have been reported (Nickrent, 2016).
ES-16 (Propagules likely to disperse in trade as contaminants or hitchhikers)	y - low	2	The first plants reported in North America were found mixed with <i>Bromus inermis</i> along the edges of a grain field; "on account of the location of the plants, the suggestion is rather strong that seeds of the <i>Thesium</i> may have been introduced with <i>Bromus</i> seed" (Stevens, 1944). The species was subsequently reported to be "growing abundantly and spreading in pasture/hay ground" in one site in Montana (McClay, 2011). It is speculated that Montana populations may have come from neighboring North Dakota in hay brought by big game hunting outfitters for their horses (Musselman and Hayes, 1996). <i>Thesium ramosum</i> has been recorded as an alien species in cereal crops in Estonia and is believed to have been introduced with grain (Gudžinskas and Žalneravičius, 2017). The probable pathways of introduction in Lithuania are speculated to be seeds of forage herbs or other cultivated plants (Gudžinskas and Žalneravičius, 2017).
ES-17 (Number of natural dispersal vectors)	1	-2	Propagule traits for questions ES-17a through ES-17e: Fruits are single-seeded nutlets (achenes), 4-6 mm long and glabrous with raised, longitudinal parallel nerves on the ovary wall (ANPC, 2013). The basal portion is a swollen pedicel, 1.5-2 mm long; the central portion is 2-3 mm long; and the perianth, which persists at the apex, is 1-2 mm long (Nickrent, 2016). Dispersal mechanisms for the genus are reported as "simple bathychory," which may mean dispersal by falling, and dispersal by ants (Hendrych, 1972).
ES-17a (Wind dispersal)	n - mod		We found no evidence, and the seeds have no obvious adaptations for wind dispersal.
ES-17b (Water dispersal)	? - max		We found no direct evidence. Plants are reported to tolerate spring flooding in Canada (AISC, 2014), and it is speculated that "floods could easily carry it downstream"

Weed Risk Assessment for *Thesium ramosum* (thesium)

Question ID	Answer - Uncertainty	Score	Notes (and references)
			(Duckworth, 2014). New populations at Bowmont Park and Beaverdam Flats in Calgary, Canada occur along the Bow River (McLean, 2018) further suggesting dispersal via water. Because the evidence is circumstantial, we answered "unknown" with maximum uncertainty.
ES-17c (Bird dispersal)	? - max		Unknown. We found no evidence, and the seeds have no obvious adaptations for bird dispersal, but the elaiosomes could potentially attract birds, so we answered "unknown" with maximum uncertainty.
ES-17d (Animal external dispersal)	y - low		Seeds have swollen pedicels that function as elaiosomes (Nickrent, 2016), which are small, usually fatty structures that serve to attract ants and other seed dispersers. Field researchers in Canada have repeatedly observed ants carrying seeds to anthills (St. Mary's University, 2019); ants also form seed caches (McLean, 2018b). The flower stalk develops into a white, fleshy, berry-like elaiosome, promoting dispersal of the seeds by ants; "Probably in all Thesia, myrmecochory takes place during the dissemination of fruits" (Hendrych, 1972). Direct evidence for myrmecochory is also reported for the congener <i>T. chinense</i> (Suetsugu, 2015).
ES-17e (Animal internal dispersal)	? - max		We found no evidence.
ES-18 (Evidence that a persistent (>1yr) propagule bank (seed bank) is formed)	y - high	0	We found no evidence. Other <i>Thesium</i> spp. form persistent seed banks (van Wilgen and Forsyth, 1992; Caballero et al., 2003; Cerabolini et al., 2003; Kraaij and van Wilgen, 2014; Clause et al., 2016). Due to evidence from congeners and the fact that <i>T. ramosum</i> is parasitic and likely requires specific host conditions for germination, we answered "yes" with high uncertainty.
ES-19 (Tolerates/benefits from mutilation, cultivation or fire)	n - high	-1	We found no evidence.
ES-20 (Is resistant to some herbicides or has the potential to become resistant)	n - low	0	We found no evidence. The species is not listed by Heap (2019).
ES-21 (Number of cold hardiness zones suitable for its survival)	7	0	
ES-22 (Number of climate types suitable for its survival)	6	2	
ES-23 (Number of precipitation bands suitable for its survival)	7	0	
IMPACT POTENTIAL			
General Impacts			
Imp-G1 (Allelopathic)	? - max		We found no evidence. Other <i>Thesium</i> spp. may exhibit allelopathy (Luo and Guo, 2007).
Imp-G2 (Parasitic)	y - negl	0.1	<i>Thesium ramosum</i> is a root hemi-parasite that can obtain nutrients through specialized root structures in addition to photosynthesizing (Hendrych, 1964; Xia and Gilbert, 2003; Nickrent, 2016). <i>Thesium</i> spp. are host generalists, parasitizing a wide range of host plants, including monocots

Weed Risk Assessment for *Thesium ramosum* (thesium)

Question ID	Answer - Uncertainty	Score	Notes (and references)
			and dicots and occasionally conifers and ferns (Hendrych, 1972; McClay, 2011). <i>Thesium ramosum</i> has been reported on a variety of hosts in the United States (Montana) (Musselman and Hayes, 1996) and Canada (Alberta) (McLean, 2015), including grasses, forbs, trees, and shrubs.
Impacts to Natural Systems			Note: <i>Thesium ramosum</i> is not well studied in its introduced range, and published information about its impacts in different systems is relatively lacking. Therefore, we answered a number of the following questions with "unknown" or high uncertainty.
Imp-N1 (Changes ecosystem processes and parameters that affect other species)	n - high	0	We found no evidence. The species is present in national and provincial parks and conservation areas in Lithuania and Canada (ANPC, 2013; Gudžinskas and Žalneravičius, 2017; Nickrent, 2016) and is spreading into native prairie ecosystems in Montana (McLean, 2018b), but no further information is available. As a parasitic plant, it seems unlikely to be a transformer species, so we answered "no" with high uncertainty.
Imp-N2 (Changes habitat structure)	? - max		Unknown; we found no evidence..
Imp-N3 (Changes species diversity)	y - high	0.2	Some populations in Fish Creek Provincial Park in Canada can be quite dense with <i>T. ramosum</i> appearing to replace other species, although this has not been quantified (McLean, 2018b). We found no further evidence.
Imp-N4 (Is it likely to affect federal Threatened and Endangered species?)	? - max		<i>Thesium ramosum</i> appears to spread primarily along roads, trails, and waterways in parks and conservation areas, but it has also spread into less disturbed systems such as fescue prairies in Montana (McLean, 2018b). This suggests that it could affect threatened and endangered plant species in the prairie ecosystem, although it is currently unclear whether it has any of the impacts listed in Imp-N1 through Imp-N3. The United States Fish and Wildlife Service (USFWS, 2019) lists several threatened and endangered plants in grassland or prairie ecosystems in Montana and Idaho, and Environment Canada (2014) lists 34 species at risk in the prairie ecozone in Canada, including eight plants.
Imp-N5 (Is it likely to affect any globally outstanding ecoregions?)	n - low	0	Based on its current distribution in North America, <i>T. ramosum</i> does not appear likely to affect any globally outstanding ecoregions as defined by Ricketts et al. (1999)
Imp-N6 [What is the taxon's weed status in natural systems? (a) Taxon not a weed; (b) taxon a weed but no evidence of control; (c) taxon a weed and evidence of control efforts]	c - low	0.6	In the United States, <i>T. ramosum</i> is introduced in several widely separated natural areas in Montana, including riparian sites and adjacent grasslands and meadows (CPNWH, 2019). It was once noted that it "may prove to be a benign addition to the weed flora as in North Dakota" (Musselman and Hayes, 1996); however, it now appears to be causing increased concern as it is spreading further into native prairie systems (McLean, 2018b). In Canada, it occurred first in the valley basin and on the adjacent slopes of Fish Creek in Fish Creek Provincial Park. Now it is reported from hundreds of largely open, sunny areas in the park, including grasslands, meadows, fields, and trails, as well as from the adjacent Cross Conservancy (ANPC,

Weed Risk Assessment for *Thesium ramosum* (thesium)

Question ID	Answer - Uncertainty	Score	Notes (and references)
			2013). Although the park is public, near an urban center, and heavily used and was historically a managed ranch, and although many of the other reports are from disturbed sites, the species also appears in less disturbed areas away from trails (McLean, 2018b). Detector dogs have been used in survey efforts (Government of Alberta, 2017), and researchers at St. Mary's University are testing control methods, including herbicide application and hand-pulling, in experimental plots (St. Mary's University, 2019). In Lithuania, it was recently reported from dry grassland habitats in Trakai Historical National Park, where it is considered an established alien but not invasive (Gudžinskas and Žalneravičius, 2017). The alternate answers for the uncertainty simulation were both "b".
Impact to Anthropogenic Systems (e.g., cities, suburbs, roadways)			
Imp-A1 (Negatively impacts personal property, human safety, or public infrastructure)	n - low	0	<i>Thesium ramosum</i> occurs along railways, roadsides, and trails and in developments in its introduced range in Europe (Kalinowski, 2014; Gudžinskas and Žalneravičius, 2017; Kaplan et al., 2017) and the United States (McClay, 2011). We found no evidence, however, of impacts on property, safety, or infrastructure, and since it is low-growing and hard to see, these impacts seem unlikely.
Imp-A2 (Changes or limits recreational use of an area)	n - low	0	We found no evidence (see A1).
Imp-A3 (Affects desirable and ornamental plants, and vegetation)	? - max		We found no evidence. Because <i>T. ramosum</i> occurs around human developments and is parasitic, we answered "unknown".
Imp-A4 [What is the taxon's weed status in anthropogenic systems? (a) Taxon not a weed; (b) Taxon a weed but no evidence of control; (c) Taxon a weed and evidence of control efforts]	b - mod	0.1	<i>Thesium ramosum</i> is reported as an alien plant along roadsides and railways in its introduced range in Europe (Kalinowski, 2014; Gudžinskas and Žalneravičius, 2017; Kaplan et al., 2017) and as a weed in the United States, where it is common along trails and roads and in developments in Bozeman, MT (Musselman and Hayes, 1996; McClay, 2011) We found no evidence of control efforts in these environments. The alternate answers for the uncertainty simulation were "a" and "c".
Impact to Production Systems (agriculture, nurseries, forest plantations, orchards, etc.)			
Imp-P1 (Reduces crop/product yield)	? - max		We found no direct evidence. <i>Thesium ramosum</i> is reported as a weed of crop fields in Europe in its native range (Williams and Hunyadi, 1987; Kaplan et al., 2017) and as a weed of cereals in Estonia (Gudžinskas and Žalneravičius, 2017), although no further details are available. Because it is parasitic and seems likely to affect yields if present as a weed, and because of the overall lack of available information, we answered "unknown".
Imp-P2 (Lowers commodity value)	? - max		Unknown. We found no evidence (see Imp-P1).
Imp-P3 (Is it likely to impact trade?)	y - high	0.2	<i>Thesium ramosum</i> could travel as a contaminant of seed, grain (Stevens, 1944; Gudžinskas and Žalneravičius, 2017), or hay (Musselman and Hayes, 1996). All <i>Thesium</i> spp. are regulated as pests by the Republic of Korea (PCIT, 2019),

Weed Risk Assessment for *Thesium ramosum* (thesium)

Question ID	Answer - Uncertainty	Score	Notes (and references)
			so the presence of <i>T. ramosum</i> in commodities could affect trade.
Imp-P4 (Reduces the quality or availability of irrigation, or strongly competes with plants for water)	n - mod	0	We found no evidence to indicate that <i>T. ramosum</i> is exceptionally competitive for water.
Imp-P5 (Toxic to animals, including livestock/range animals and poultry)	n - high	0	<i>Thesium ramosum</i> has been grazed in its introduced range in the United States (Adams, 2018) and Canada (McLean, 2018a). We found no further evidence. <i>Thesium laciniatum</i> , <i>T. lineatum</i> , and <i>T. viride</i> are eaten by people, used medicinally, and browsed by mammals (PROTA4U, 2019). <i>Thesium lineatum</i> is reported as poisonous to livestock in certain conditions, but preliminary tests suggest that its toxicity may be dependent on host associations (PROTA4U, 2019).
Imp-P6 [What is the taxon's weed status in production systems? (a) Taxon not a weed; (b) Taxon a weed but no evidence of control; (c) Taxon a weed and evidence of control efforts]	b - low	0.2	<i>Thesium ramosum</i> is reported as a minor weed in eastern Europe (Williams and Hunyadi, 1987) and occurred "in the past, as a weed in crop fields" in the Czech Republic (Kaplan et al., 2017). More recently, it has been reported as a weed of cereals in Estonia, probably introduced with grain, although details are unavailable (Gudžinskas and Žalneravičius, 2017). We found no evidence of control efforts. The alternate answers for the uncertainty simulation were both "c".
GEOGRAPHIC POTENTIAL			Unless otherwise indicated, the following evidence represents geographically referenced points obtained from the Global Biodiversity Information Facility (GBIF Secretariat, 2019).
Plant hardiness zones			
Geo-Z1 (Zone 1)	n - negl	N/A	No evidence found.
Geo-Z2 (Zone 2)	n - negl	N/A	No evidence found.
Geo-Z3 (Zone 3)	y - low	N/A	Canada (Calgary; location is at the border between Zones 3 and 4). Also present in Russia in Udmurtia, which is completely within Zone 3) (Baranova and Puzirjev, 1998) and in the town of Chalturin in the Kirov area (Hendrych, 1968).
Geo-Z4 (Zone 4)	y - negl	N/A	Canada (Calgary; location is at the border between Zones 3 and 4); Armenia (several points); Russia (one point). Also in the United States (Montana) [points plotted with coordinates from Consortium of Pacific Northwest Herbaria (CPNWH, 2019).]
Geo-Z5 (Zone 5)	y - negl	N/A	Armenia, Russia (Caucasus), Turkey (several points). Also the United States (Montana) (CPNWH, 2019).
Geo-Z6 (Zone 6)	y - negl	N/A	Austria, Georgia, Russia, Slovakia, Turkey (many points). Also present in southeastern Czech Republic (Hendrych, 1968; Kaplan et al., 2017). "Widespread in Turkey except S & W Anatolia" (Turkey is primarily within Zones 6 and 7) (Miller, 1982). "[A] plant of the Balkans, Russia, and eastern Europe" (These areas are primarily with Zones 6 and 7) (Hendrych, 1964; Musselman and Hayes, 1996).

Weed Risk Assessment for *Thesium ramosum* (thesium)

Question ID	Answer - Uncertainty	Score	Notes (and references)
Geo-Z7 (Zone 7)	y - negl	N/A	Austria, Georgia, Greece, Russia, Slovakia, Turkey (several points). Also present in southeastern Czech Republic (Hendrych, 1968; Kaplan et al., 2017). "Widespread in Turkey except S & W Anatolia" (Turkey is primarily within Zones 6 and 7) (Miller, 1982). "[A] plant of the Balkans, Russia, and eastern Europe" (These areas are primarily within Zones 6 and 7) (Hendrych, 1964; Musselman and Hayes, 1996).
Geo-Z8 (Zone 8)	y - low	N/A	Albania, Greece, Ukraine (Crimea) (several points). Two points in Spain are questionable and not supported by local flora (Real Jardín Botánico, 2019). In general, however, the species range described by Hendrych (1968) indicates a high density of occurrence along the coasts of Croatia and Bosnia and Herzegovina, which would include Zone 8. Also described by Romo et al. (2004) as "present in the southern part of the Crimean peninsula" and "quite frequent in the southern part of the area."
Geo-Z9 (Zone 9)	y - mod	N/A	A few points in Greece, several in southern Ukraine; one isolated point in China (Yunnan), which may be erroneous, as it falls outside the range described in the flora (Xia and Gilbert, 2003). In general, the range described by Hendrych (1968) indicates a high density of occurrence along the coasts of Croatia and Bosnia and Herzegovina, which would include Zone 9.
Geo-Z10 (Zone 10)	n - mod	N/A	No points in this Zone (GBIF Secretariat, 2019), although many are close. The species range described by Hendrych (1968) also seems to exclude this Zone.
Geo-Z11 (Zone 11)	n - negl	N/A	No evidence found.
Geo-Z12 (Zone 12)	n - negl	N/A	No evidence found.
Geo-Z13 (Zone 13)	n - negl	N/A	No evidence found.
Köppen -Geiger climate classes			
Geo-C1 (Tropical rainforest)	n - negl	N/A	No evidence found.
Geo-C2 (Tropical savanna)	n - negl	N/A	No evidence found.
Geo-C3 (Steppe)	y - low	N/A	Armenia, Crimea, Turkey (few points). Possibly one point in the United States (Montana) (CPNWH, 2019). Two points in Spain are probably erroneous (see Z8). The species range described by Hendrych (1968) and Miller (1982) includes steppe in central Turkey and in Kazakhstan northeast of the Caspian sea; Hendrych also describes it as a steppe species.
Geo-C4 (Desert)	y - high	N/A	No georeferenced points found. It does, however, appear to occur in this climate class in Kazakhstan (Hendrych, 1968).
Geo-C5 (Mediterranean)	y - negl	N/A	Albania, Greece, Turkey (several points). This climate class also coincides with the species range described by Hendrych (1968).
Geo-C6 (Humid subtropical)	y - negl	N/A	Crimea, Georgia, Greece, Russia, Turkey (several points). This climate class also coincides with the species range in Croatia and Serbia and around the Black Sea as described by Hendrych (1968).

Weed Risk Assessment for *Thesium ramosum* (thesium)

Question ID	Answer - Uncertainty	Score	Notes (and references)
Geo-C7 (Marine west coast)	y - mod	N/A	Crimea and Turkey (one point each). Appears to coincide with a few small patches in the species range in Bosnia and Herzegovina and Turkey on the southern edge of the Black Sea as described by Hendrych (1968).
Geo-C8 (Humid cont. warm sum.)	y - negl	N/A	Armenia, Austria, Georgia, Russia, Slovakia, Turkey, Canada (Calgary) (many points). Also present in southeastern Czech Republic (Hendrych, 1968; Kaplan et al., 2017) and the United States (Montana and Teton County, ID) (CPNWH, 2019).
Geo-C9 (Humid cont. cool sum.)	y - negl	N/A	Armenia, Georgia, Russia, Slovakia (many points). This climate class also coincides with the species range described by Hendrych (1968).
Geo-C10 (Subarctic)	n - negl	N/A	No evidence found.
Geo-C11 (Tundra)	n - negl	N/A	No evidence found.
Geo-C12 (Icecap)	n - negl	N/A	No evidence found.
10-inch precipitation bands			
Geo-R1 (0-10 inches; 0-25 cm)	y - high	N/A	Armenia (several points). Also appears to occur in this precipitation band in Kazakhstan (Hendrych, 1968) and described as "widespread in Turkey except S & W Anatolia" (Miller, 1982), which includes some small patches within this band.
Geo-R2 (10-20 inches; 25-51 cm)	y - low	N/A	Armenia, Crimea (several points). Two points in Spain are probably erroneous (see Geo-Z8). Also described as "Widespread in Turkey except S & W Anatolia" (Miller, 1982), which includes several patches within this precipitation band, and present in Kazakhstan northeast of the Caspian sea, which is primarily within this precipitation band (Hendrych, 1968).
Geo-R3 (20-30 inches; 51-76 cm)	y - negl	N/A	Armenia, Austria, Georgia, Greece, Russia, Slovakia, Turkey, Canada (Calgary) (several points). Also two points in the United States (Montana) (CPNWH, 2019). Also present in southeastern Czech Republic (Hendrych, 1968; Kaplan et al., 2017) and described as "a plant of the Balkans, Russia, and eastern Europe," which are primarily within this precipitation band (Hendrych, 1964; Musselman and Hayes, 1996).
Geo-R4 (30-40 inches; 76-102 cm)	y - negl	N/A	Armenia, Austria, Greece, Russia, Turkey (several points). Also three points in the United States (Montana) (CPNWH, 2019). This precipitation band also coincides with the species range in the Balkans and the Caucasus described by Hendrych (1968).
Geo-R5 (40-50 inches; 102-127 cm)	y - negl	N/A	Armenia, Austria, Greece, Turkey (several points). This precipitation band also coincides with the species range in the Balkans and the Caucasus described by Hendrych (1968).
Geo-R6 (50-60 inches; 127-152 cm)	y - mod	N/A	Albania, Armenia, Greece, Turkey (few points). This precipitation band is quite well represented in the species range but only at higher elevations. It is unclear if the species occurs at these elevations, so we listed moderate uncertainty.

Weed Risk Assessment for *Thesium ramosum* (thesium)

Question ID	Answer - Uncertainty	Score	Notes (and references)
Geo-R7 (60-70 inches; 152-178 cm)	y - high	N/A	Austria, Russia, Turkey (very few points). This precipitation band is quite well represented in the species range but only at higher elevations. It is unclear if the species occurs at these elevations, so we listed high uncertainty.
Geo-R8 (70-80 inches; 178-203 cm)	n - mod	N/A	No georeferenced locations. This precipitation band does occur near the tops of mountains within the species range but Hendrych (1968) describes <i>T. ramosum</i> as a species of lower plains that only ascends mountains in the southern parts of its range. In general, the climate of "higher mountain levels" is "usually unfavourable for the normal growth of [<i>T. ramosum</i>]".
Geo-R9 (80-90 inches; 203-229 cm)	n - mod	N/A	No georeferenced locations. This precipitation band does occur near the tops of mountains within the species range, but see Geo-R8.
Geo-R10 (90-100 inches; 229-254 cm)	n - mod	N/A	One georeferenced location in Georgia may be an anomaly. This precipitation band does occur near the tops of mountains within the species range, but see Geo-R8.
Geo-R11 (100+ inches; 254+ cm)	n - negl	N/A	No evidence found.
ENTRY POTENTIAL			
Ent-1 (Plant already here)	n - negl	0	First reported in the United States in 1944 (Stevens, 1944) and known from Idaho, Montana, and North Dakota (Kartesz, 2015). Although this species is already present in the United States, we set this answer to 'no' to evaluate the likelihood that additional material would enter the United States.
Ent-2 (Plant proposed for entry, or entry is imminent)	n - negl	0	<i>Thesium ramosum</i> has not been proposed for import into the United States.
Ent-3 [Human value & cultivation/trade status: (a) Neither cultivated or positively valued; (b) Not cultivated, but positively valued or potentially beneficial; (c) Cultivated, but no evidence of trade or resale; (d) Commercially cultivated or other evidence of trade or resale]	a - negl	0	<i>Thesium ramosum</i> is not known to be cultivated or positively valued for any purpose (e.g., Bailey and Bailey, 1976; Wiersema and León, 1999; IPK Gatersleben, 2019; University of Minnesota, 2019).
Ent-4 (Entry as a contaminant)			
Ent-4a (Plant present in Canada., Mexico, EU or China)	y - negl		<i>Thesium ramosum</i> is present in Canada in Alberta (McClay, 2011). It is also present as a native species in southeastern Europe and China (Hendrych, 1964; 1968; Xia and Gilbert, 2003) and is present in Europe (Kalinowski, 2014; Gudžinskas and Žalneravičius, 2017; Kaplan et al., 2017; Randall, 2017; DAISIE, 2019; NOBANIS, 2019).
Ent-4b (Contaminant of plant propagative material (except seeds))	n - mod	0	We found no evidence suggesting that this species is a contaminant of propagative plant material.
Ent-4c (Contaminant of seeds for planting)	y - mod	0.08	<i>Thesium ramosum</i> was first found in North America mixed with <i>Bromus inermis</i> along the edges of a grain field: "on account of the location of the plants, the suggestion is rather

Weed Risk Assessment for *Thesium ramosum* (thesium)

Question ID	Answer - Uncertainty	Score	Notes (and references)
			strong that seeds of the <i>Thesium</i> may have been introduced with <i>Bromus</i> seed" (Stevens, 1944). It has been recorded as an alien species in cereal crops in Estonia and is believed to have been introduced with grain (Gudžinskas and Žalneravičius, 2017). It is speculated that it may have entered Lithuania with seeds of forage herbs or other cultivated plants (Gudžinskas and Žalneravičius, 2017).
Ent-4d (Contaminant of ballast water)	n - negl	0	<i>Thesium ramosum</i> is a terrestrial species (Hendrych, 1964; 1968; Xia and Gilbert, 2003; Bojňanský and Fargašová, 2007; Kaplan et al., 2017; Nickrent, 2016).
Ent-4e (Contaminant of aquarium plants or other aquarium products)	n - negl	0	This pathway is not likely as <i>T. ramosum</i> is a terrestrial species (See Ent-4d).
Ent-4f (Contaminant of landscape products)	? - max		It is speculated that <i>T. ramosum</i> seeds could be easily spread in soil (AISC, 2014); however, we found no specific evidence that this occurs.
Ent-4g (Contaminant of containers, packing materials, trade goods, equipment or conveyances)	y - high	0.04	It is speculated that <i>T. ramosum</i> seeds could be easily spread through foot or vehicular traffic (AISC, 2014). The species is reported to spread along roadsides and railways in Europe (Kalinowski, 2014; Gudžinskas and Žalneravičius, 2017; Kaplan et al., 2017) and along trails and roads and in developments in North America (McClay, 2011), although the means of spread is not reported.
Ent-4h (Contaminants of fruit, vegetables, or other products for consumption or processing)	n - mod	0	We found no evidence suggesting that this species contaminates highly processed commodities.
Ent-4i (Contaminant of some other pathway)	e - high	0.08	<i>Thesium ramosum</i> grows in pasture and hay ground in Montana, and it is speculated that Montana populations may have come from neighboring North Dakota in hay brought by big game hunting outfitters for their horses (Musselman and Hayes, 1996; McClay, 2011).
Ent-5 (Likely to enter through natural dispersal)	n - mod	0	Seeds of <i>T. ramosum</i> are thought to be spread primarily by falling or by ants; they are nutlets with no obvious adaptations for wind or other long-range dispersal (Hendrych, 1972; Musselman and Hayes, 1996; CPNWH, 2019). Natural spread by water or birds or other wildlife is possible, but we found no evidence to support it.