United States Department of Agriculture

United States
Department of
Agriculture

Animal and
Plant Health
Inspection
Service

February 10,
2021

Version 1

Weed Risk Assessment for *Brassica tournefortii* (Brassicaceae) – Sahara mustard

Brassica tournefortii growth habit (Shebs, 2008)

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Executive Summary

The result of the weed risk assessment for *Brassica tournefortii* is High Risk of spreading or causing harm in the United States. We estimate that 9 to 34 percent of the United States is suitable for the establishment. *Brassica tournefortii* is a xerophytic annual herb that grows in rocky and sandy environments in its native range and invades deserts and rangelands in its introduced range. It is an invasive species in the southwestern United States, present in about 40 counties, and a threat to desert ecosystems. It is also an agricultural weed.

This species can form dense monocultures, and the basal rosette can smother other vegetation. The plant matures early and is self-pollinating, producing seeds before native species have flowered. Seed production and viability are high, and seeds are dispersed by wind and water and by sticking to animals and vehicles. Also, they have spread as agricultural contaminants and may be dispersed internally by seed-eating animals.

In natural settings, *B. tournefortii* displaces native desert wildflowers, including an endangered plant; reduces arthropod diversity; impacts a threatened lizard; and damages the globally significant Sonoran Desert community.

As an agricultural weed, *Brassica tournefortii* can reduce yield even at low densities and taints milk when eaten by dairy cattle. Herbicide-resistant populations have been detected in Australia. Plants for planting may also be a risk factor since the species is believed to have first entered the United States through date palms for planting.

It is under official control in parts of California and Nevada and on federal lands in the Mojave Desert, including Lake Mead National Recreation Area, Joshua Tree National Park, Organ Pipe Cactus National Monument, Saguaro National Park, the Coachella Valley National Wildlife Refuge, and the Colorado Plateau at Grand Canyon National Park. *Brassica tournefortii* is regulated in Chile, Brazil, and Peru and could impact trade as a contaminant of canola and other commodities, such as date palm trees. The species is also invasive in Mexico, Australia, and South Africa.

Plant Information and Background

PLANT SPECIES: *Brassica tournefortii* Gouan (Brassicaceae) (NGRP, 2020; The Plant List, 2013)

SYNONYMS: Plants of the World Online (POWO, 2020) lists *B. tournefortii* as a synonym of *Coincya tournefortii* (Gouan) Alcaraz, T.E.Díaz, Rivas Mart. & Sánchez-Gómez. The Plant List (2013), however, lists *B. tournefortii* as the accepted name and *C. tournefortii* as the synonym, while the National Genetic Resources Program (NGRP, 2020) does not list *C. tournefortii* at all.

COMMON NAMES: Sahara mustard (NGRP, 2020; Trader et al., 2006; VanTassel et al., 2014; Winkler et al., 2019), African mustard (Berry et al., 2014; Chauhan et al., 2006; NGRP, 2020), Asian mustard (Kartesz, 2015; NGRP, 2020; NRCS, 2020), long-fruit turnip, Mediterranean mustard, Mediterranean turnip, pale cabbage, wild turnip (NGRP, 2020).

BOTANICAL DESCRIPTION: *Brassica tournefortii* is an annual herb (Calflora, 2020) that grows 10 to 100 cm tall and has a long taproot (Auld and Medd, 1992; Minnich and Sanders, 2000; Weber, 2003). Leaves are arranged in a basal rosette and can measure up to 30 cm long (NDA, 2019). Flowers are small and dull yellow; the fruit is a deeply veined cream-colored silique with a distinctive beak. Each fruit contains 14 to 30 seeds (Auld and Medd, 1992; GTA, n.d.; Minnich and Sanders, 2000; Weber, 2003). The seeds are brown or red, spherical, and 1 to 1.6 mm in diameter. They are covered with many veins (Bojinansky and Fargasova, 2007; GTA, n.d.; Minnich and Sanders, 2000).

INITIATION: APHIS received a market access request for corn seed for planting from South Africa. *Brassica tournefortii* was identified as a possible contaminant of that pathway; it is evaluated in this document to estimate its risk potential as a weed and invasive plant.

WRA AREA[1]: United States and Territories.

FOREIGN DISTRIBUTION: *Brassica tournefortii* is native to the Mediterranean region and ranges across the Middle East and western Asia (NGRP, 2020; POWO, 2020; Weber, 2003). Its range includes northern Africa, Azerbaijan, Turkmenistan, Uzbekistan, Pakistan, Greece, Italy, and Spain (NGRP, 2020). It is naturalized in South Africa, Australia, New Zealand, India, Chile, and Mexico (Jaryan et al., 2012; Khuroo et al., 2007; Nagmouchi and Alsubeie, 2020; NGRP, 2020; Randall, 2007; Weber, 2003) and is considered invasive in Australia, South Africa, Chile, and North America (Alfaro and Marshall, 2019; Nagmouchi and Alsubeie, 2020; Weber, 2003). It is a casual alien in Belgium (Verloove, 2006), Ireland (Reynolds, 2002), and likely the United Kingdom (Stace, 2010), though the USDA National Genetic Resources Program (NGRP, 2020) lists it as naturalized. Stace (2010) reports that it is frequently introduced to the United Kingdom in wool; therefore, it seems

[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).

more likely to be a recurring waif than a truly established species. *Brassica tournefortii* is also reported from Colombia, France, Mauritania, Niger, Portugal, and Senegal (POWO, 2020). The Global Biodiversity Information Facility (GBIF Secretariat, 2019) includes several records from Scandinavia, a few from Japan, and one from Russia; these may represent the location of herbarium records or cultivated plants. The most recent collection dates are 1987 for Russia, 2003 for Japan, and 1989 for Scandinavia. Since we found very few records and none that are recent, we believe that the species is most likely a waif in these regions. *Brassica tournefortii* is cultivated as an oilseed crop in India and Pakistan (Alfaro and Marshall, 2019; Nagmouchi and Alsubeie, 2020; Winkler et al., 2019). It is regulated in Brazil, Chile, and Peru (PCIT, 2020).

U.S. DISTRIBUTION AND STATUS: *Brassica tournefortii* is naturalized in the United States (Calflora, 2020; NGRP, 2020). In the early 1980s, it was present in the California and Nevada deserts and spreading in Arizona (Rollins, 1981). It is currently reported from 15 counties in California, 11 in Arizona, 5 in Nevada, and 3 in New Mexico, Utah, and Texas (EDDMapS, 2020; Kartesz, 2015; NRCS, 2020). We found no horticultural interest in the plant on popular gardening forums (Dave's Garden, 2020; GardenWeb, 2020) and no evidence that it is available for purchase (Amazon, 2020; Plant Information Online, 2020; The Plant List, 2013). The seeds are regulated in Nevada (USDA-AMS, 2017), where the species is listed as a noxious weed (NDA, 2019). It has a pest rating of “C” in California (Kelch, 2017) and is also regulated in Utah and Arizona (NPB, 2020). All *Brassica* species are regulated in Texas, and all *Brassica* seeds are regulated in Washington and Idaho as potential hosts for pathogens (NPB, 2020). *Brassica tournefortii* has been targeted for control by local, state, and federal officials in California and Nevada and is managed on various federal lands in the Mojave desert (Trader et al., 2006). APHIS does not regulate this species nor the genus *Brassica* (APHIS, 2020).

Analysis

ESTABLISHMENT/SPREAD POTENTIAL: *Brassica tournefortii* is spreading in the United States. It was introduced to California in the 1920s and had appeared in Arizona in the 1940s, Texas in the 1970s, Nevada in the 1980s, and New Mexico and Utah in the 1990s (Winkler et al., 2019). The population in California expanded significantly in the 1970s and 1980s (Minnich and Sanders, 2000). The plant is a self-compatible annual (Calflora, 2020; Winkler et al., 2019) that typically self-pollinates (Alfaro and Marshall, 2019). Plants typically produce 800 to 1200 seeds each and have an average production of about 22,000 seeds/m^2 (Trader et al., 2006). Detached stem fragments and entire mature plants can be blown by the wind, resulting in the dispersal of seeds (Sanchez-Flores, 2007; Trader et al., 2006). Rodents collect and store the seeds (Bangle et al., 2008), and other animals may consume and disperse the seeds (Sanchez-Flores, 2007). Both fruit and seeds have sticky coatings that allow for dispersal on animals (Weber, 2003; Winkler et al., 2019), vehicles, and shoes (Bangle et al., 2008). The film on the seeds also allows for dispersal by water (Winkler et al., 2019); seeds remain viable after six weeks of submersion (Bangle et al., 2008). Seeds can remain dormant in the seed bank for a year or more (Nagmouchi and Alsubeie, 2020). Populations vary substantially from year to year, as is typical for annuals with large seed banks (Bangle et al., 2008). *Brassica tournefortii* can form monocultures (Weber, 2003). The species was likely introduced to California through date palms for cultivation (Minnich and Sanders, 2000). It can also be a contaminant of grain, wool, and other commodities (Clement and Foster, 1994; Stace, 2010). Herbicide-resistant populations have been detected in Australia (Heap, 2020). We had very low uncertainty for this risk element due to abundant literature on its establishment and spread.

Risk score = 25.0 Uncertainty index = 0.05

IMPACT POTENTIAL: *Brassica tournefortii* is a significant environmental weed in Australia (Groves et al., 2005) and the United States (Cal-IPC, 2006; Nagmouchi and Alsubeie, 2020). It accumulates high fuel loads and can be a fire hazard in areas that are not fire-adapted (Curtis and Bradley, 2015). Berry et al. (2014) report that it is likely to be an ecosystem transformer. It is a threat to biodiversity in Australian rangelands (Martin et al., 2006), and in the United States, it reduces the diversity of both native plants and arthropods (Nagmouchi and Alsubeie, 2020; VanTassel et al., 2014). The federally endangered Coachella Valley milkvetch (*Astragalus lentiginosus* var. *coachellae*) and the federally threatened Coachella Valley fringe-toed lizard (*Uma inornata*) are negatively impacted by *B. tournefortii* (Barrows et al., 2009; VanTassel et al., 2014). It is one of the top six weeds likely to damage the Sonoran Desert community (Sanchez-Flores, 2007), a globally significant ecoregion (Ricketts et al., 1999). The suppression of native annuals also reduces human enjoyment of the desert wildflower displays (Abella et al., 2013; Barrows et al., 2009). Finally, Sanchez-Flores (2007) reports that it changes habitat structure and availability of food plants for animals. *Brassica tournefortii* is managed in at least three states and six national conservation areas (Trader et al., 2006). *Brassica tournefortii* is also a principal agricultural weed in Australia and a common agricultural weed in Egypt (Holm et al., 1991), as well as in its native range (Winkler et al., 2019). In Australia, it reduces the yield of canola and winter cereals (Mahajan et al., 2018), even at low densities (Nagmouchi and Alsubeie, 2020). As a contaminant, it reduces the value of cereals, and it can taint milk when eaten by dairy cattle (Auld and Medd, 1992; Meadly, 1958). It is the third most costly herbicide-resistant weed to manage in Australia (Llewellyn et al., 2016). The weed is regulated in Brazil, Chile, and Peru (PCIT, 2020), so it could impact trade as a contaminant of canola or other commodities (Dellow et al., 2006; Stace, 2010). We had very low uncertainty for this risk element since its impact is well-documented.

Risk score = 4.1 Uncertainty index = 0.06

RISK MODEL RESULTS: The risk scores for establishment/spread and impact potential were used to estimate the probabilities of invasiveness and overall risk result (See Figure 1).

Model Probabilities: P(Major Invader) = 98.6%
P(Minor Invader) = 1.4%
P(Non-Invader) = 0%
Risk Result = High Risk
Risk Result after Secondary Screening = Not Applicable

GEOGRAPHIC POTENTIAL: Using the PPQ climate-matching model for weeds (Magarey et al., 2017), we estimate that about 9 to 34 percent of the United States is suitable for the establishment of *B. tournefortii* (Fig. 2). The smaller number is the percentage for which we have very high certainty, while the larger percentage includes areas for which we have lower certainty of climate suitability. The larger area represents the joint distribution of Plant Hardiness Zones 7-12, areas with 0-60 inches of annual precipitation, and the following Köppen-Geiger climate classes: steppe, desert, Mediterranean, humid subtropical, marine west coast, and humid continental cool summers (Appendix). The area of the United States shown to be climatically suitable was determined using only these three climatic variables. Other factors, such as soil, hydrology, disturbance regime, and species interactions may alter the areas in which this species is likely to establish. In its native range, *B. tournefortia* grows in rocky, sandy, and disturbed areas (Weber, 2003). It invades desert dunes, coastal scrub, grasslands, and shrublands in North America and Australia (Cal-IPC, 2006; Rollins, 1981; Weber, 2003) and is spreading in the Mojave and Sonoran deserts in the southwestern United States and Mexico (DiTomaso and Barney, 2012; Minnich and Sanders, 2000). It also grows along roadsides and in fields and disturbed areas in the United States and Australia (Auld and Medd, 1992; Rollins, 1981). It does best on sandy soil with a high water holding capacity (Nagmouchi and Alsubeie, 2020).

ENTRY POTENTIAL: We did not assess the entry potential of *Brassica tournefortii* since it is already present in the United States (NRCS, 2020).

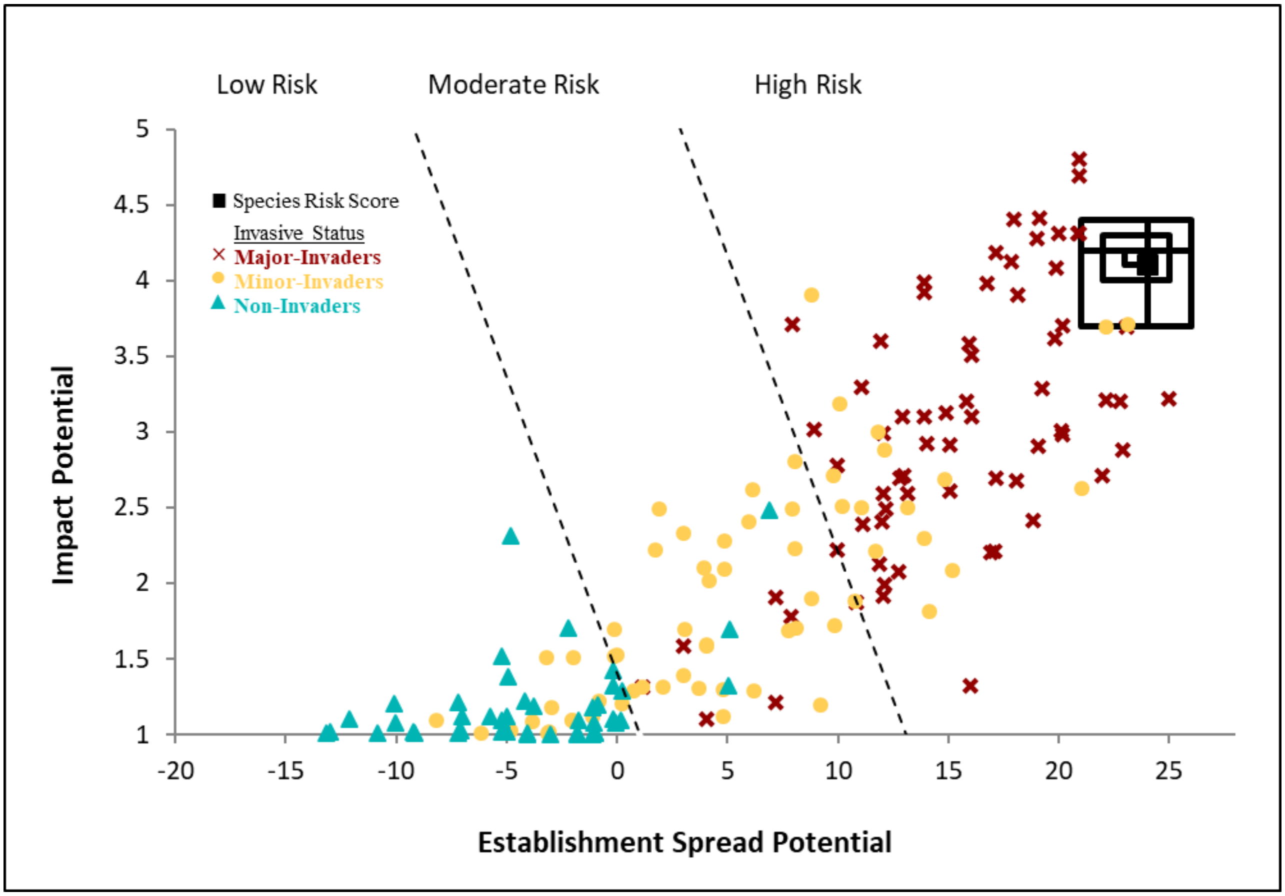

Figure 1. Risk and uncertainty results for *Brassica tournefortii*; the risk score for this species (solid black symbol) is plotted relative to the risk scores of the species used to develop and validate the PPQ WRA model (Koop et al., 2012). The results from the uncertainty analysis are plotted around the risk score for *B. tournefortii*. The smallest, black box contains 50 percent of the simulated risk scores, the second 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)

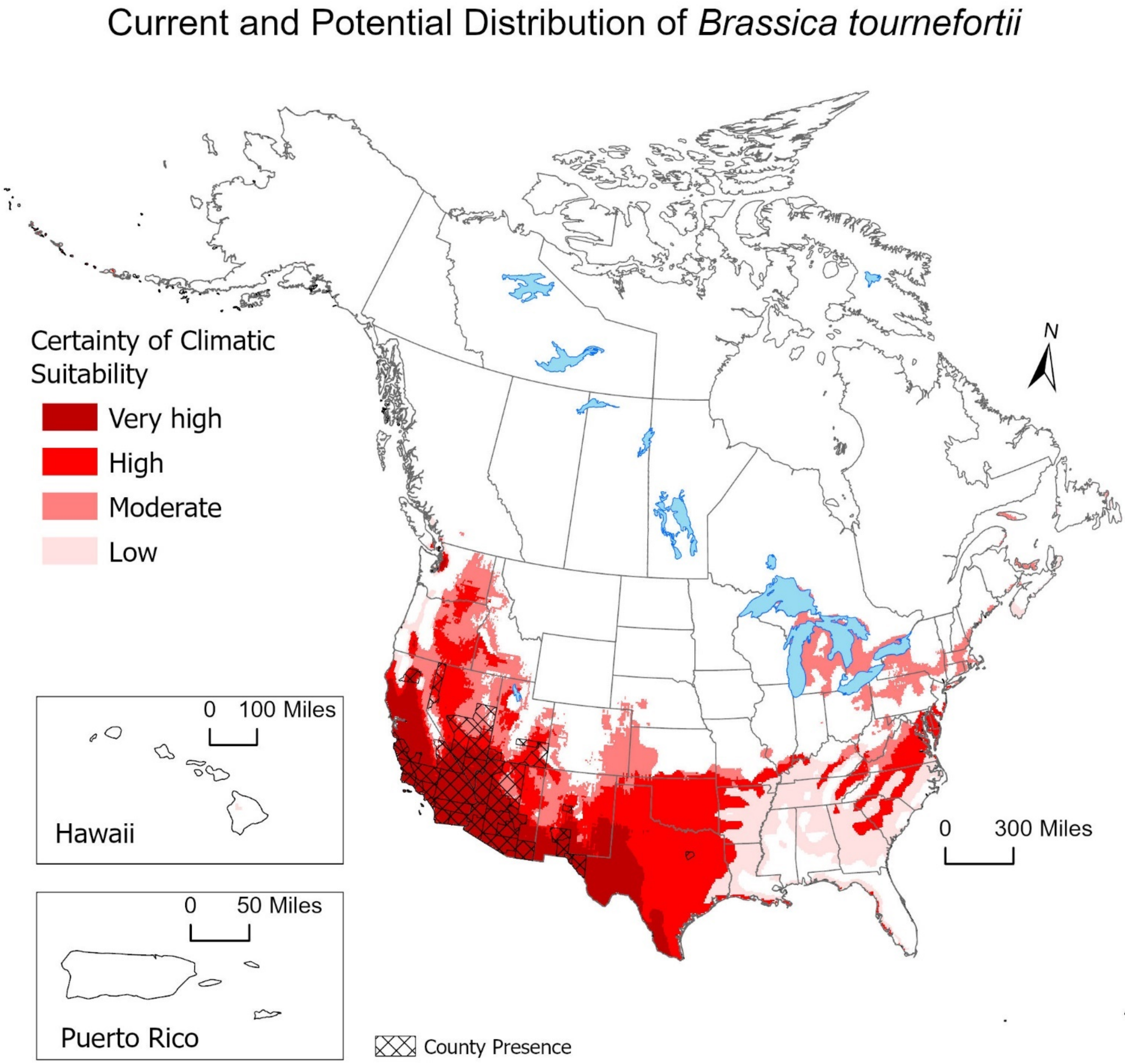

Figure 2. Current and potential distribution of *Brassica tournefortii* in the United States. Climatic suitability was determined using the APHIS-PPQ climate matching tool for invasive plants (Magarey et al., 2017). The known distribution of *B. tournefortii* was based on county distribution records from online databases and other sources (see text). Map components are shown at different scales.

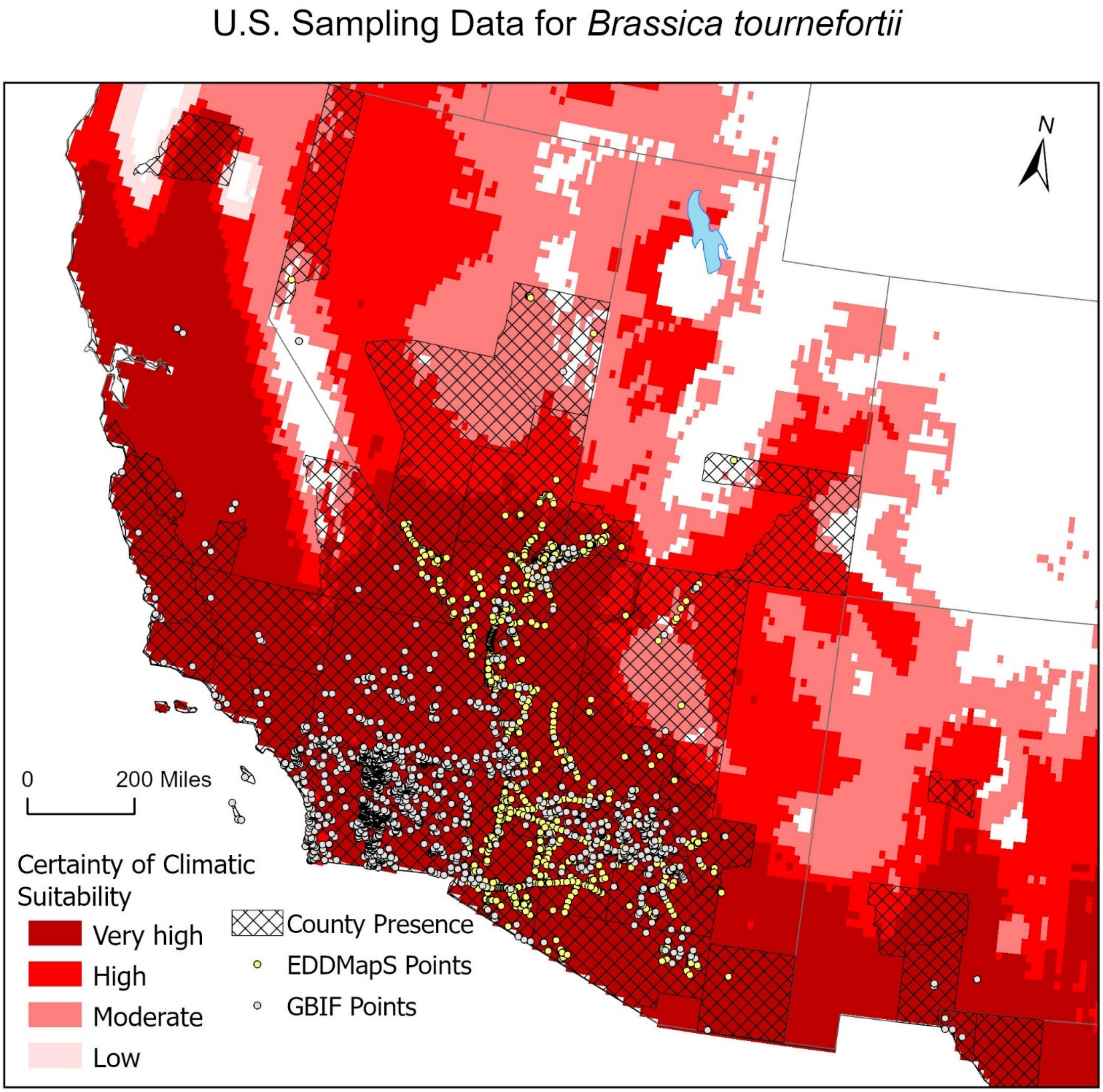

Figure 3. Presence data for *Brassica tournefortii* in the United States. Climatic suitability was determined using the APHIS-PPQ climate matching tool for invasive plants (Magarey et al., 2017). County presence information is from the USDA Plants Database (NRCS, 2020), Kartesz (2015), and EDDMapS (2020). Point data is from EDDMapS (2020) and the Global Biodiversity Information Facility (GBIF Secretariat, 2019).

Discussion

The result of the weed risk assessment for *Brassica tournefortii* is High Risk of spreading or causing harm in the United States. *Brassica tournefortii* is a generalist in arid and semi-arid environments and can tolerate a wide range of environmental conditions (Nagmouchi and Alsubeie, 2020). It is drought-tolerant (Nagmouchi and Alsubeie, 2020) and can reproduce during drought even at only 10 percent of its maximum size (Sanchez-Flores, 2007). It depends on disturbance to establish in new areas (Weber, 2003); soil disturbance by native animals has encouraged its spread in California (Westbrooks, 1998). It resprouts from the seed bank after fire, and the population recovers within one or two years (Minnich and Sanders, 2000; Weber, 2003). Because B. tournefortii flowers early in the year, it consumes water and nutrients in seed production before native plants can mature (Minnich and Sanders, 2000). Alfaro and Marshall (2019) compared native, cultivated, and invasive genotypes of B. tournefortii. They found that cultivated genotypes are shorter and have more appressed branches than native or invasive genotypes. Furthermore, invasive genotypes have larger leaves and tend to mature faster than native genotypes, and cultivated genotypes have larger leaves and mature faster than invasive genotypes. Genetic studies show that one introduction was responsible for most of the populations in North America, but two more recent introductions have occurred in California. These different genotypes could potentially hybridize and increase the invasive range (Winkler et al., 2019). Since the cultivated genotypes display an even greater degree of competitive traits than the current invasive genotypes, it may be that the establishment of even the cultivated forms in natural areas could be cause for concern. Furthermore, if control efforts do not remove all reproductive individuals in an area, the remaining plants may have higher reproductive output, ultimately resulting in no population change (Trader et al., 2006).

Our uncertainty analysis shows that even if some of our answers to the risk assessment questions were to change, the species would very likely still be assessed as High Risk. We found weak evidence that the species is dispersed by birds (Bangle et al., 2008) and that it is allelopathic (Nagmouchi and Alsubeie, 2020; Underwood, 2014). Stronger evidence would reduce our uncertainty, as would additional information on the shade tolerance of *B. tournefortii* and the way it changes habitat structure.

Suggested Citation

PPQ. 2021. Weed risk assessment for *Brassica tournefortii* Gouan (Brassicaceae) – Sahara mustard. United States Department of Agriculture, Animal and Plant Health Inspection Service, Plant Protection and Quarantine (PPQ), Raleigh, NC. 24 pp.

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Appendix. Weed risk assessment for *Brassica tournefortii* Gouan (Brassicaceae)

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.

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	*Brassica tournefortii* is native to the Mediterranean region and ranges into the Middle East and western Asia (NGRP, 2020; POWO, 2020; Weber, 2003). It is considered invasive in Australia, South Africa, Chile, and North America (Alfaro and Marshall, 2019; Nagmouchi and Alsubeie, 2020; Weber, 2003; Winkler et al., 2018). It spread from California through the southwestern United States from the 1920s through the 1990s (Minnich and Sanders, 2000; Winkler et al., 2019). Our answers for the uncertainty simulation were both "e."
ES-2 (Is the species highly domesticated)	n - negl	0	It is grown as an oilseed crop in India and Pakistan (Alfaro and Marshall, 2019). Cultivated genotypes, however, have larger leaves and tend to mature faster than invasive genotypes (Alfaro and Marshall, 2019); consequently, the plant is not being bred for traits that would make it less likely to establish and spread.
ES-3 (Significant weedy congeners)	y - negl	1	The genus *Brassica* includes 44 Eurasian species (Mabberley, 2008). Holm et al. (1991) list *B. campestris*, *B. juncea*, and *B. rapa* as serious or principal weeds somewhere in the world. Simard et al. (2006) report that *B. rapa* is a weed, but it is also cultivated to a small degree. *Brassica juncea* and *B. campestris* are also cultivated (Bazaya et al., 2004; Brown and Brown, 1996), and *B. nigra* is also listed as a weed (Brown and Brown, 1996).
ES-4 (Shade tolerant at some stage of its life cycle)	y - high	0	In North America, *B. tournefortii* grows more densely under perennial shrub canopy (Berry et al., 2014), and Henrickson (2021) indicates that volunteers that work to eradicate the plant should check under the shade of shrubs and cacti. The Plants for a Future database (PFAF, 2021), however, reports that it cannot grow in shade. Therefore, we answered "yes" with high uncertainty.
ES-5 (Plant a vine or scrambling plant, or forms tightly appressed basal rosettes)	y - low	1	Leaves grow in a basal rosette and can measure up to 30 cm long (NDA, 2019; USFS, 2015; Weber, 2003). Meadly (1958) reported that the basal rosette can smother other plants.

Question ID	Answer - Uncertainty	Score	Notes (and references)
ES-6 (Forms dense thickets, patches, or populations)	y - negl	2	The species can form monocultures (Minnich and Sanders, 2000; Weber, 2003). The image in Abella et al. (2013) shows a dense population with little space for any other species.
ES-7 (Aquatic)	n - negl	0	It grows in arid and semi-arid environments and is not an aquatic plant (Nagmouchi and Alsubeie, 2020).
ES-8 (Grass)	n - negl	0	It is in the family Brassicaceae (NGRP, 2020) and is not a grass.
ES-9 (Nitrogen-fixing woody plant)	n - negl	0	We found no evidence that *B. tournefortii* fixes nitrogen. Furthermore, it is not a woody member of a nitrogen-fixing family (Santi et al., 2013).
ES-10 (Does it produce viable seeds or spores)	y - negl	1	It reproduces from seed (Bojinansky and Fargasova, 2007; Minnich and Sanders, 2000).
ES-11 (Self-compatible or apomictic)	y - negl	1	*Brassica tournefortii* is self-compatible (Minnich and Sanders, 2000; Winkler et al., 2019) and reproduces mainly through self-fertilization (Winkler et al., 2019. Outcrossing is possible but occurs less than 12 percent of the time (Winkler, 2017).
ES-12 (Requires specialist pollinators)	n - negl	0	It is self-pollinating (Alfaro and Marshall, 2019; Winkler et al., 2018) and therefore, it does not need specialist 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	It is an annual (Alfaro and Marshall, 2019; Calflora, 2020). Plants can germinate at different times of year, resulting in several reproductive cohorts (Trader et al., 2006). We found no evidence that more than one consecutive generation can be produced in a single year, but Chauhan et al (2006) observed a 58 percent germination rate for fresh seeds in the laboratory. Therefore, more than one generation per year may be possible if plants mature quickly enough. Seeds may remain dormant under unfavorable conditions, resulting in more than one year between generations (Nagmouchi and Alsubeie, 2020), but we answered "b" because the question refers to the minimum generation time. Our alternative answers were “a” and "c."
ES-14 (Prolific seed producer)	y - negl	1	Each plant can produce 750 to 16,000 seeds (Minnich and Sanders, 2000; Weber, 2003; Winkler et al., 2019), with an average of 800 to 1200 (Trader et al., 2006). Trader et al. (2006) observed an average production of 5600 seeds per 0.25 m^2 plot, or about 22,000 seeds/m^2. With a seed viability of about 90 percent (Chauhan et al., 2006), the species meets the threshold for prolific seed production.
ES-15 (Propagules likely to be dispersed unintentionally by people)	y - negl	1	It is believed to have dispersed along the railways in Australia (Winkler et al., 2019). A sticky gel on wet fruits and seeds allows them to be dispersed on vehicles and shoes (Bangle et al., 2008; Sanchez-Flores, 2007). In Arizona, when vehicles drag tires behind them, the action both disperses and buries seeds (Malusa et al., 2003).

Question ID	Answer - Uncertainty	Score	Notes (and references)
ES-16 (Propagules likely to disperse in trade as contaminants or hitchhikers)	y - negl	2	It was probably introduced to California through date palms for cultivation (Minnich and Sanders, 2000). It has entered Belgium in grain (Verloove, 2006) and through wool, grain, spices and grass used in crafts in the United Kingdom (Clement and Foster, 1994; Stace, 2010).
ES-17 (Number of natural dispersal vectors)	4	4	Propagule information for ES-17a through ES-17e: The fruit is a deeply veined, cream-colored silique about 3 to 7 cm long and 2 to 3 mm wide, with a distinctive beak about 1 to 2 cm long. Each fruit contains 14 to 30 seeds, with 1 or 2 seeds in the beak. The fruit often hardens with the seeds inside (Auld and Medd, 1992; GTA, n.d.; Minnich and Sanders, 2000; Weber, 2003). Seeds of *B. tournefortii* are brown or red, spherical, and 1 to 1.6 mm in diameter. They are covered with many veins (Bojinansky and Fargasova, 2007; GTA, n.d.; Minnich and Sanders, 2000).
ES-17a (Wind dispersal)	y - negl		In the southwestern United States, mature plants can form tumbleweeds to disperse seeds, and loose stem fragments with fruit can be blown by the wind (Sanchez-Flores, 2007; Trader et al., 2006).
ES-17b (Water dispersal)	y - negl		A film on the seeds allows dispersal on water (Winkler et al., 2019). Seeds can be spread by water flow in stream channels (Berry et al., 2014). Dried plants can float on lakes with the seed pods intact, and seedlings have been found on lake shores (Bangle et al., 2008). Seeds remain viable after six weeks of submersion (Bangle et al., 2008).
ES-17c (Bird dispersal)	? - max		Bangle et al. (2008) report that it may be dispersed by pigeons, but we found no other evidence of dispersal by birds; therefore, we answered "unknown."
ES-17d (Animal external dispersal)	y - negl		A sticky gel forms on wet fruits and this allows them to be dispersed on animals (Minnich and Sanders, 2000; Weber, 2003). Seeds also have a film that allows dispersal on animals (Winkler et al., 2019). Rodents cache the seeds, resulting in dispersal (Bangle et al., 2008). Briggs and Redak (2016) observed harvester ants (*Pogonomyrmex rugosus*) collecting the seeds while foraging, which may contribute to their dispersal.
ES-17e (Animal internal dispersal)	y - low		Seeds are dispersed internally by seed-eating animals (Sanchez-Flores, 2007). Camp et al. (2020) report that southern hairy-nosed wombats (*Lasiorhinus latifrons*) will eat *B. tournefortii*, but they do not indicate whether seeds are ingested or remain viable after passing through the digestive tract. Marshal et al. (2004) similarly found material from *B. tournefortii* in the droppings of desert mule deer (*Odocoileus hemionus eremicus*) in California but do

Question ID	Answer - Uncertainty	Score	Notes (and references)
			not give any information on whether viable seeds were recovered.
ES-18 (Evidence that a persistent (>1yr) propagule bank (seed bank) is formed)	y - negl	1	Seeds remain viable in the seed bank for a year or more after production and likely stay dormant until conditions allow germination (Nagmouchi and Alsubeie, 2020; Winkler et al., 2019). The mucilaginous seed coat may block water and oxygen absorption and delay germination until conditions are suitable (Bangle et al., 2008). Seeds remain viable in dry storage for nearly three years (Bangle et al., 2008). Chauhan et al. (2006) found that 77 to 87 percent of seeds buried in mesh bags decayed within a year, but Mahajan et al. (2020) found that the majority of seeds buried at 2 cm were viable after 18 months, and some remained viable for up to 30 months. The species displays a pattern of boom-or-bust years, which is also characteristic of annuals with a substantial seed bank (Bangle et al., 2008). Chauhan et al. (2006) report that the use of mesh bags may lead to overestimates of seed decay. Given the preponderance of evidence, we answered "yes" with negligible uncertainty.
ES-19 (Tolerates/benefits from mutilation, cultivation or fire)	n - low	1	We found no evidence.
ES-20 (Is resistant to some herbicides or has the potential to become resistant)	y - negl	1	Resistance to ALS-inhibitor herbicides has been reported in cereals in Australia (Heap, 2020; Mobli et al., 2020).
ES-21 (Number of cold hardiness zones suitable for its survival)	6	0	
ES-22 (Number of climate types suitable for its survival)	6	2	
ES-23 (Number of precipitation bands suitable for its survival)	6	0	
IMPACT POTENTIAL			
General Impacts			
Imp-G1 (Allelopathic)	? - max		It is reported to be allelopathic (Nagmouchi and Alsubeie, 2020). Underwood (2014) found that the root extracts included a compound known to be allelopathic, but greenhouse experiments did not show a negative effect on the two species tested. Therefore, we answered "unknown."
Imp-G2 (Parasitic)	n - negl	0	We found no evidence that *B. tournefortii* is parasitic. Furthermore, it does not belong to a family known to include parasitic plants (Heide-Jorgensen, 2008).
Impacts to Natural Systems			
Imp-N1 (Changes ecosystem processes and parameters that affect other species)	y - negl	0.4	It accumulates a high fuel load and is a fire hazard in scrublands and in areas that are not fire-adapted (Curtis and Bradley, 2015; Trader et al., 2006; Weber, 2003). Therefore, it is likely to be an ecosystem transformer (Berry et al., 2014).

Question ID	Answer - Uncertainty	Score	Notes (and references)
Imp-N2 (Changes habitat structure)	y - low	0.2	*Brassica tournefortii* forms monocultures (Minnich and Sanders, 2000) and changes the habitat structure and availability of food plants for wildlife (Sanchez-Flores, 2007).
Imp-N3 (Changes species diversity)	y - negl	0.2	It is a threat to biodiversity in Australian rangelands (Martin et al., 2006). It outcompetes native desert annuals (Berry et al., 2014; Nagmouchi and Alsubeie, 2020) and reduces native plant diversity (VanTassel et al., 2014). Increasing *B. tournefortii* cover is correlated with decreased arthropod abundance and diversity in sandy deserts of the Coachella Valley, independent of the harm to native plants (VanTassel et al., 2014). It grows taller than native annuals with a density of up to 625 plants/m^2, so it crowds and shades the native species (Bangle et al., 2008).
Imp-N4 (Is it likely to affect federal Threatened and Endangered species?)	y - negl	0.1	Brassica tournefortii suppresses U.S. native plants including threatened species (Berry et al., 2014). Coachella Valley milkvetch (*Astragalus lentiginosus* var. *coachellae*), a Federal Endangered species, produced about eight times as many seed pods per plant in research plots that were cleared of *B. tournefortii* compared to unweeded plots (Barrows et al., 2009). It has a negative impact on the Coachella Valley fringe-toed lizard (*Uma inornata*), a Federal Threatened species (Barrows et al., 2009; VanTassel et al., 2014).
Imp-N5 (Is it likely to affect any globally outstanding ecoregions?)	y - negl	0.1	It is rated as one of the top six weeds that would likely cause ecological damage to the Sonoran Desert (Sanchez-Flores, 2007), which is a globally significant ecoregion (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 - negl	0.6	It is a significant environmental weed in Australia (Groves et al., 2005; Rozefelds et al., 1999). In the United States, it is under official management in the Mojave Weed Management Area in California, the Clark County Cooperative Weed Management area in Nevada, Lake Mead National Recreation Area, Joshua Tree National Park, Organ Pipe Cactus National Monument, Saguaro National Park, the Coachella Valley National Wildlife Refuge, and the Colorado Plateau at Grand Canyon National Park. It is also being controlled by the Las Vegas Field Office of the Bureau of Land Management (Trader et al., 2006). The California Invasive Plant Council (Cal-IPC, 2006) rates it as severe in impact and invasiveness and moderate in distribution. Trader et al. (2006) report that it is one of the most invasive plants in natural areas of California. The species is a threat to remote shoreline habitats in North America (Nagmouchi and Alsubeie, 2020). Our alternative answers for the uncertainty simulation were both "b."
Impact to Anthropogenic Systems (e.g., cities, suburbs, roadways)			

Question ID	Answer - Uncertainty	Score	Notes (and references)
Imp-A1 (Negatively impacts personal property, human safety, or public infrastructure)	n - low	0	We found no evidence of this kind of impact.
Imp-A2 (Changes or limits recreational use of an area)	y - negl	0.1	Eliminating *B. tournefortii* from an area of desert nearly doubled the abundance of native wildflowers, which have a high aesthetic value (Abella et al., 2013). Barrows et al. (2009) remark that their removal of *B. tournefortii* from experimental plots benefited visitors who were able to see the desert wildflowers released from the visual dominance of the invasive species.
Imp-A3 (Affects desirable and ornamental plants, and vegetation)	n - low	0	We found no evidence of this kind of 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]	a - mod	0	Although *B. tournefortii* reduces the aesthetic value of desert wildflowers, we found no evidence that it is a weed in lawns or gardens. Control efforts are underway to reduce the impact of this weed in the desert, but these are described under Imp-N6. Therefore we answered "a," with "b" and "c" as our alternative answers.

Impact to Production Systems (agriculture, nurseries, forest plantations, orchards, etc.)			
Imp-P1 (Reduces crop/product yield)	y - negl	0.4	Infestations can reduce agricultural yield even at low densities (Chauhan et al., 2006; Nagmouchi and Alsubeie, 2020). In Australia, it can reduce yield of canola and winter cereals (Mahajan et al., 2018). It is ranked seventh in terms of yield loss across all crops in Australia, resulting in annual losses of 41,000 tons (Llewellyn et al., 2016).
Imp-P2 (Lowers commodity value)	y - negl	0.2	When eaten by dairy cattle, it can taint milk (Auld and Medd, 1992; Meadly, 1958). In Australia, it is the third most costly herbicide-resistant weed to manage, resulting in an annual cost of $7.8 million in additional herbicide costs (Llewellyn et al., 2016). It also reduces the value of cereals as a contaminant (Meadly, 1958).
Imp-P3 (Is it likely to impact trade?)	y - negl	0.2	It is regulated in Brazil, Chile, and Peru (PCIT, 2020). It can be a contaminant of canola seed (Dellow et al., 2006) grain, and other commodities (Stace, 2010; Verloove, 2006). Therefore, it could impact trade.
Imp-P4 (Reduces the quality or availability of irrigation, or strongly competes with plants for water)	n - low	0	We found no evidence of this impact.

Question ID	Answer - Uncertainty	Score	Notes (and references)
Imp-P5 (Toxic to animals, including livestock/range animals and poultry)	n - low	0	*Brassica* species in general can be toxic under certain circumstances, such as excessive grazing, but these are also used both as food for humans and as animal fodder (Burrows and Tyrl, 2013). Glucosinolates are toxic to livestock in large amounts and are present in *B. tournefortii* (Camp et al., 2020). The plant is, however, grown as fodder during the winter in India (Kaushik and Kumar, 2003) and is grown as an oilseed crop in India and Pakistan (Alfaro and Marshall, 2019). Meadly (1958) reported that it is not valued as forage but that the young plants are eaten by livestock. No mention is made of toxicity. We therefore answer "no" with low uncertainty.
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	*Brassica tournefortii* is a principal weed in Australia and a common weed in Egypt (Holm et al., 1991). It is ranked as the sixth most troublesome crop weed in Australia based on revenue loss (Llewellyn et al., 2016; Mobli et al., 2020) and is the most common winter weed in the northern grain region of Australia (Mahajan et al., 2020). It is controlled with herbicides in Australia (Llewellyn et al., 2016). The plant is a weed of corn in Egypt (Ahmed and Slima, 2020). It is an agricultural weed in its native range (Winkler et al., 2019). Our alternative answers for the uncertainty simulation were both "b."
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	We found no evidence of presence in this zone.
Geo-Z2 (Zone 2)	n - negl	N/A	We found no evidence of presence in this zone.
Geo-Z3 (Zone 3)	n - negl	N/A	We found no evidence of presence in this zone.
Geo-Z4 (Zone 4)	n - negl	N/A	We found no evidence of presence in this zone.
Geo-Z5 (Zone 5)	n - low	N/A	1 point in the United States (Nevada)
Geo-Z6 (Zone 6)	y - mod	N/A	1 point in the United States (Nevada) and Russia; also some presence in Nevada from EDDMapS (2020)
Geo-Z7 (Zone 7)	y - low	N/A	2 points in Norway and the United States (Arizona); 1 in Finland, Germany, and Australia; also some presence in Nevada and Arizona from EDDMapS (2020)
Geo-Z8 (Zone 8)	y - negl	N/A	Many points in the United States, 9 in Australia, 7 in the United Kingdom, 6 in Spain, 5 in Pakistan, 4 in Sweden, 3 in Norway, 2 in France and New Zealand, 1 in Azerbaijan

Question ID	Answer - Uncertainty	Score	Notes (and references)
Geo-Z9 (Zone 9)	y - negl	N/A	Many points in Spain, Australia, Mexico, and the United States; a few in Belgium; 9 in New Zealand; 7 in the United Kingdom; 5 in France; 4 in Morocco; 3 in South Africa; 2 in Greece; 1 in Azerbaijan, Israel, Tunisia, and Saudi Arabia
Geo-Z10 (Zone 10)	y - negl	N/A	Many points in Spain, Israel, Australia, Mexico, and the United States; 7 in Greece; 6 in New Zealand; 5 in South Africa; 3 in Morocco, Jordan, and Saudi Arabia; 2 in Algeria; 1 in Italy, Sardinia, Azerbaijan, Egypt, and Pakistan
Geo-Z11 (Zone 11)	y - negl	N/A	Many points in Spain, Israel, Australia, Mexico, and the United States (California); some in South Africa; 8 in Greece; 7 in France and New Zealand; 5 in Sardinia; 3 in Egypt; 2 in Sicily and Turkey; 1 in Portugal
Geo-Z12 (Zone 12)	y - low	N/A	Many points in Israel, Australia, Mexico, and the United States; 9 in South Africa; 3 in Lebanon; 1 in Morocco and Burkina Faso. Almost all these points, however, are in narrow coastal regions, reflecting the effect of oceans on temperature. Since we found few points in inland regions, we have low rather than negligible uncertainty.
Geo-Z13 (Zone 13)	n - negl	N/A	We found no evidence of presence in this zone.
Köppen -Geiger climate classes			
Geo-C1 (Tropical rainforest)	n - negl	N/A	We found no evidence of presence in this climate class.
Geo-C2 (Tropical savanna)	n - mod	N/A	1 point in Burkina Faso
Geo-C3 (Steppe)	y - negl	N/A	Many points in the United States, Mexico, Australia, Israel, and Spain; 6 in Pakistan and Greece; 3 in South Africa; 2 in Morocco; 1 in Azerbaijan
Geo-C4 (Desert)	y - negl	N/A	Many points in the United States, Mexico, Australia, Israel, and Spain; 7 in South Africa; 4 in Saudi Arabia and Egypt; 2 in Jordan; 1 in Oman and Tunisia
Geo-C5 (Mediterranean)	y - negl	N/A	Many points in the United States, Australia, Israel, and Spain; some in South Africa; a few in France; 7 in Morocco; 5 in Greece; 4 in Crete and Sardinia; 3 in Turkey; 2 in Algeria, Azerbaijan, and Sicily; 1 in Cyprus and Italy
Geo-C6 (Humid subtropical)	y - low	N/A	Many points in Australia, 4 in Japan, 1 in Mexico
Geo-C7 (Marine west coast)	y - negl	N/A	Many points in Australia and New Zealand; some in the United Kingdom; a few in Belgium; 5 in France; 3 in Mexico, South Africa, and Norway; 2 in Spain; 1 in Germany
Geo-C8 (Humid cont. warm sum.)	n - low	N/A	We found no evidence of presence in this climate class but have low rather than negligible uncertainty because the species is present in similar climate classes.
Geo-C9 (Humid cont. cool sum.)	y - low	N/A	4 points in Sweden; 1 in the United States (Arizona), Russia, Finland, and Norway; also some presence in Nevada and Arizona from EDDMapS (2020)

Question ID	Answer - Uncertainty	Score	Notes (and references)
Geo-C10 (Subarctic)	n - high	N/A	2 points in Norway
Geo-C11 (Tundra)	n - negl	N/A	We found no evidence of presence in this climate class.
Geo-C12 (Icecap)	n - negl	N/A	We found no evidence of presence in this climate class.
10-inch precipitation bands			
Geo-R1 (0-10 inches; 0-25 cm)	y - negl	N/A	Many points in Australia, Israel, Spain, Mexico, and the United States; 9 in South Africa; 5 in Pakistan; 4 in Saudi Arabia and Egypt; 3 in Jordan; 2 in Morocco; 1 in Oman, Cyprus, and Crete
Geo-R2 (10-20 inches; 25-51 cm)	y - negl	N/A	Many points in Australia, Israel, Spain, and the United States; some in Mexico; a few in Greece; 5 in South Africa; 4 in Morocco and France; 2 in Algeria, Azerbaijan, Turkey, Cyprus, Crete, Sicily, and Sardinia; 1 in Pakistan and Burkina Faso
Geo-R3 (20-30 inches; 51-76 cm)	y - negl	N/A	Many points in Australia, South Africa, and Israel; some in Spain; 9 in New Zealand; 7 in France; 6 in the United States (California, Nevada, and Arizona); 4 in Sardinia; 3 in Lebanon, Greece, and Mexico; 1 in Russia, Morocco, Germany, and Sweden
Geo-R4 (30-40 inches; 76-102 cm)	y - negl	N/A	Many points in Australia; 9 in Belgium; 4 in New Zealand; 3 in Greece, Spain, the United Kingdom, Sweden, and Mexico; 2 in Morocco; 1 in Azerbaijan, Italy, France, Portugal, and Finland
Geo-R5 (40-50 inches; 102-127 cm)	y - low	N/A	9 points in New Zealand; 4 in Australia, the United Kingdom, and Norway; 1 in Belgium
Geo-R6 (50-60 inches; 127-152 cm)	y - high	N/A	4 points in the United Kingdom, 3 in France
Geo-R7 (60-70 inches; 152-178 cm)	n - high	N/A	2 points in the United Kingdom, 1 in New Zealand and Norway
Geo-R8 (70-80 inches; 178-203 cm)	n - mod	N/A	1 point in New Zealand and Japan
Geo-R9 (80-90 inches; 203-229 cm)	n - mod	N/A	3 points in Japan
Geo-R10 (90-100 inches; 229-254 cm)	n - low	N/A	1 point in Norway
Geo-R11 (100+ inches; 254+ cm)	n - low	N/A	1 point in Mexico
ENTRY POTENTIAL			
Ent-1 (Plant already here)	y - negl	1	It is present in California, Texas, Arizona, Nevada, New Mexico, and Utah (Kartesz, 2015; NRCS, 2020)
Ent-2 (Plant proposed for entry, or entry is imminent)	-	N/A	
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	-	N/A	

Question ID	Answer - Uncertainty	Score	Notes (and references)
other evidence of trade or resale]			
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	