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Weed Risk Assessment for *Apera spica-venti* (L.) P. Beauv. (Poaceae) – Common windgrass

Left: Botanical illustration of *A. spica-venti* (source: Host et al., 1805). Top right: Infestation in a Michigan wheat field (source: Sprague, 2016). Bottom right: An infestation that is herbicide-resistant in a Czech wheat field (source: Soukup, 2016).

Agency Contact:

Plant Epidemiology and Risk Analysis Laboratory
Center for Plant Health 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 27606

Introduction Plant Protection and Quarantine (PPQ) regulates noxious weeds under the authority of the Plant Protection Act (7 U.S.C. § 7701-7786, 2000) and the Federal Seed Act (7 U.S.C. § 1581-1610, 1939). A noxious weed is defined as "any plant or plant product that can directly or indirectly injure or cause damage to crops (including nursery stock or plant products), livestock, poultry, or other interests of agriculture, irrigation, navigation, the natural resources of the United States, the public health, or the environment" (7 U.S.C. § 7701-7786, 2000). We use the PPQ weed risk assessment (WRA) process (PPQ, 2015) to evaluate the risk potential of plants, including those newly detected in the United States, those proposed for import, and those emerging as weeds elsewhere in the world.

The PPQ WRA process includes three analytical components that together describe the risk profile of a plant species (risk potential, uncertainty, and geographic potential; PPQ, 2015). At the core of the process is the predictive risk model that evaluates the baseline invasive/weed potential of a plant species using information related to its ability to establish, spread, and cause harm in natural, anthropogenic, and production systems (Koop et al., 2012). Because the predictive model is geographically and climatically neutral, it can be used to evaluate the risk of any plant species for the entire United States or for any area within it. We then use a stochastic simulation to evaluate how much the uncertainty associated with the risk analysis affects the outcomes from the predictive model. The simulation essentially evaluates what other risk scores might result if any answers in the predictive model might change. Finally, we use Geographic Information System (GIS) overlays to evaluate those areas of the United States that may be suitable for the establishment of the species. For a detailed description of the PPQ WRA process, please refer to the *PPQ Weed Risk Assessment Guidelines* (PPQ, 2015), which is available upon request.

We emphasize that our WRA process is designed to estimate the baseline—or unmitigated—risk associated with a plant species. We use evidence from anywhere in the world and in any type of system (production, anthropogenic, or natural) for the assessment, which makes our process a very broad evaluation. This is appropriate for the types of actions considered by our agency (e.g., Federal regulation). Furthermore, risk assessment and risk management are distinctly different phases of pest risk analysis (e.g., IPPC, 2015). Although we may use evidence about existing or proposed control programs in the assessment, the ease or difficulty of control has no bearing on the risk potential for a species. That information could be considered during the risk management (decision-making) process, which is not addressed in this document.

	***Apera spica-venti* (L.) P. Beauv. – Common windgrass**

Species Information

Family: Poaceae

Synonyms: *Agrostis spica-venti* L. (basionym) (NGRP, 2016), *A. anemagrostis* Syme, *A. gracilis* Salisb., *A. ventosa* Dulac, *Anemagrostis spica-venti* (L.) Trin., *Apera longiseta* Klokov, *Festuca spica-venti* (L.) Raspail, *Muhlenbergia spica-venti* (L.) Trin., *Agrostis anemagrostis* ssp. *spica-venti* (L.) Syme (ITIS, 2016). Additional synonyms are available on The Plant List (2016).

Common names: Common wind grass, loose silky-bent, silky-bent grass, wind grass (NGRP, 2016), loose silkbent (ITIS, 2016), windgrass (Weakley, 2015), and common windgrass (Northam and Callihan, 1992).

Botanical description: *Apera spica-venti* is an erect annual grass that grows from 0.3 to 1.5 meters high (Bojňanský and Fargašová, 2007; Salisbury, 1961; Soukup et al., 2006). The leaf blades are approximately 0.5 cm wide by 30 cm long (Soukup et al., 2006). Flowering panicles are very diffuse (Stace, 2010). Seeds (i.e., caryopses) are oblong-ellipsoid, about 1.3-2.3 mm long and about 0.4 mm wide, and are tightly enclosed by a hardened lemma and palea (Bojňanský and Fargašová, 2007; Salisbury, 1961; Warwick et al., 1987). For a more detailed botanical description refer to the following sources: Polunin, 1969; Warwick et al., 1985.

Initiation: PPQ received a market access request for wheat seed for planting from the government of Italy (MPAAF, 2010). A commodity import risk assessment determined that *A. spica-venti* may be associated with this commodity as a seed contaminant. In this assessment, the PERAL Weed Team evaluated the risk potential of this species to the United States to help policy makers determine whether it should be regulated as a Federal Noxious Weed.

Foreign distribution and status: *Apera spica-venti* is native to Eurasia and naturally ranges from western Europe (e.g., France, Spain, United Kingdom) to eastern Europe (e.g., Belarus, Bulgaria, Ukraine) and on to middle Asia (e.g., Kazakhstan and southern Siberia) (Bojňanský and Fargašová, 2007; Luneva and Budrevskaya, 2016; NGRP, 2016). However, for some of these countries or regions it may instead be an alien that was introduced before 1500 A.D. (an archaeophyte), for example, in Finland (Kurtto and Lahti, 1987) and the United Kingdom (Dunn, 1905; Ryves et al., 1996). *Apera spica-venti* is a casual alien in Ireland (Reynolds, 2002) and Iceland (Wasowicz et al., 2013). It is naturalized in Algeria, Canada, Crete, Corsica, Japan, Morocco, Norway, Slovakia, Sweden, the Czech Republic, and the Russian Far East (i.e., the provinces of Primorye and Sakhalin) (Mito and Uesugi, 2004; NGRP, 2016; Pyšek et al., 2012; Warwick et al., 1985). *Apera spica-venti* is occasionally cultivated in Europe as an ornamental (Dunn, 1905; Salisbury, 1961), and the panicles are sometimes dried for decoration (cited in Warwick et al., 1985).

U.S. distribution and status: *Apera spica-venti* is naturalized in a few counties in each of 18 states (OR, WA, CA, ID, TX, MO, KY, OH, MI, PA, MD, DE, NJ, NY, CT, MA, VT, ME) (App. B; Kartesz, 2016; NRCS, 2016; Weakley, 2015) and is classified as an agricultural weed by the Weed Science Society of America (WSSA, 2010). It was first reported for the United States in the early 1800s in Pennsylvania and Virginia and was probably introduced in contaminated seed grain (Northam and Callihan, 1992). This species does not appear to have spread much in the 150 years after its introduction; in 1953, the USDA described it as sparingly introduced (USDA-FS, 1953). However, in the last few decades it has become an increasing problem in winter wheat in Michigan (Chomas and Kells, 2001; Sprague, 2013) and in adjacent areas in southern Ontario, Canada. Control has been difficult in winter wheat because of similar crop and weed phenologies (Chomas and Kells, 2001; Sprague, 2013). In Oregon, *A. spica-venti* is one of the most frequent weed seed contaminants in Kentucky bluegrass seed (Alderman et al., No Date), probably because the two species have very similar seed sizes[1] (Bojňanský and Fargašová, 2007). In an online gardening forum, a commenter from Nebraska said that it is easily grown and that the flowers can be dried for winter decoration (Dave's Garden, 2016); however, it is not clear if that commenter was actually growing it. We found no other evidence that *A. spica-venti* is cultivated as an ornamental in the United States (e.g., Brenzel, 1995; eBay, 2016; GardenWeb.com, 2016; Page and Olds, 2001; Univ. of Minn., 2016).

WRA area[2]: Entire United States, including territories.

1. *Apera spica-venti* analysis

Establishment/Spread Potential

Apera spica-venti has already demonstrated an ability to establish and spread beyond its native range (e.g., NGRP, 2016; Warwick et al., 1985), including in the United States (Northam and Callihan, 1992). This species is a wind-pollinated (Warwick et al., 1985), outcrossing annual (Warwick et al., 1987) that produces from 1,000 to 16,000 seeds per plant (Gerhards and Massa, 2011; Soukup et al., 2006). In winter cereals, including wheat, it forms dense populations of up to several hundred plants per square meter (Melander et al., 2008; Northam and Callihan, 1992; Warwick et al., 1985). *Apera spica-venti* is dispersed locally by farmers on contaminated field equipment, such as combines (Gerhards and Massa, 2011; Warwick et al., 1985). It is dispersed over longer distances as a contaminant of grass seed (Alderman et al., No Date; Salisbury, 1961; Warwick et al., 1985), grain (Stace, 2010), and bird seed (Hanson and Mason, 1985). This species is also dispersed by wind, water, and animals (Haywood and Druce, 1919; McNeill, 1981; Ryves et al., 1996; Soukup et al., 2006; Warwick et al., 1985). We had a low level of uncertainty for this risk element.

Risk score = 22 Uncertainty index = 0.08

Impact Potential

Apera spica-venti has been reported as an agricultural weed in numerous countries, including Canada (Darbyshire, 2003), the United Kingdom (Ryves et al., 1996), the former USSR (Keller et al., 1935), and the United States (Northam and Callihan,

[1] Kentucky blue grass: 1.5-2.0 mm x 0.5-0.6 mm vs. *A. spica-venti*: 1.3-2.3 mm x 0.4 mm (Bojňanský and Fargašová, 2007).

[2] "WRA area" is the area in relation to which the weed risk assessment is conducted (definition modified from that for "PRA area") (IPPC, 2012).

1992; WSSA, 2010). It is the most prevalent and important weed of winter cereals, particularly wheat, in many European countries (Hamouzová et al., 2014; Luneva and Budrevskaya, 2016; Melander et al., 2008; Soukup et al., 2006). Because plants typically overgrow the crop, they compete for light, water, and nutrients (Gerhards and Massa, 2011). *Apera spica-venti* reduces yield (McNeill, 1981; Warwick et al., 1985), reduces the value of production (Anonymous, 2016; Chomas and Kells, 2001; Gerhards and Massa, 2011), and may potentially affect trade since it is regulated by several countries (APHIS, 2016). In one experimental study in Europe examining the effect of tillage, crop rotation, and herbicide treatments, it reduced wheat yield between 10 to 30 percent in spite of control efforts (Melander et al., 2008). "Targeted control of silky bent grass is commonly carried out only in winter cereals using herbicides, furthermore cultural measures such as proper crop rotation and soil tillage may decrease the infestation significantly" (Soukup et al., 2006). *Apera spica-venti* is difficult to control in wheat because it germinates at the same and has a similar phenology as wheat. Furthermore, the development of herbicide resistance in European populations (Heap, 2016) has made this species a more troublesome weed in wheat. We had a very low level of uncertainty for this risk element.
Risk score = 2.5 Uncertainty index = 0.05

Geographic Potential Based on three climatic variables, we estimate that about 90 percent of the United States is suitable for the establishment of *A. spica-venti* (Fig. 1). This predicted distribution is based on the species' known distribution elsewhere in the world and includes point-referenced localities and areas of occurrence. The map for *A. spica-venti* represents the joint distribution of Plant Hardiness Zones 2-10, areas with 10-100 inches of annual precipitation, and the following Köppen-Geiger climate classes: steppe, Mediterranean, humid subtropical, marine west coast, humid continental (warm and cool summers), subarctic, and tundra.

The area of the United States shown to be climatically suitable (Fig. 1) is likely overestimated since our analysis considered only three climatic variables. Other environmental variables, such as soil and habitat type, may further limit the areas in which this species is likely to establish. *Apera spica-venti* occurs in agricultural areas and disturbed sites, including cultivated fields, ditches, roadsides, railways, waste ground, and sandy tracks (BSBI, 2016; Darbyshire, 2003; Weakley, 2015). It primarily occurs in northern temperate regions with a moderately cool climate. In the Czech Republic, higher weed infestations were associated with areas where the temperature between October and December was above 5 °C and there was moderate precipitation (cited in Warwick et al., 1985). *Apera spica-venti* prefers sandy soils (Bojňanský and Fargašová, 2007; Dunn, 1905; Luneva and Budrevskaya, 2016; Northam and Callihan, 1992; Ryves et al., 1996; Stace, 2010).

Entry Potential We did not assess the entry potential of this species because it is already present in the United States (Kartesz, 2016; NRCS, 2016; Weakley, 2015).

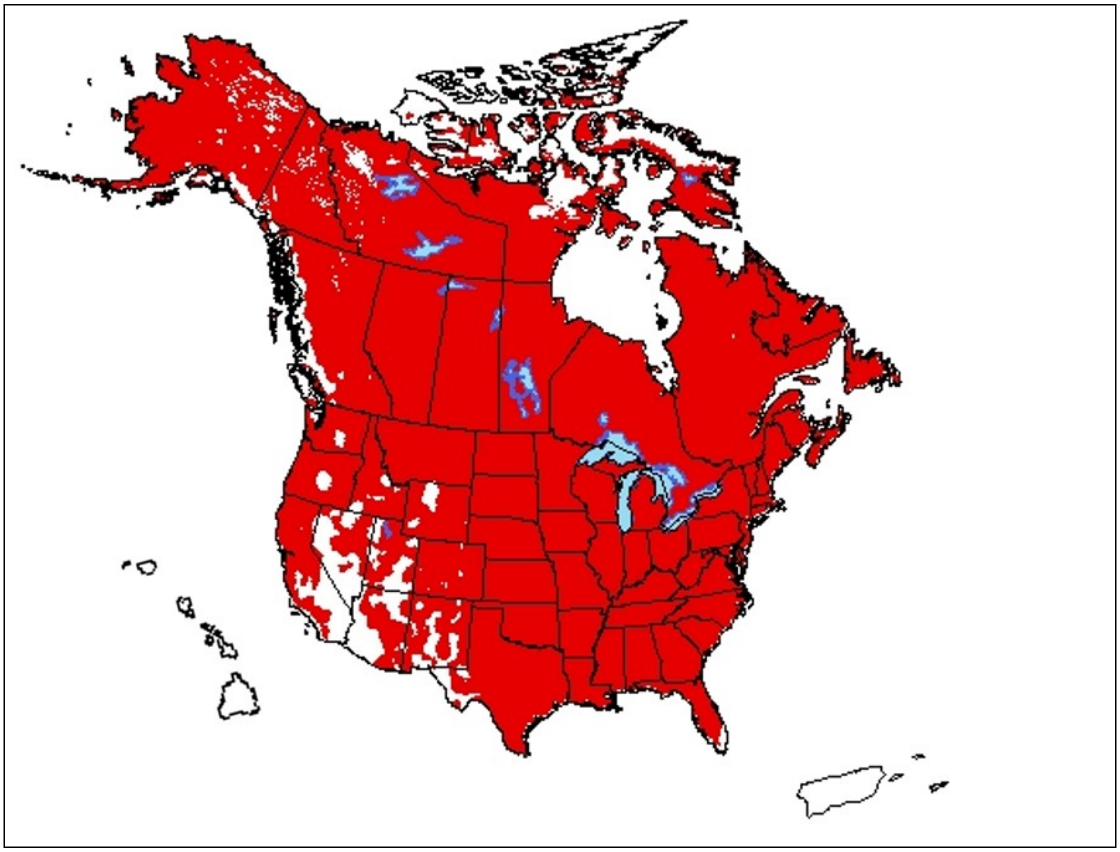

Figure 1. Potential geographic distribution of *Apera spica-venti* in the United States and Canada. Map insets for Hawaii and Puerto Rico are not to scale.

2. Results

Model Probabilities: P(Major Invader) = 92.8%
P(Minor Invader) = 7.0%
P(Non-Invader) = 0.2%
Risk Result = High Risk
Secondary Screening = Not Applicable

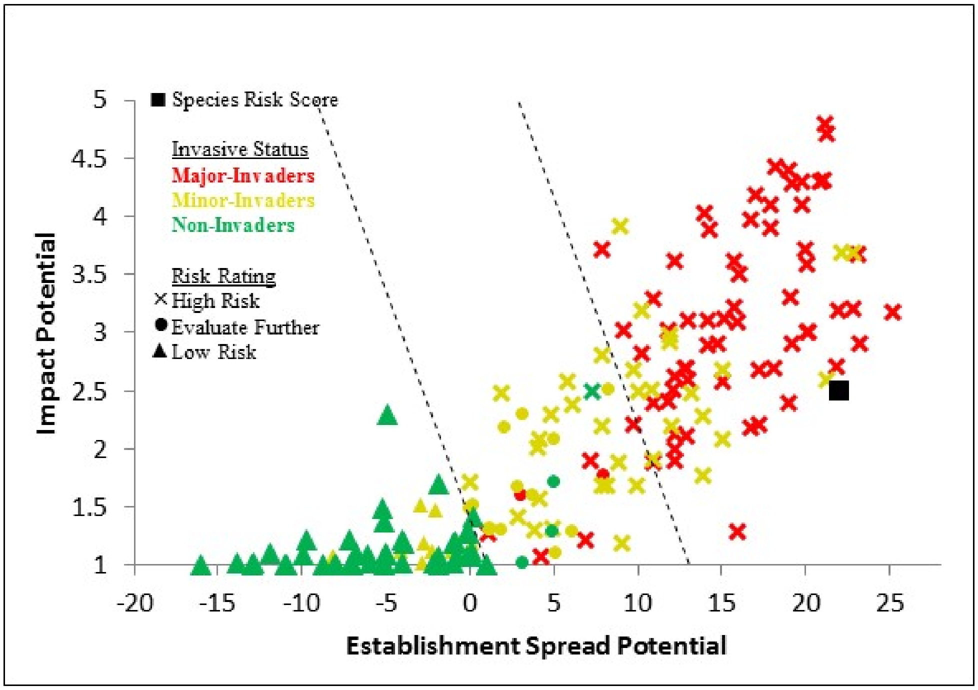

Figure 2. *Apera spica-venti* risk score (black box) relative to the risk scores of species used to develop and validate the PPQ WRA model (other symbols). See Appendix A for the complete assessment.

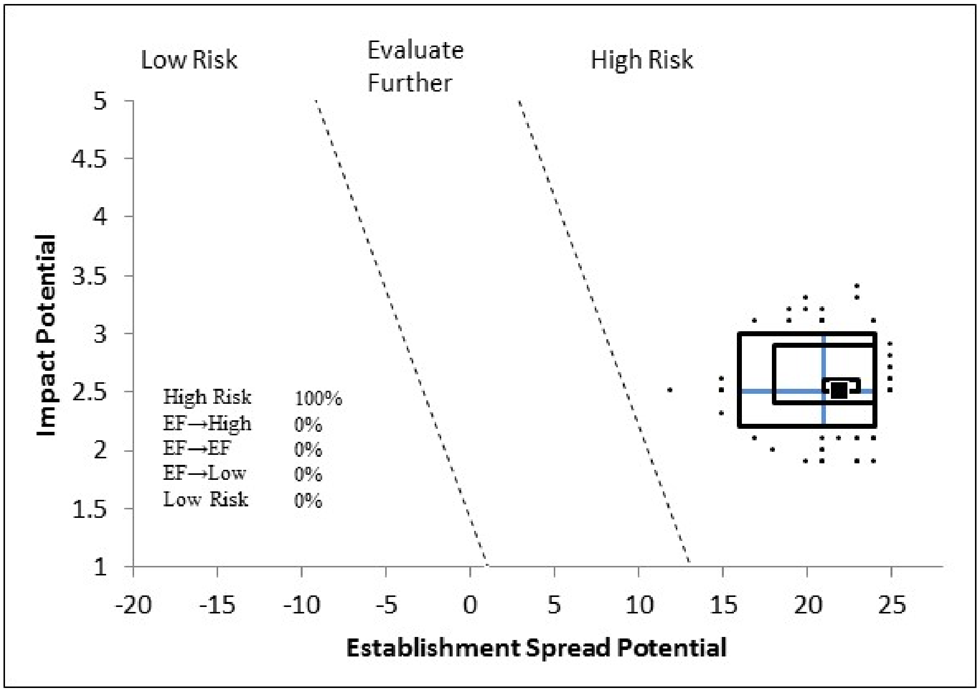

Figure 3. Model simulation results (N=5,000) for uncertainty around the risk score for *A. spica-venti*. The blue "+" symbol represents the medians of the simulated outcomes. The smallest box contains 50 percent of the outcomes, the second 95 percent, and the largest 99 percent.

3. Discussion

The result of the weed risk assessment for *Apera spica-venti* is High Risk (Fig. 2). Overall, we had a low level of uncertainty because its biology has been well characterized by numerous peer-reviewed publications. Our uncertainty analysis supports our conclusion of High Risk because all of the simulated risk scores are well within the high-risk region (Fig. 3). *Apera spica-venti* is an invasive species that thrives in winter cereal production systems (Hamouzová et al., 2014; Luneva and Budrevskaya, 2016; Melander et al., 2008; Soukup et al., 2006). Polish researchers estimated the economic threshold level for winter wheat to be about 10-20 plants per square meter (Rola and Rola, 1983), which *A. spica-venti* easily exceeds (Northam and Callihan, 1992; Warwick et al., 1985).

Although *A. spica-venti* has been in North America for nearly 200 years, it has only begun to spread and become problematic in the last few decades (Northam and Callihan, 1992; Sprague, 2013; USDA-FS, 1953). Its recent change in behavior may be due to several factors, including reduction in frequency or intensity of soil tillage (Melander et al., 2008; Soukup et al., 2006), increases in the frequency of winter cereals in crop rotations (Soukup et al., 2006), and introduction, spread, or evolution of weedier genotypes (McNeill, 1981). "Further spreading of *A. spica-venti* in temperate cereal producing areas around the world is expected" (Nordmeyer, 2009), including within the mesic winter-grain regions of North America (Northam and Callihan, 1992). Given the high levels of genetic diversity observed in Canadian populations of *A. spica-venti*, this species should also be capable of adapting to local conditions (Warwick et al., 1987).

Wheat is an economically important crop for North American farmers. Currently, *A. spica-venti* can be controlled with a combination of techniques, including cultural practices, proper crop rotations, and the application of herbicides (Gast et al., 2007; Luneva and Budrevskaya, 2016; Sprague, 2013; Warwick et al., 1985). However, of particular concern for North American farmers is the introduction or development of herbicide resistance. In Europe, *Apera spica-venti* has developed resistance to a variety of herbicides, and in some populations it has expressed resistance to multiple types of herbicides (Heap, 2016). Soukup et al. (2006) conclude that herbicide resistance "may pose a serious problem with regard to the natural range of occurrence of silky bent grass and [the] economical importance of winter cereals in this region." Although there is no evidence that *A. spica-venti* has developed herbicide resistance in the United States, if it did, the economic value of North American wheat may be affected.

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Appendix A. Weed risk assessment for *Apera spica-venti* (L.) P. Beauv. (Poaceae). Below is all of 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, where 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	*Apera spica-venti* is native to Eurasia, and ranges from western Europe (e.g., France, Spain, United Kingdom) to eastern Europe (e.g., Belarus, Bulgaria, Ukraine) and on to middle Asia (e.g., Kazakhstan and southern Siberia) (Bojňanský and Fargašová, 2007; Luneva and Budrevskaya, 2016; NGRP, 2016). However, for some of these countries or regions it may instead be an alien that was introduced before 1500 A.D. (an archaeophyte), for example, in Finland (Kurtto and Lahti, 1987) and the United Kingdom (Dunn, 1905; Ryves et al., 1996). It is a casual alien in Ireland (Reynolds, 2002) and Iceland (Wasowicz et al., 2013). It is naturalized in Algeria, Crete, Corsica, Japan, Morocco, Norway, Slovakia, Sweden, the Czech Republic, and the Russian Far East (i.e., the provinces of Primorye and Sakhalin) (Mito and Uesugi, 2004; NGRP, 2016; Pyšek et al., 2012). Historically in the Czech Republic, *A. spica-venti* was more limited by climate and soils, but changes associated with modern farming practices have increased its spread throughout the country (Soukup et al., 2006). "In Eastern Europe, *A. spica-venti* spreads constantly" (Nordmeyer, 2009). This species was first detected in St. Louis, MO, in 1954 and then rapidly spread throughout the railroad network of the city (Mühlenbach, 1979). It is spreading in cereal-grain fields in Michigan (Gereau and Rabeler, 1984; Rabeler and Crowder, 1985) and in southern Ontario, Canada (Warwick et al., 1985). Based on this evidence of spread, we classified this species as invasive and selected "e" for both alternate answers for the uncertainty analysis.
ES-2 (Is the species highly domesticated)	n - low	0	This species is occasionally cultivated in Europe as an ornamental (Dunn, 1905; Salisbury, 1961), and the panicles are sometimes dried for decoration (cited in Warwick et al., 1985); however, we found no evidence that it has been domesticated to reduce its weed potential.
ES-3 (Weedy congeners)	n - mod	0	*Apera* is a genus that contains three Eurasian species (Mabberley, 2008), all of which have been reported as weeds: *Apera intermedia*, *A. interrupta*, and *A. spica-venti* (Randall, 2012). In the Global Compendium of Weeds, *Apera spica-venti* has the highest number of references supporting its weed potential, followed by *A. interrupta* (Randall, 2012). *Apera interrupta* is considered a weed by numerous sources (e.g., Darbyshire, 2003; Salisbury, 1961); however, we did not find any evidence it is a significant weed. In Chile, it is

Question ID	Answer - Uncertainty	Score	Notes (and references)
			an insignificant weed because it has a limited distribution (Matthei, 1995).
ES-4 (Shade tolerant at some stage of its life cycle)	n - low	0	This species grows in habitats with high light intensity (Warwick et al., 1985). Its seeds require light to germinate (Hanf, 1983). A review of seed germination studies generally found that its seeds require light for germination, although some seeds did germinate under darkness (Warwick et al., 1985).
ES-5 (Plant a vine or scrambling plant, or forms tightly appressed basal rosettes)	n - negl	0	*Apera spica-venti* is an erect grass that grows from one to three feet high (Salisbury, 1961; Warwick et al., 1985); it is not a vine.
ES-6 (Forms dense thickets, patches, or populations)	y - negl	2	In southern Ontario, Canada, it grows at population densities of 190 to 259 plants per square meter in winter rye (Northam and Callihan, 1992) and 200 plants per square meter in winter wheat (Warwick et al., 1985). In one experimental study in Europe examining the effect of tillage, crop rotation, and herbicide treatments, seedling densities in the spring ranged between 0 to 600 plants per square meter (Melander et al., 2008).
ES-7 (Aquatic)	n - negl	0	This species is a terrestrial herb (Warwick et al., 1985); it is not an aquatic plant.
ES-8 (Grass)	y - negl	1	*Apera spica-venti* is a grass (NGRP, 2016).
ES-9 (Nitrogen-fixing woody plant)	n - negl	0	We found no evidence that this species fixes nitrogen. Furthermore, it is neither in a plant family known to contain nitrogen-fixing species (Martin and Dowd, 1990; Santi et al., 2013) nor a woody plant.
ES-10 (Does it produce viable seeds or spores)	y - negl	1	This species reproduces by seeds (Luneva and Budrevskaya, 2016; Soukup et al., 2006).
ES-11 (Self-compatible or apomictic)	n - negl	-1	A breeding study that bagged inflorescences revealed that plants are primarily self-incompatible, as only a few seeds were produced from 25 selfed[3] individuals (Warwick et al., 1987). Furthermore, this same study examined isozyme variation within and among nine Canadian and six European *A. spica-venti* populations and found that populations are outcrossing.
ES-12 (Requires specialist pollinators)	n - negl	0	Typical for grasses (Faegri and Van der Pijl, 1979), this species is wind-pollinated (Warwick et al., 1985), and consequently, it does not depend on pollinators.
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]	b - negl	1	*Apera spica-venti* is primarily a winter annual (Hakansson, 2003; Soukup et al., 2006), although it can also behave as a summer annual (Warwick et al., 1985). It produces one generation per year (Warwick et al., 1985). Alternate answers for the uncertainty simulation were both "c."
ES-14 (Prolific seed producer)	y - low	1	Researchers have reported that plants produce between 1,100 to 2,000 seeds per plant (Gerhards and Massa, 2011; Warwick et al., 1985) and between 3,000 to 5,000 seeds per plant (Anonymous, 2016); however, others report seed production rates of up to 16,000 seeds per plant (Luneva and Budrevskaya, 2016; Soukup et al., 2006). It is not clear from these studies how many

[3] Selfed individuals were plants that were pollinated with their own pollen.

Question ID	Answer - Uncertainty	Score	Notes (and references)
			panicles plants typically produce or how many seeds are produced per square meter. If we assume plant densities of about 200 per square meter (Northam and Callihan, 1992; Warwick et al., 1985), 1000 seeds per plant, and a seed viability rate of about 80 percent (Soukup et al., 2006), then we can expect *A. spica-venti* to produce 160,000 seeds per square meter, which greatly exceeds our threshold of 5,000. In one experimental study examining the effect of tillage, crop rotation, and herbicide treatments, panicle densities in the summer ranged between 1 to 337 panicles per square meter (Melander et al., 2008). In another study, after two years of no control, panicle densities reached 222 panicles per square meter in control plots and 463 panicles per square meter in plots with herbicide-resistant plants (Gerhards and Massa, 2011). Even with conservative (i.e., low) estimates of plant fertility, density, and seed viability, we are confident that this species readily produces more than 5,000 seeds per square meter.
ES-15 (Propagules likely to be dispersed unintentionally by people)	y - negl	1	Custom combining (i.e., the practice of harvesting crops for others) moves seeds from farm to farm in southern Ontario, Canada (Warwick et al., 1985). "Contaminations of combine harvesters may also play an important role in seed dispersal from field to field" (Gerhards and Massa, 2011). Because the seeds are relatively light, they are readily blown out of combines with the chaff (Hanf, 1983).
ES-16 (Propagules likely to disperse in trade as contaminants or hitchhikers)	y - negl	2	This species is a contaminant of grass seed (Salisbury, 1961; Warwick et al., 1985), and during a 20-year period in Oregon, it was one of the most frequent seed contaminants in Kentucky bluegrass grown for seed, having been found in some seed lots every year over the 21-year study period (Alderman et al., No Date). It was introduced to England as a grain contaminant (Stace, 2010) and has been cultivated from bird seed (Hanson and Mason, 1985). In Dublin, it is present around docks (Ryves et al., 1996), suggesting movement in trade. *Apera spica-venti* is one of the most common weed species present in fields of grasses grown for seed, and in grass seed samples taken before cleaning, it occurred at frequencies of about 20-40 percent (Cagaš et al., 2006). *Apera spica-venti* was likely introduced to the United States in contaminated seed grain (Northam and Callihan, 1992). A 1970s infestation in southern Ontario probably represents a new introduction from Europe in grain seed (McNeill, 1981). Furthermore, based on patterns of genetic diversity, it is likely that the Ontario populations were derived from at least two separate introduction events (Warwick et al., 1987). It is not clear how likely or how often this species would be a contaminant of wheat seed for planting given that wheat seeds are larger (2.8-3.6 mm by 6.0-8.2 mm; Bojňanský and Fargašová, 2007), and thus the two may be able to be separated during seed cleaning.

Question ID	Answer - Uncertainty	Score	Notes (and references)
ES-17 (Number of natural dispersal vectors)	4	4	Fruit and seed traits for ES-17a through ES-17e: Seeds (i.e., caryopses) are oblong-ellipsoid, about 1.3-2.3 mm long and about 0.4 mm wide, and are tightly enclosed by a hardened lemma and palea (Bojňanský and Fargašová, 2007; Salisbury, 1961; Warwick et al., 1987).
ES-17a (Wind dispersal)	y - low		Although this species has no clear adaptions for wind dispersal, such as wings or plumes, it is reported to be easily dispersed by wind because the seeds are small and light (McNeill, 1981; Soukup et al., 2006; Warwick et al., 1985). Consequently, we answered yes but with low uncertainty.
ES-17b (Water dispersal)	y - mod		Seeds are dispersed by water (Soukup et al., 2006; Warwick et al., 1985).
ES-17c (Bird dispersal)	n - mod		We found no evidence for this type of dispersal vector.
ES-17d (Animal external dispersal)	y - mod		*Apera spica-venti* is described as a rare wool-alien (i.e., a species that readily adheres to wool and can thus be a contaminant in raw wool or wool products) (Haywood and Druce, 1919; Ryves et al., 1996). The congener, *A. interrupta* was introduced to Belgium as a wool-alien (Verloove, 2006). In one study that examined levels of seed predation by different predator types, researchers showed that at feeding stations protected from large invertebrates and vertebrates, some seeds of *A. spica-venti* were still removed, suggesting that some small insects or slugs are removing seeds (Fischer et al., 2011); but it is unknown if the seeds were being consumed or if they could possibly have been deposited elsewhere.
ES-17e (Animal internal dispersal)	y - mod		Seeds are dispersed in manure (Warwick et al., 1985).
ES-18 (Evidence that a persistent (>1yr) propagule bank (seed bank) is formed)	y - negl	1	The available evidence on long-term seed persistence is somewhat variable. Reports include estimates of 1-2 years (Warwick et al., 1985), 1-4 years (Koch and Hurle, 1978 in Soukup et al., 2006), and 6-7 years (Luneva and Budrevskaya, 2016). In one experimental study of buried seeds, some seeds (0.3 - 46 percent, depending on burial depth) survived for the maximum period of the study, which was 13 months (Melander et al., 2008), indicating some minimum level of long-term persistence. Another seed burial study showed that about 85 percent of seeds germinated after burial 2 years (Andersson and Espeby, 2009). Seeds exhibit little primary dormancy and can germinate shortly after they are harvested or shed (Melander et al., 2008; Warwick et al., 1985). Seeds exhibit the highest germination rates when they are planted on the soil surface or at a depth of about 1 mm (Soukup et al., 2006). Germination decreases with increasing burial depth down to about 2 cm (Soukup et al., 2006), after which they are completely inhibited (Luneva and Budrevskaya, 2016).
ES-19 (Tolerates/benefits from mutilation, cultivation or fire)	? - max	0	This species does not reproduce vegetatively (Warwick et al., 1985); however, it does tiller (Bryan and Brent, 1990). Therefore, like most grasses, it may tolerate mutilation.
ES-20 (Is resistant to some	y - negl	1	In the 1990s, this species started developing resistance to

Question ID	Answer - Uncertainty	Score	Notes (and references)
herbicides or has the potential to become resistant)			a variety of herbicides (Heap, 2016). *Apera spica-venti* growing in cereals such as wheat and spring barley has developed resistance to three different herbicides [acetolactate synthase (ALS) inhibitors, photosystem II (PSII) inhibitors, acetyl CoA carboxylase (ACCase) inhibitors] across multiple European countries (e.g., Austria, Czech Republic, Denmark, France, Germany, Lithuania, Poland, Sweden, Switzerland) (Hamouzová et al., 2014; Heap, 2016; Krysiak et al., 2011). Cases of multiple resistances have also been documented. For example, in Austria in 2009, *A. spica-venti* evolved resistance to both ALS and PSII inhibitors in cereals (Heap, 2016). In Germany, populations resistant to all three herbicides emerged in spring barley and winter wheat. Other cases of single and multiple herbicide resistance are described in the International Survey of Herbicide Resistant Weeds (Heap, 2016).
ES-21 (Number of cold hardiness zones suitable for its survival)	9	0	
ES-22 (Number of climate types suitable for its survival)	8	2	
ES-23 (Number of precipitation bands suitable for its survival)	9	1	
IMPACT POTENTIAL			
General Impacts			
Imp-G1 (Allelopathic)	n - low	0	We found no evidence that *A. spica-venti* is allelopathic. One study that examined the allelopathic potential of several weed species on the growth of several crop species found that in contrast to some of the other weed species, *A. spica-venti* had no allelopathic effect (Kazinczi et al., 1997).
Imp-G2 (Parasitic)	n - negl	0	We found no evidence that this species is parasitic. Furthermore, this species is not a member of a plant family known to contain parasitic plant species (e.g., Heide-Jorgensen, 2008; Nickrent, 2009).
Impacts to Natural Systems			
Imp-N1 (Changes ecosystem processes and parameters that affect other species)	n - low	0	We found no evidence of this impact. We used low uncertainty for the questions in this risk subelement because there is no evidence that this species is even a weed of natural areas.
Imp-N2 (Changes habitat structure)	n - low	0	We found no evidence of this impact.
Imp-N3 (Changes species diversity)	n - low	0	We found no evidence of this impact.
Imp-N4 (Is it likely to affect federal Threatened and Endangered species?)	n - low	0	Because *A. spica-venti* is not a weed of natural areas, it seems unlikely that it would affect Federal threatened and endangered species, which are expected to occur primarily in natural areas.
Imp-N5 (Is it likely to affect any globally outstanding ecoregions?)	n - low	0	Because *A. spica-venti* is not a weed of natural areas and has no known ecosystem level impacts, it seems unlikely that it would affect globally outstanding regions in the United States.
Imp-N6 [What is the taxon's weed status in natural systems? (a) Taxon not a weed; (b) taxon a weed but no	a - low	0	We found no evidence that this species is considered a weed of natural areas. Alternate answers for the uncertainty simulation were both "b."

Question ID	Answer - Uncertainty	Score	Notes (and references)
evidence of control; (c) taxon a weed and evidence of control efforts]			
Impact to Anthropogenic Systems (e.g., cities, suburbs, roadways)			
Imp-A1 (Negatively impacts personal property, human safety, or public infrastructure)	n - mod	0	We found no evidence of this impact.
Imp-A2 (Changes or limits recreational use of an area)	n - mod	0	We found no evidence of this impact.
Imp-A3 (Affects desirable and ornamental plants, and vegetation)	n - mod	0	We found no evidence of this impact.
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	*Apera spica-venti* occurs in disturbed areas (Weakley, 2015). It is a weed of roadsides, railways, field edges, ditches, and waste places in North America (Darbyshire, 2003; Northam and Callihan, 1992). 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)	y - negl	0.4	*Apera spica-venti* primarily damages winter cereals such as wheat and barley, but it also impacts winter rape, forage, and spring wheat (Soukup et al., 2006). Plants typically overgrow the crop in summer and thus effectively compete for light, water, and nutrients (Gerhards and Massa, 2011). Although *A. spica-venti* is not aggressive during its early stages of growth, in spring, growth greatly increases and it easily overtops cereals (Soukup et al., 2006). In southern Ontario at densities of 200 plants per square meter, it reduces winter wheat yield by an average of about 27 percent, although reductions of 50-100 percent have been reported (McNeill, 1981; Warwick et al., 1985). In one experimental study in Europe examining the effect of tillage, crop rotation, and herbicide treatments, *Apera spica-venti* reduced wheat yield between 10- 30 percent in spite of various control efforts (Melander et al., 2008). "Particularly notable is the fact that, under favourable conditions of soil and climate, herbicide application with a target control level of 90% was not a safeguard against yield loss..." (Melander et al., 2008). Another study found that even with herbicide application, this species reduced wheat yield by about 8-10 percent relative to control plots (Gerhards and Massa, 2011). Frost damage to winter crops or the use of shorter crop varieties increases the competitive advantage of *A. spica-venti* (Soukup et al., 2006). In southern Ontario, one study did not detect a significant impact of *A. spica-venti* on winter rye yield (Bryan and Brent, 1990). "An economic threshold level [for wheat] was calculated by comparison of the value of yield losses caused by different infestations which for Poland for *A. spica-venti* was established as 10-20 weeds/m²" (Rola and Rola, 1983). In the Banat Hill region of Central Europe, it occurs at a

Question ID	Answer - Uncertainty	Score	Notes (and references)
			density of about 52 plants per square meter in winter wheat (Manea et al., 2009), which exceeds the economic threshold proposed by Rola and Rola (1983).
Imp-P2 (Lowers commodity value)	y - negl	0.2	*Apera spica-venti* greatly reduces the quality of grain and interferes with harvest (Anonymous, 2016). "Transferring our results to practical farming conditions, single patches of silky bent grass populations with resistance to ALS-inhibitors will rapidly spread over larger farm units, thus resulting in significant costs, persistence and yield losses in cropping systems with high percentage of winter annual cereals" (Gerhards and Massa, 2011). Because this species germinates at the same time that wheat does, controlling it with herbicides may damage wheat plants (Chomas and Kells, 2001). *Apera spica-venti* "was more damaging to barley in terms of harvesting impedance, increased grain moisture and grain contamination by weed seeds than to wheat" (Roder et al., 1986).
Imp-P3 (Is it likely to impact trade?)	y - low	0.2	*Apera spica-venti* is a contaminant of grass seed (Alderman et al., No Date; Warwick et al., 1985) and grain (Stace, 2010), and has been cultivated from bird seed (Hanson and Mason, 1985). Brazil, India, the Republic of Korea, and Mexico regulate this species in imports (APHIS, 2016). Although we did not find any evidence that it has impacted U.S. trade, it may in the future if the species continues to spread or if trading partners become concerned about the spread of biotypes with herbicide resistance. Over the last five years, the United States has been exported about 30 million tons of wheat per year (Bond and Liefert, 2016).
Imp-P4 (Reduces the quality or availability of irrigation, or strongly competes with plants for water)	n - mod	0	We found no evidence of this impact.
Imp-P5 (Toxic to animals, including livestock/range animals and poultry)	n - low	0	We found no evidence that this species is toxic (e.g., Bruneton, 1999; Burrows and Tyrl, 2013).
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]	c - negl	0.6	*Apera spica-venti* has been well documented as a weed in numerous countries, including Canada (Darbyshire, 2003), the United Kingdom (Ryves et al., 1996), the former USSR (Keller et al., 1935), and the United States (Northam and Callihan, 1992; WSSA, 2010). It is the most prevalent and important weed of winter cereals in many European countries (Hamouzová et al., 2014; Luneva and Budrevskaya, 2016; Melander et al., 2008; Soukup et al., 2006). *Apera* species, along with other grassy weed genera, are among the most difficult to control weeds in wheat because their biology is similar to the crop (Evans, 1991). Management techniques include proper crop rotation, seed cleaning, and the use of herbicide (Gast et al., 2007; Luneva and Budrevskaya, 2016; Warwick et al., 1985). "Targeted control of silky bent grass is commonly carried out only in winter cereals using herbicides, furthermore cultural measures such as proper crop rotation and soil tillage may decrease the infestation significantly" (Soukup et al., 2006). Proper

Question ID	Answer - Uncertainty	Score	Notes (and references)
			control of this weed to minimize yield loss requires appropriate combinations of cultural controls, preventative strategies, and herbicide applications (Gerhards and Massa, 2011; Melander et al., 2008). Holm et al. (1979) classify *A. spica-venti* as a common weed in Finland, Germany, and Spain, meaning it is very widespread in a variety of crops and requires constant efforts to maintain under control, but it never seriously threatens crops. However, they evaluated this species about 20 years before it began evolving resistance to herbicides (Heap, 2016). Herbicide resistance is likely making management of this species more difficult. The concern over the development and dispersal of herbicide resistance prompted a study investigating methods of detecting resistance early in fields (Schulz et al., 2014). In an effort to find other methods for reducing the impact of weeds in winter wheat, one researcher examined whether there is variation among wheat cultivars for their ability to suppress growth of *A. spica-venti* and other weeds (Bertholdsson and Sveriges, 2011). Alternate answers for the uncertainty analysis were both "b."
GEOGRAPHIC POTENTIAL			Unless otherwise indicated, the following evidence represents geographically referenced points obtained from the Global Biodiversity Information Facility (GBIF, 2016).
Plant hardiness zones			
Geo-Z1 (Zone 1)	n - mod	N/A	We found no evidence that it occurs in this hardiness zone.
Geo-Z2 (Zone 2)	y - high	N/A	A few scattered points in Russia (GBIF, 2016; Luneva and Budrevskaya, 2016).
Geo-Z3 (Zone 3)	y - mod	N/A	Occurs in a Russian region that includes this zone (Luneva and Budrevskaya, 2016). A few points in Austria (GBIF, 2016).
Geo-Z4 (Zone 4)	y - negl	N/A	Some points in Austria, Finland, Norway, and Russia.
Geo-Z5 (Zone 5)	y - negl	N/A	Some points in Austria, Finland, Germany, and Norway.
Geo-Z6 (Zone 6)	y - negl	N/A	Germany and Norway (GBIF, 2016). The Czech Republic (Soukup et al., 2006).
Geo-Z7 (Zone 7)	y - negl	N/A	France, Germany, and Sweden.
Geo-Z8 (Zone 8)	y - negl	N/A	France, Germany, and the Netherlands.
Geo-Z9 (Zone 9)	y - negl	N/A	France, the Netherlands, and the United Kingdom.
Geo-Z10 (Zone 10)	y - high	N/A	Three points in France, and two in the United States (California).
Geo-Z11 (Zone 11)	n - low	N/A	We found no evidence that it occurs in this hardiness zone.
Geo-Z12 (Zone 12)	n - negl	N/A	We found no evidence that it occurs in this hardiness zone.
Geo-Z13 (Zone 13)	n - negl	N/A	We found no evidence that it occurs in this hardiness zone.
Köppen -Geiger climate classes			
Geo-C1 (Tropical rainforest)	n - negl	N/A	We found no evidence that it occurs in this climate class.
Geo-C2 (Tropical savanna)	n - negl	N/A	We found no evidence that it occurs in this climate class.
Geo-C3 (Steppe)	y - mod	N/A	One point in the United States (California), one in

Question ID	Answer - Uncertainty	Score	Notes (and references)
			Turkey, and three in Spain (GBIF, 2016). A few points in Russia (Luneva and Budrevskaya, 2016).
Geo-C4 (Desert)	n - mod	N/A	We found no evidence that it occurs in this climate class.
Geo-C5 (Mediterranean)	y - low	N/A	Some points in France, Greece, Spain, and the United States (California and Oregon). The species is found in sub Mediterranean climates in Europe (Warwick et al., 1985).
Geo-C6 (Humid subtropical)	y - high	N/A	One or two points each in Croatia, Greece, and Japan. Occurs in one county in Texas in the United States that is present in this climate class (Kartesz, 2016). We used high uncertainty because the evidence is limited and because these occurrences may only represent transient populations.
Geo-C7 (Marine west coast)	y - negl	N/A	France and Germany.
Geo-C8 (Humid cont. warm sum.)	y - low	N/A	A few points in Georgia and Russia (Luneva and Budrevskaya, 2016). For the United States, we found one point in Missouri (GBIF, 2016), and records that it is present in a few counties in Ohio and Pennsylvania that are in this climate class (Kartesz, 2016).
Geo-C9 (Humid cont. cool sum.)	y - negl	N/A	Austria and Germany. The Czech Republic (Soukup et al., 2006).
Geo-C10 (Subarctic)	y - negl	N/A	France, Germany, and Russia. A few points in Slovenia.
Geo-C11 (Tundra)	y - high	N/A	Some points in mountainous regions of Austria and France. Two points in Switzerland, and one in Bulgaria. We used high uncertainty because the number of records for this climate class were limited.
Geo-C12 (Icecap)	n - negl	N/A	We found no evidence that it occurs in this climate class.
10-inch precipitation bands			
Geo-R1 (0-10 inches; 0-25 cm)	n - high	N/A	We found no evidence that it occurs in this precipitation band.
Geo-R2 (10-20 inches; 25-51 cm)	y - negl	N/A	A few points in Greece and Spain, and one point in Turkey. Two points in the United States (California; GBIF, 2016). Occurs in areas of Denmark receiving 26-42 cm of annual precipitation (Melander et al., 2008).
Geo-R3 (20-30 inches; 51-76 cm)	y - negl	N/A	This species is widely distributed throughout Europe and Russia (GBIF, 2016; Luneva and Budrevskaya, 2016; NGRP, 2016; Soukup et al., 2006), which include areas with this precipitation band.
Geo-R4 (30-40 inches; 76-102 cm)	y - negl	N/A	See evidence for Geo-R3.
Geo-R5 (40-50 inches; 102-127 cm)	y - negl	N/A	See evidence for Geo-R3.
Geo-R6 (50-60 inches; 127-152 cm)	y - negl	N/A	See evidence for Geo-R3.
Geo-R7 (60-70 inches; 152-178 cm)	y - negl	N/A	See evidence for Geo-R3.
Geo-R8 (70-80 inches; 178-203 cm)	y - negl	N/A	See evidence for Geo-R3.
Geo-R9 (80-90 inches; 203-229 cm)	y - high	N/A	A few points in the French Alps. One point in the German Alps, and one point in Slovenia. We used high uncertainty because there were only a few records for this precipitation band.
Geo-R10 (90-100 inches; 229-254 cm)	y - high	N/A	One point in the French Alps. Three points in Austria, and one point in Slovenia.
Geo-R11 (100+ inches; 254+ cm)	n - high	N/A	We found no evidence that it occurs in this precipitation band.
ENTRY POTENTIAL			

Question ID	Answer - Uncertainty	Score	Notes (and references)
Ent-1 (Plant already here)	y - negl	1	*Apera spica-venti* is naturalized in a few counties in each of 18 states (OR, WA, CA, ID, TX, MO, KY, OH, MI, PA, MD, DE, NJ, NY,CT, MA, VT, ME) (Kartesz, 2016; NRCS, 2016; Weakley, 2015).
Ent-2 (Plant proposed for entry, or entry is imminent)	-	N/A	
Ent-3 (Human value & cultivation/trade status)	-	N/A	
Ent-4 (Entry as a contaminant)			
Ent-4a (Plant present in Canada, Mexico, Central America, the Caribbean or China)	-	N/A	
Ent-4b (Contaminant of plant propagative material (except seeds))	-	N/A	
Ent-4c (Contaminant of seeds for planting)	-	N/A	
Ent-4d (Contaminant of ballast water)	-	N/A	
Ent-4e (Contaminant of aquarium plants or other aquarium products)	-	N/A	
Ent-4f (Contaminant of landscape products)	-	N/A	
Ent-4g (Contaminant of containers, packing materials, trade goods, equipment or conveyances)	-	N/A	
Ent-4h (Contaminants of fruit, vegetables, or other products for consumption or processing)	-	N/A	
Ent-4i (Contaminant of some other pathway)	-	N/A	
Ent-5 (Likely to enter through natural dispersal)	-	N/A	

Appendix B. U.S. distribution of *Apera spica-venti*.