United States Department of Agriculture

Weed Risk Assessment for *Euphorbia falcata* L. (Euphorbiaceae) – Sickle spurge

United States Department of Agriculture

Animal and Plant Health Inspection Service

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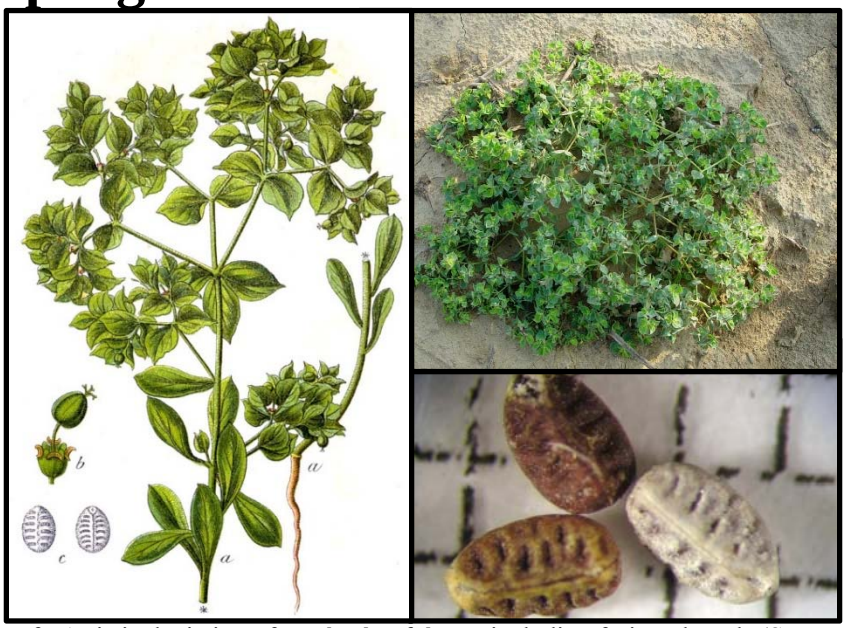

Left: Artistic depiction of *Euphorbia falcata*, including fruit and seeds (Sturm, 1906). Top right: Entire plant in field (Mrkvicka, 2002). Bottom right: Seed (Herbarium JACA, 2016).

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.

Species Information

***Euphorbia falcata* L. – Sickle spurge**

Family: Euphorbiaceae

Synonyms: Several synonyms are listed within The Plant List (2016) and the World Checklist for Selected Plant Families (WCSP, 2016), but none were useful in finding information on this taxon.

Common names: Sickle spurge (Williams, 1982).

Botanical description: *Euphorbia falcata* is an erect annual herb that is found along roadsides, at disturbed sites, and in agricultural systems (AgroAtlas, 2016; Hanf, 1983; James and Harden, 2016; Mrázek, 2012; Pysek et al., 2002; Randall, 2007). It typically grows to a height of 10-20 cm, but may grow as tall as 40 cm (AgroAtlas, 2016; Hanf, 1983). It produces a white sap when cut (AgroAtlas, 2016). Flowers are formed in cup-shaped bracts with a single female flower surrounded by many male flowers (i.e., cyathia) (James and Harden, 2016). Seeds are "barrel-shaped, quadrangular, with deep, brownish-red transverse grooves on surface" (Hanf, 1983) and measure approximately 1 mm wide by 2 mm long (Can and Küçüker, 2015; The Digital Plant Atlas, 2016). Two subspecies of *E. falcata* occur in the literature, *E. falcata* subsp. *falcata* and *E. falcata* subsp. *macrostegia* (Euphorbia PBI, 2012). We were unable to identify descriptors that separate these two subspecies, but *E. falcata* subsp. *macrostegia* is limited to Turkey and Cypress, whereas *E. falcata* subsp. *falcata* has a broader distribution that includes Turkey and Cypress (Euphorbia PBI, 2012). We included all information at the subspecies level, but found no information for *E. falcata* subsp. *macrostegia* that was useful in evaluating the assessment questions. For transparency, we clearly specified when information was obtained at the subspecies level in the assessment.

Initiation: PPQ received a market access request for wheat seed for human and animal consumption from the government of Ukraine (Government of Ukraine, 2013). A commodity import risk assessment determined that *Euphorbia falcata* could be associated with this commodity as a seed contaminant. In this assessment, we 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: *Euphorbia falcata* is native to the Mediterranean region (e.g., Egypt, Turkey, and Italy) but also extends into middle and eastern Europe (e.g., Hungary, Poland, and Germany) (Richardson et al., 2006; Weakley, 2015) and portions of temperate and tropical Asia (e.g., India, Pakistan, Afghanistan) (NGRP, 2016). It is considered a "minor weed" in western Europe (Williams, 1982) and a "common weed" in Morocco, Portugal, and northern Turkey (Altay and Ozturk, 2012; Holm et al., 1979). In Poland, *E. falcata* is considered critically endangered in some localities (Zając and Zając, 2014). *Euphorbia falcata* is considered adventive in Far East Asia (AgroAtlas,

2016) and is naturalized in Australia and Chile (Castro et al., 2005; Pysek et al., 2002; Richardson et al., 2006; Ugarte et al., 2011). The status of *E. falcata* in the Czech Republic is convoluted. Pysek et al. (2002) indicate that this species is naturalized in the Czech Republic, and even speculate that the species was invasive when it initially colonized this country. This speculation may be responsible for other researchers indicating this species is invasive (e.g., Randall, 2007; Randall, 2012). It is not clear how long ago *E. falcata* established in the Czech Republic, but it is long enough for some researchers to consider the species native to this area (e.g., NGRP, 2016). Subsequently, the confusion in nativity for *E. falcata* in the Czech Republic has led to some researchers labeling it a "vulnerable" species in the country (Kolářová et al., 2013; Mrázek, 2012), a label that would suggest that it is native and also in decline.

U.S. distribution and status: *Euphorbia falcata* is naturalized in the United States, with occurrences dating back to 1911 (Steele, 1911). Despite this long history, there are only 19 county occurrences (in eight eastern states) reported for the species (Kartesz, 2016; NRCS, 2016). Most occurrences are found between northeastern Tennessee and eastern Pennsylvania. The western-most occurrence is in western Iowa. In the United States, *E. falcata* is reported from species inventories (Braun, 1934; Core, 1940; Davis and Core, 1940; Steele, 1911) and regional floras (Weakley, 2015). Some vegetation inventories indicate that the species can be "abundant" (e.g., Davis and Core, 1940; Steele, 1911), but more recent accounts consider it "rare" (e.g., Weakley, 2015). There is no indication that this species is cultivated (e.g., Bailey Nurseries, 2016; Dave's Garden, 2016; Greenleaf Nursery Company, 2016; Lowe's, 2016; Monrovia, 2016; San Marcos Growers, 2001; Univ. of Minn., 2016) or is being managed or regulated in the United States.

WRA area[1]: Entire United States, including territories.

1. *Euphorbia falcata* analysis

Establishment/Spread Potential

Euphorbia falcata is an annual species (Altay and Ozturk, 2012; Cakovic et al., 2012; Džigurski et al., 2013; Landolt, 1977) that produces viable seed (Caballero et al., 2003; José-María and Sans, 2011). There is some indirect evidence that *E. falcata* may self-pollinate, but more frequently, it is pollinated by generalist pollinating insects (Pinke and Pál, 2009). Seeds of *E. falcata* are small, measuring approximately 1 mm wide by 2 mm long (Can and Küçüker, 2015; The Digital Plant Atlas, 2016) and are dispersed by ants and potentially by seed-feeding birds (Nicolai and Boeken, 2012; Pinke and Pál, 2009). The seeds have fine hairs that also allow them to stick to objects when wet (Grubert, 1974), suggesting it may also disperse externally on

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

animals. It is not clear if the seeds of *E. falcata* are unintentionally dispersed by humans, but the species is frequently found in disturbed areas, such as roadsides (James and Harden, 2016; Richardson et al., 2006; Weakley, 2015) and foot paths (Greuter, 1979), which indicates that it may. *Euphorbia falcata* has naturalized in several countries outside its native range, including Chile (Castro et al., 2005; Ugarte et al., 2011), Australia (Richardson et al., 2006), and the United States (Weakley, 2015), but has not spread widely in these countries. We had average uncertainty with this risk element because there were several questions we were unable to answer.
Risk score = 9 Uncertainty index = 0.19

Impact Potential *Euphorbia falcata* is considered a weed in agricultural crop systems and rangelands in the Mediterranean region (Abbasvand et al., 2013; José-María et al., 2013; Kolářová et al., 2013). It occurs in other areas, such as rail and roadways (AgroAtlas, 2016; James and Harden, 2016; Richardson et al., 2006; Steele, 1911; Weakley, 2015), but has not been noted as a weed in these systems. This species does not appear to be actively controlled, but field populations are suspected to decline as a result of agricultural intensification (José-María and Sans, 2011). Many *Euphorbia* spp. have allelopathic effects on other plants (Hussain, 1980; Qasem and Foy, 2001; Steenhagen and Zimdahl, 1979; Tanveer et al., 2010) and can be toxic to livestock. Although *E. falcata* is considered a medicinal plant, its toxicological effects may be one of the reasons it is considered medicinal. For instance, *E. falcata* is used as a laxative and as a treatment for psoriasis, but prolonged treatment with *E. falcata* may cause external ulcers (Leporatti et al., 1985). We had average uncertainty for this risk element.
Risk score = 1.3 Uncertainty index = 0.14

Geographic Potential Based on three climatic variables, we estimate that about 89 percent of the United States is suitable for the establishment of *Euphorbia falcata* (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 *E. falcata* represents the joint distribution of Plant Hardiness Zones 3-12, areas with 0-70 inches of annual precipitation, and the following Köppen-Geiger climate classes: steppe, desert, Mediterranean, humid subtropical, marine west coast, humid continental warm summers, humid continental 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. Habitats where *E. falcata* has been identified include rangelands (Abbasvand et al., 2013), saline wetlands (Altay and Ozturk, 2012), rail and roadways (AgroAtlas, 2016; James and Harden, 2016; Richardson et al., 2006; Steele, 1911; Weakley, 2015), and cereal crops (Hanf, 1983; José-María et al., 2013;

Kolářová et al., 2013).

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

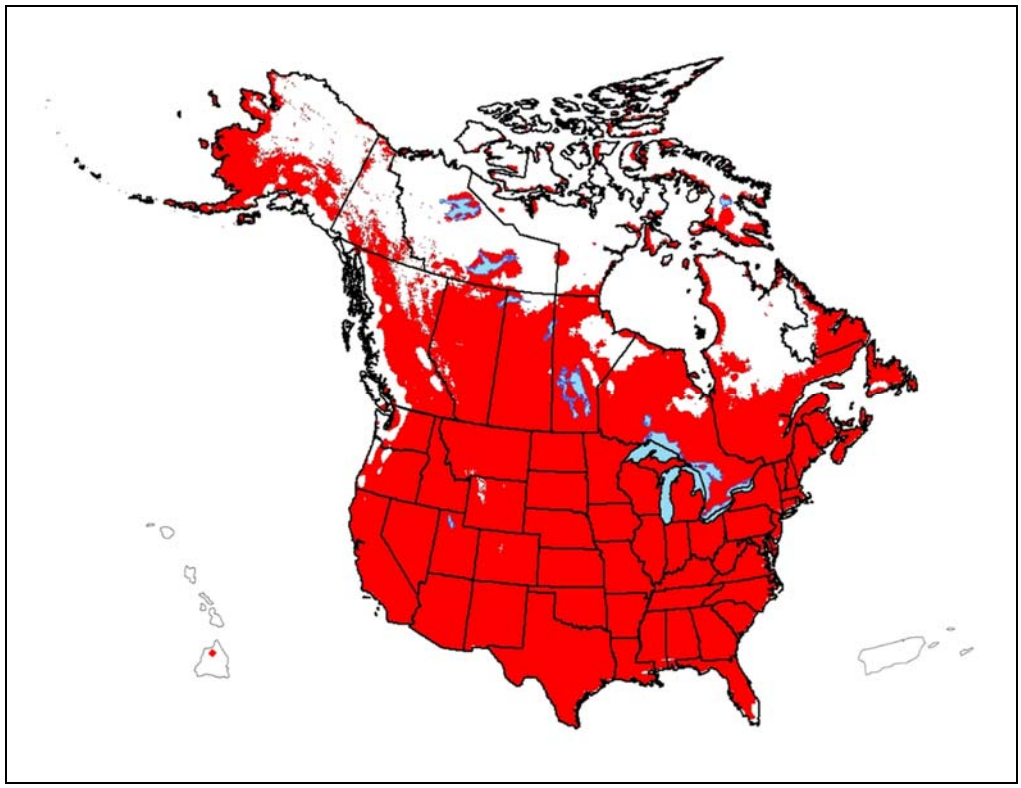

Figure 1. Potential geographic distribution of *Euphorbia falcata* in the United States and Canada. Map insets for Hawaii and Puerto Rico are not to scale.

2. Results

Model Probabilities: P(Major Invader) = 22.6%
P(Minor Invader) = 68.0%
P(Non-Invader) = 9.4%

Risk Result = Evaluate Further

Secondary Screening = High Risk

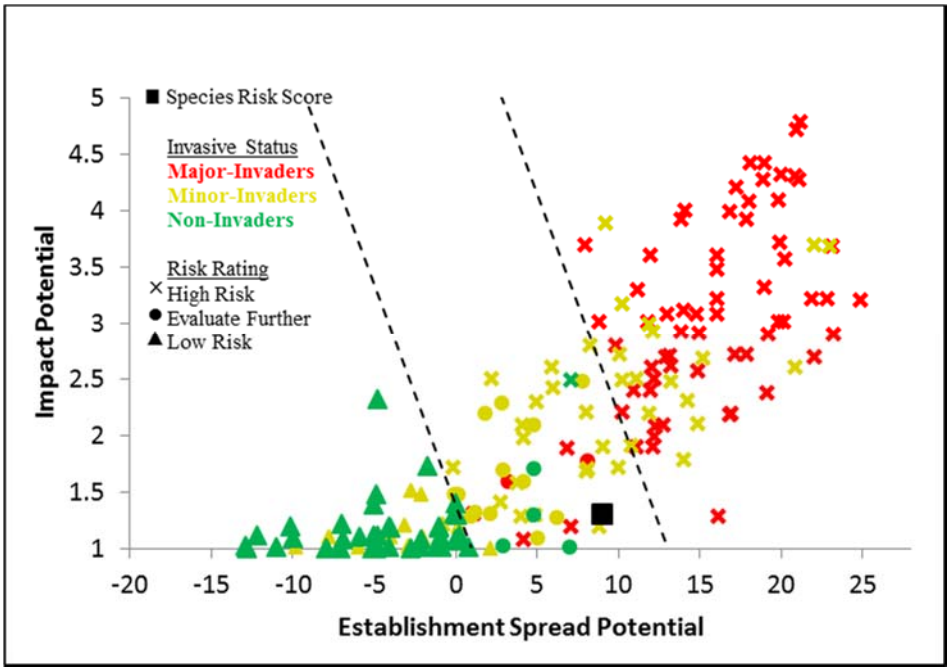

Figure 2. *Euphorbia falcata* risk score (black box) relative to the risk scores of species used to develop and validate the PPQ WRA model (other symbols). See Appendix A for the complete assessment.

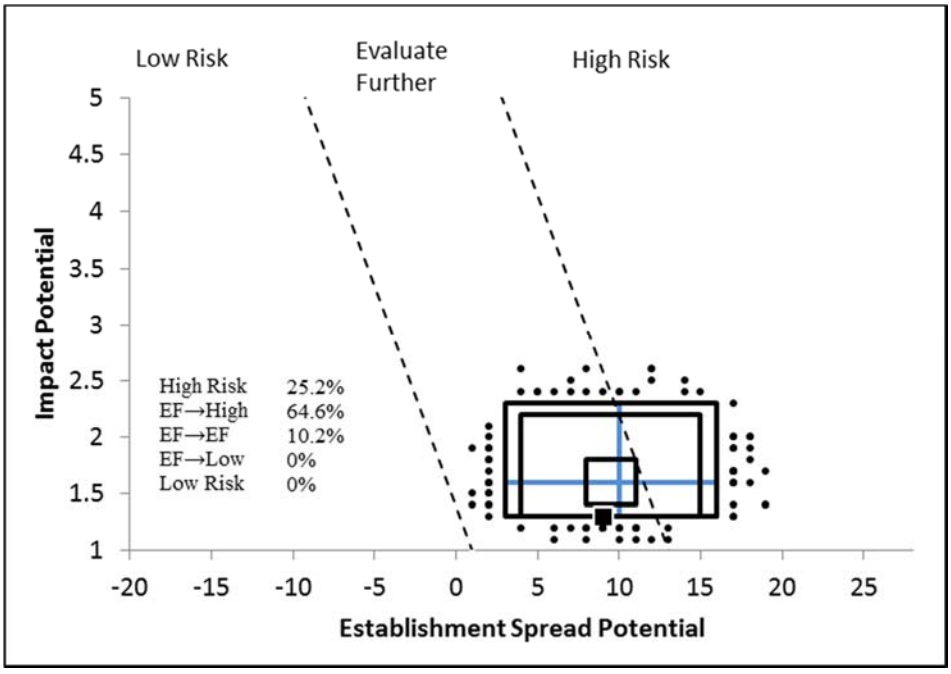

Figure 3. Model simulation results (N=5,000) for uncertainty around the risk score for *Euphorbia falcata*. The blue "+" symbol represents the medians of the simulated outcomes. The smallest box contains 50 percent of the outcomes, the second 95 percent, and the largest 99 percent.

3. Discussion

The result of the weed risk assessment for *Euphorbia falcata* is High Risk after secondary screening (Fig. 2). There was an average amount of uncertainty associated with this assessment because we were unable to answer several questions due to a lack of biological information. A few researchers have discussed or examined the chemical makeup of *E. falcata* (El Bribri et al., 2013; Vasas et al., 2012), but none have studied the biology of the species in any significant detail. The genus *Euphorbia* contains over 2,000 species (El Bribri et al., 2013; Frajman and Schönswetter, 2011) that constitute a wide diversity of growth forms and traits. To focus only on the closely related species, we limited the congeneric data to species in the same subgenus (*Esula*) and section (*Pithyusa*) as *E. falcata* (Riina et al., 2013), which excluded well-studied species like *Euphorbia esula*, which is an invasive weed in the western United States. More research on seed production, dispersal, and agricultural impacts of this species would help reduce the uncertainty in this assessment.

The Association of Official Seed Analysts has classified *E. falcata* as a seed contaminant of crops (AOSA, 2014). Our assessment indicates that trade in wheat seed or grain is a likely pathway for the entry of *E. falcata* into the United States because its seeds mature in late summer (Džigurski et al., 2013), which is approximately the time when wheat would be harvested (NASS, 1997; Wicks et al., 1986). Although *E. falcata* is a relatively short-statured plant (typically 10-20 cm, but up to 40 cm tall), it is likely that seeds from this plant would be harvested with wheat. A general rule for harvesting wheat is to cut stems at one-third of the mean height of the crop so that there is stubble to minimize soil erosion (McMaster et al., 2000). The height of wheat varies from 63-107 cm (Thomas et al., 1993; Wicks et al., 1986), meaning that the harvesting height would be between 21-35 cm. Therefore, it is likely that some of the taller *E. falcata* plants would be harvested. If no other seed cleaning or mitigations are performed on wheat seed, then it is likely that *E. falcata* would be found as a contaminant of wheat seed or grain.

We are also certain that *E. falcata* can establish outside its native range, as demonstrated by its naturalization in the United States (Weakley, 2015), Chile (Ugarte et al., 2011; Castro et al., 2005), and Australia (Richardson et al., 2006). What is less clear is why *Euphorbia falcata* remains geographically limited with no reported impacts in its naturalized distribution despite detections of the species in these countries since the early 20th century (1911-1944). The lack of spread and impacts in these areas may be due to an inability to disperse quickly or cause significant impacts, but may also represent a mismatch in climate for this species in these regions. Based on *E. falcata*'s native Mediterranean range and the general nature of *Euphorbia* spp., *E. falcata* is likely adapted to drier climates.

Although drier climates exist in the countries *E. falcata* has naturalized in, there is no evidence the species occurs in those areas. For example, in the United States it is limited to the eastern United States (Weakley, 2015) which is much wetter than the western United States. Therefore, the limited dispersal and reported impacts could also be a consequence of not having ideal growing conditions for the plant.

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Appendix A. Weed risk assessment for *Euphorbia falcata* L. (Euphorbiaceae). 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]	e - low	2	*Euphorbia falcata* is native to the Mediterranean region (e.g., Egypt, Turkey, and Italy) but also extends into middle and eastern Europe (e.g., Hungary, Poland, and Germany) (Richardson et al., 2006; Weakley, 2015) and portions of temperate and tropical Asia (e.g., India, Pakistan, Afghanistan) (NGRP, 2016). Populations have naturalized on other continents, including in the United States, Australia, and Chile. In the eastern United States it is described as "rare" (Weakley, 2015), and in Australia, it is considered "uncommon" (Richardson et al., 2006). It was first found in Chile in 1944 (Castro et al., 2005; Ugarte et al., 2011) and has only been reported from one "Administrative region" in the country (Castro et al., 2005). In the Czech Republic, *E. falcata*'s invasive status is slightly complicated. Pysek et al. (2002) speculate that *E. falcata* is a "post-invasive" species, meaning that the species was invasive when it was first introduced to the Czech Republic and that has influenced other authors to call this species invasive (Randall, 2007; Randall, 2012). However, for the current time period, Pysek et al. (2002) indicate that *E. falcata* is better described as naturalized. It is not clear how long ago *E. falcata* established in the Czech Republic, but it is long enough ago for some researchers to consider the species native to this area (e.g., NGRP, 2016). Subsequently, the confusion in nativity for *E. falcata* in the Czech Republic has led to some researchers labeling it a "vulnerable" species in the country (Kolářová et al., 2013; Mrázek, 2012), which would suggest that it is native and also in decline. Because the only mention of an invasive status is speculated for another time period, we answered "e" with two alternative answers of "f."
ES-2 (Is the species highly domesticated)	n - low	0	*Euphorbia falcata* is considered a medicinal plant (Gharnit and Ennabili, 2000; Kirbag et al., 2013; Mahmoudi et al., 2012; Özbïlgïn and Çïtoğl, 2012), but there is no indication that this species is cultivated (e.g., Bailey Nurseries, 2016; Dave's Garden, 2016; Greenleaf Nursery Company, 2016; Lowe's, 2016; Monrovia, 2016; San Marcos Growers, 2001; Univ. of Minn., 2016) or has been bred for traits associated with a reduced invasive potential.
ES-3 (Weedy congeners)	y - mod	1	There are more than 2,000 *Euphorbia* species (El Bribri et al., 2013; Frajman and Schönswetter, 2011). Congeners for this question were considered to be species within the same subgenus (*Esula*) and section (*Pithyusa*) as *E. falcata*, which accounts for about 36 species (Riina et al., 2013).

Question ID	Answer - Uncertainty	Score	Notes (and references)
			Holm et al. (1979) list *E. gaillordoti* as a principal weed in Lebanon, and Randall (2012) lists this species and three other closely related congeners as weeds or naturalized: *Euphorbia seguieriana*, *E. nicaeensis*, and *E. macroclada*. However, we were unable to find direct evidence of impact or invasiveness of these species, so we used moderate uncertainty.
ES-4 (Shade tolerant at some stage of its life cycle)	n - mod	0	We could not find evidence that this species is shade tolerant. *Euphorbia falcata* occurs mostly in full light, but may sometimes survive in slightly shady conditions (Landolt, 1977). *Euphorbia falcata* occurs in open areas (Hanf, 1983) such as roadsides and disturbed areas (James and Harden, 2016; Weakley, 2015). We answered no because the species is found in open areas, but used moderate uncertainty because this trait has not been well studied and the species could be shade tolerant at some stage of its life cycle.
ES-5 (Plant a vine or scrambling plant, or forms tightly appressed basal rosettes)	n - negl	0	*Euphorbia falcata* is not described as a vine; it is an herbaceous annual with leaves branching from upright stalks (AgroAtlas, 2016; Hanf, 1983; James and Harden, 2016; Mrázek, 2012).
ES-6 (Forms dense thickets, patches, or populations)	n - low	0	Densities of *E. falcata* average 25 plants/m^2 when found under *Salsola oppositifolia* (a shrub) and in gaps it averages 10 plants/m^2 in Spain (Pugnaire et al., 2004). These densities are relatively low, however, when compared to the overall number of individual plants for all species found in these areas (1,114 plants/m^2 under *Salsola oppositifolia* and 1,356 plants/m^2 in gaps) (Pugnaire et al., 2004), suggesting that *E. falcata* does not outcompete other species. Other reported densities of *E. falcata* are much lower than this: 1.3 plants/m^2 in Turkey (Demir and Tepe, 2001) and 1.7 plants/m^2 in France (Dutoit et al., 1999). Some populations of *E. falcata* have also been described as "abundant" and "plentiful" (Davis and Core, 1940; Steele, 1911). We answered no with low uncertainty (rather than negligible) because qualitative descriptions (i.e., abundant and plentiful) seem to contradict the quantitative data.
ES-7 (Aquatic)	n - negl	0	This species is a terrestrial plant found along roadsides and is not considered aquatic (James and Harden, 2016; Weakley, 2015). It has, however, been observed in a saline wetland in Turkey (Altay and Ozturk, 2012).
ES-8 (Grass)	n - negl	0	*Euphorbia falcata* is a member of the Euphorbiaceae family, which does not contain grasses (NGRP, 2016; Weakley, 2015).
ES-9 (Nitrogen-fixing woody plant)	n - negl	0	We found no evidence that *E. falcata* fixes nitrogen, and it is not a member of a plant family known to contain nitrogen-fixing species (Martin and Dowd, 1990; Santi et al., 2013). Furthermore, this species is an herb and not a woody plant (Weakley, 2015).
ES-10 (Does it produce viable seeds or spores)	y - negl	1	A study aimed at describing the species within a seed bank of a natural area recovered seeds that germinated and grew into *E. falcata* seedlings (Caballero et al., 2003). *Euphorbia falcata* was also recovered from the seed bank

Question ID	Answer - Uncertainty	Score	Notes (and references)
			of agricultural fields in Catalonia (José-María and Sans, 2011).
ES-11 (Self-compatible or apomictic)	y - high	1	*Euphorbia falcata* is normally insect pollinated, but may alternatively self-pollinate (Pinke and Pál, 2009). We used high uncertainty since this is the only reference to this species regarding its ability to self-pollinate and they did not use direct evidence.
ES-12 (Requires specialist pollinators)	n - mod	0	*Euphorbia falcata* is typically insect pollinated (Pinke and Pál, 2009). *Euphorbia* spp. are typically pollinated by multiple pollinators (Salmaki et al., 2011). We used moderate uncertainty because the determination of the answer was partly based on congeners.
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 - low	1	*Euphorbia falcata* is a therophyte (Altay and Ozturk, 2012; Cakovic et al., 2012; Džigurski et al., 2013; Landolt, 1977), meaning that it is an annual species. We did not find any evidence that the species could have multiple generations within the same year, or that a generation could take longer than one year. Therefore we selected alternate answers of "a" and "c."
ES-14 (Prolific seed producer)	? - max	0	*Euphorbia falcata* has been reported to occur at densities of 1.3 plants/m^2 (Demir and Tepe, 2001), 1.7 plants/m^2 (Dutoit et al., 1999), and 25 plants/m^2 (Pugnaire et al., 2004). However, we found no other information on seed production to allow us to estimate seed production per square meter. Consequently, we answered unknown.
ES-15 (Propagules likely to be dispersed unintentionally by people)	y - high	1	We found no direct evidence that this species is unintentionally dispersed by people. Seeds of *E. falcata* are small, measuring approximately 2 mm in length (Can and Küçüker, 2015). Along with agricultural areas, the plant is often found along roadsides (AgroAtlas, 2016; James and Harden, 2016; Richardson et al., 2006; Weakley, 2015), foot pathways (Greuter, 1979), and disturbed places such as trash heaps (AgroAtlas, 2016). Because it is present in disturbed areas frequented by people, it seems likely that it may be dispersed unintentionally by people. We used high uncertainty because this answer was based on inference.
ES-16 (Propagules likely to disperse in trade as contaminants or hitchhikers)	y - negl	0	*Euphorbia falcata* is listed as a crop contaminant by the Association of Official Seed Analysts (AOSA, 2014). *Euphorbia falcata* seed ripen in late summer (Džigurski et al., 2013), which is also the general time when wheat seed is harvested (NASS, 1997; Wicks et al., 1986). Wheat is generally harvested at one-third the mean stem height (McMaster et al., 2000). Mean wheat height ranges between 63-107 cm depending on cultivar (Thomas et al., 1993; Wicks et al., 1986), which means that harvesting heights would be 21-35 cm. The typical height for *E. falcata* plants is 10-20 cm, but some may reach 40 cm (AgroAtlas, 2016; Hanf, 1983), meaning that some of the population would likely be harvested.
ES-17 (Number of natural dispersal vectors)	2	0	Seed and propagule traits for questions ES-17a through ES-17e. Seeds are about 2 mm in length (Can and Küçüker, 2015). The average seed size for *E. falcata* subsp. *falcata* is 1.63 mm x 1.04 mm (Pahlevani and

Question ID	Answer - Uncertainty	Score	Notes (and references)
			Akhani, 2011). *Euphorbia falcata* seeds are "barrel-shaped, quadrangular, with deep, brownish-red transverse grooves on surface" (Hanf, 1983). Seeds of *E. falcata* have "spiral cellulosic hairs embedded in mucilage" (cited in Western, 2012). The mucilage produced by *E. falcata*, resulting from wetting of the seeds, was shown to help the seeds adhere to the surface of a petri dish and can be difficult to knock off (Grubert, 1974). Seeds from two closely related (subgenus *Esula* section *Pithyusa*) perennial congeners, *E. boetica* and *E. nicaeensis* (Riina et al., 2013), have explosive seed dispersal, with seeds capable of traveling up to eight meters (Narbona et al., 2005). The most prevalent fruit type in the Euphorbiaceae is a three-carpellate schizocarp that explosively opens (Webster, 1994).
ES-17a (Wind dispersal)	n - low		Wind dispersal is rare in the family Euphorbiaceae (Webster, 1994). Photographs of the fruit and seed for *E. falcata* (AgroAtlas, 2016; Can and Küçüker, 2015) do not indicate any obvious adaptations for wind dispersal.
ES-17b (Water dispersal)	n - mod		*Euphorbia falcata* is typically terrestrial (James and Harden, 2016; Weakley, 2015), but has been found in wetland areas (Altay and Ozturk, 2012). We answered no since *E. falcata* is a terrestrial species, but had moderate uncertainty because it occurs in wetlands.
ES-17c (Bird dispersal)	? - max		Seeds from *E. falcata* were found at a low frequency in the diet for *Coturnix coturnix* (quail), but the viability of these seeds were not evaluated (Pinke and Pál, 2009). The mucilage produced by *E. falcata* seeds allows them to adhere to surfaces (Grubert, 1974), which could lead to the external dispersal of this species by birds. Hanson (2000) indicates that there is a chance *E. falcata* is dispersed by birds, but was unable to corroborate it with direct evidence. We answered unknown since it seems unlikely that seeds would be viable after being consumed by a seed-eating bird and we have no direct evidence of other types of bird dispersal.
ES-17d (Animal external dispersal)	y - low		Ant dispersal is fairly common in the family Euphorbiaceae (Webster, 1994). Species that have a caruncle (an appendage on seeds containing fats) are more likely to attract ants for dispersal (Narbona et al., 2005; Webster, 1994). *Euphorbia falcata* has a caruncle (Can and Küçüker, 2015; James and Harden, 2016; Salmaki et al., 2011), but very slight pressure is enough to remove it from the seed (Can and Küçüker, 2015). Some studies suggest that ants aid in the movement of *E. falcata* seeds (cited in Bonet and Pausas, 2004; Nicolai and Boeken, 2012), but we found no direct evidence for this type of movement. In addition, when wet, the seeds of *E. falcata* produce a mucilage that helps them stick to surfaces (Grubert, 1974), which may allow dispersal on the external surfaces of other animals. We answered yes because dispersal by ants seems likely, but we used low (rather than negligible) uncertainty because there is no direct evidence for the movement of seeds by ants or other animals.

Question ID	Answer - Uncertainty	Score	Notes (and references)
ES-17e (Animal internal dispersal)	? - max		We found no evidence that seeds of *E. falcata* are dispersed by animals internally.
ES-18 (Evidence that a persistent (>1yr) propagule bank (seed bank) is formed)	? - max	0	*Euphorbia falcata* was observed in several studies on seed banks, but the longevity of the seeds was not evaluated (Caballero et al., 2003; Dutoit et al., 1999).
ES-19 (Tolerates/benefits from mutilation, cultivation or fire)	n - low	-1	A reduction of *E. falcata* populations in Catalonia was speculated to be the result of "agricultural intensification" (José-María and Sans, 2011). In addition, populations of *E. falcata* declined following fire in Spain (Martínez-Sánchez et al., 1997). This evidence suggests that *E. falcata* is not tolerant to several forms of management, but we used low (rather than negligible) uncertainty since it is not clear how the species might respond to mowing or grazing.
ES-20 (Is resistant to some herbicides or has the potential to become resistant)	n - low	0	We found no evidence to indicate that *E. falcata* is resistant to herbicides, and it is not listed by Heap (2016).
ES-21 (Number of cold hardiness zones suitable for its survival)	10	1	
ES-22 (Number of climate types suitable for its survival)	9	2	
ES-23 (Number of precipitation bands suitable for its survival)	7	0	
IMPACT POTENTIAL			
General Impacts			
Imp-G1 (Allelopathic)	? - max	0.1	We found no direct evidence that *E. falcata* is allelopathic; however, *Euphorbia* spp. tend to be associated with allelopathic effects (Qasem and Foy, 2001).
Imp-G2 (Parasitic)	n - negl	0	We found no evidence that *E. falcata* is a parasitic plant. Furthermore, this species is a member of the family Euphorbiaceae, which is not known to contain parasitic plants (Heide-Jorgensen, 2008; Nickrent, 2016).
Impacts to Natural Systems			
Imp-N1 (Changes ecosystem processes and parameters that affect other species)	n - low	0	We found no evidence that *E. falcata* changes ecosystem processes. Because we found no evidence that *E. falcata* invades or is considered a weed of natural systems, we used low uncertainty for this and the other questions in this risk sub-element.
Imp-N2 (Changes habitat structure)	n - low	0	We found no evidence that *E. falcata* changes habitat structure.
Imp-N3 (Changes species diversity)	n - low	0	We found no evidence that *E. falcata* changes or limits species diversity.
Imp-N4 (Is it likely to affect federal Threatened and Endangered species?)	n - low	0	We found no evidence to suggest that *E. falcata* would affect Threatened and Endangered species.
Imp-N5 (Is it likely to affect any globally outstanding ecoregions?)	n - low	0	We found no evidence to suggest that *E. falcata* would affect U.S. globally outstanding ecoregions.
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	a - low	0	Because we found no evidence to suggest that *E. falcata* is a weed in natural systems, we answered "a." Both alternate answers for the uncertainty simulation are "b."

Question ID	Answer - Uncertainty	Score	Notes (and references)
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 - low	0	We found no evidence of this impact. *Euphorbia falcata* occurs along roadways, but no impacts are described in these areas (AgroAtlas, 2016; James and Harden, 2016; Richardson et al., 2006; Weakley, 2015). Thus, we used low uncertainty for all the questions in this sub-element.
Imp-A2 (Changes or limits recreational use of an area)	n - low	0	We did not find evidence that *E. falcata* limits the recreational use of an area. Furthermore, it seems unlikely that it would have this impact as a low-stature terrestrial herb.
Imp-A3 (Affects desirable and ornamental plants, and vegetation)	n - low	0	We did not find evidence that *E. falcata* affects desirable or ornamental plants (Dave's Garden, 2016).
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 - low	0	Although *E. falcata* is found along roadways and foot paths (AgroAtlas, 2016; Greuter, 1979; James and Harden, 2016; Richardson et al., 2006; Weakley, 2015) we found no evidence of impact to indicate it is considered a weed in anthropogenic systems. Both alternate answers for the uncertainty simulation are "b."
Impact to Production Systems (agriculture, nurseries, forest plantations, orchards, etc.)			
Imp-P1 (Reduces crop/product yield)	n - high	0	We found no evidence that *E. falcata* reduces yields in crops. Although we found no evidence that it reduces livestock yield, *E. falcata* is reported to be unpalatable and toxic to livestock (see evidence under Imp-P5). Because there is relatively little known about this species, we used high uncertainty.
Imp-P2 (Lowers commodity value)	n - high	0	We found no evidence that *E. falcata* lowers commodity value. Because this species has been noted to be unpalatable to livestock (see evidence under Imp-P5), it may reduce the value of grazing lands if it occurs at high enough densities. Without more detailed information about this species, we used high uncertainty.
Imp-P3 (Is it likely to impact trade?)	n - high	0	Based on the Association of Official Seed Analysts listing *E. falcata* as a seed contaminant, the time at which the seed of this species matures, and the height of the plant, it seems likely that *E. falcata* could be a seed contaminant in wheat (see ES-16). However, we found no specific regulations in place for *E. falcata* by other countries (PCIT, 2016). Israel has listed *Euphorbia* spp. on their harmful organisms list (PCIT, 2016), but it is unlikely that Israel would regulate *E. falcata* because the species has already been detected within that country (Holm et al., 1979). We did not find any other evidence that *E. falcata* might have trade impacts. We used high uncertainty because of the lack of available information on potential trade impacts.
Imp-P4 (Reduces the quality or availability of irrigation, or strongly competes with plants for water)	n - low	0	We found no evidence that *E. falcata* strongly competes for water. Because *Euphorbia* species in general are adapted to growing in dry conditions, it seems unlikely they would use an excessive amount of moisture.
Imp-P5 (Toxic to animals, including livestock/range	y - negl	0.1	*Euphorbia* spp. in general are considered poisonous (Armaki and Khaleghi, 2014). *Euphorbia falcata* has toxic

Question ID	Answer - Uncertainty	Score	Notes (and references)
animals and poultry)			properties (cited in Gharnit and Ennabili, 2000; Randall, 2012) and is "unpalatable" (Abbasvand et al., 2013), presumably for livestock. *Euphorbia falcata* has been used for its "medicinal" properties. For instance, it is used as a laxative and to treat psoriasis, but may cause ulcers if used for extended periods (Leporatti et al., 1985).
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	*Euphorbia falcata* is found and considered a weed in agricultural areas (AOSA, 2014; Pysek et al., 2002; Randall, 2007), mainly in cereal crops (Hanf, 1983; José-María et al., 2013; Kolářová et al., 2013), but also in poppy fields (Pinke et al., 2011), and rangelands (Abbasvand et al., 2013). Although not mentioned to be directly controlled, populations of *E. falcata* were noticed to diminish with agricultural intensification (José-María and Sans, 2011). Several sources indicate that *E. falcata* is a weed, but do not specify the type of system (AgroAtlas, 2016; Nestorovic and Konstantinovic, 2011). In the former USSR, it is not an important weed (AgroAtlas, 2016). Both alternate answers are "c."
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 - negl	N/A	We found no evidence that *E. falcata* occurs in this zone.
Geo-Z2 (Zone 2)	n - low	N/A	We found no evidence that *E. falcata* occurs in this zone.
Geo-Z3 (Zone 3)	y - high	N/A	Several points in the mountainous regions of Afghanistan and Pakistan. Using high uncertainty because there are only a few points in this zone compared to other, warmer, zones.
Geo-Z4 (Zone 4)	y - mod	N/A	Some points in Afghanistan.
Geo-Z5 (Zone 5)	y - low	N/A	One point in Romania and one in Austria.
Geo-Z6 (Zone 6)	y - negl	N/A	Many points in Austria and Germany.
Geo-Z7 (Zone 7)	y - negl	N/A	Many points in Spain and France.
Geo-Z8 (Zone 8)	y - negl	N/A	Many points in Spain and France.
Geo-Z9 (Zone 9)	y - negl	N/A	Many points in Spain and France.
Geo-Z10 (Zone 10)	y - negl	N/A	Single point in northern Oman.
Geo-Z11 (Zone 11)	y - negl	N/A	Multiple occurrences in southern Australia. Multiple points along coastal Israel. Several points along Greek islands. Multiple points along coastal regions of Portugal and Spain.
Geo-Z12 (Zone 12)	y - low	N/A	Multiple points along the coastal region of Israel.
Geo-Z13 (Zone 13)	n - mod	N/A	We found no evidence that *E. falcata* occurs in this zone.
Köppen -Geiger climate classes			
Geo-C1 (Tropical rainforest)	n - low	N/A	We found no evidence that *E. falcata* survives in this climate class.
Geo-C2 (Tropical savanna)	n - low	N/A	We found no evidence that *E. falcata* survives in this climate class.
Geo-C3 (Steppe)	y - negl	N/A	Many points in Spain.
Geo-C4 (Desert)	y - low	N/A	Multiple points found in Afghanistan. Single points found

Question ID	Answer - Uncertainty	Score	Notes (and references)
			in Algeria, Tunisia, Syria, Pakistan, and Israel.
Geo-C5 (Mediterranean)	y - negl	N/A	Multiple points in each of southern Australia, Portugal, France, and Spain.
Geo-C6 (Humid subtropical)	y - negl	N/A	Couple of points in southeastern Australia. Several county occurrences in the United States.
Geo-C7 (Marine west coast)	y - negl	N/A	Multiple points in Spain and France.
Geo-C8 (Humid cont. warm sum.)	y - negl	N/A	Multiple county occurrences in the United States (Kartesz, 2016). Several points in Pakistan. Multiple points in Austria.
Geo-C9 (Humid cont. cool sum.)	y - negl	N/A	Multiple points in Spain and France.
Geo-C10 (Subarctic)	y - low	N/A	Multiple points in France.
Geo-C11 (Tundra)	y - low	N/A	Single point in Spain. Multiple points in France.
Geo-C12 (Icecap)	n - high	N/A	We found no evidence that *E. falcata* survives in this climate class.
10-inch precipitation bands			
Geo-R1 (0-10 inches; 0-25 cm)	y - negl	N/A	Multiple points in Israel, Morocco, Pakistan and Afghanistan. Single points in Iran, Tunisia, Oman, and Algeria.
Geo-R2 (10-20 inches; 25-51 cm)	y - negl	N/A	Single point in southern Australia. Although we found only a single point for this band, because our evidence for the precipitation bands that precede and follow this one is strong, we used negligible uncertainty.
Geo-R3 (20-30 inches; 51-76 cm)	y - negl	N/A	Multiple points in southern Australia.
Geo-R4 (30-40 inches; 76-102 cm)	y - negl	N/A	County occurrences in the eastern United States.
Geo-R5 (40-50 inches; 102-127 cm)	y - negl	N/A	Multiple points in Greece, Spain, and France.
Geo-R6 (50-60 inches; 127-152 cm)	y - low	N/A	Single point in Greece. Multiple points in France.
Geo-R7 (60-70 inches; 152-178 cm)	y - high	N/A	Couple points in France.
Geo-R8 (70-80 inches; 178-203 cm)	n - low	N/A	We found no evidence that *E. falcata* survives in this precipitation band.
Geo-R9 (80-90 inches; 203-229 cm)	n - negl	N/A	We found no evidence that *E. falcata* survives in this precipitation band.
Geo-R10 (90-100 inches; 229-254 cm)	n - negl	N/A	We found no evidence that *E. falcata* survives in this precipitation band.
Geo-R11 (100+ inches; 254+ cm)	n - negl	N/A	We found no evidence that *E. falcata* survives in this precipitation band.
ENTRY POTENTIAL			
Ent-1 (Plant already here)	y - negl	1	*Euphorbia falcata* is already present in the United States (Weakley, 2015); consequently, we did not evaluate this risk element.
Ent-2 (Plant proposed for entry, or entry is imminent)	-	N/A	
Ent-3 (Human value & cultivation/trade status)	-	N/A	Extracts from *E. falcata* have been demonstrated to provide "good inhibition properties" to prevent steel from corroding (El Bribri et al., 2013). Extracts from *E. falcata* subsp. *falcata* var. *falcata* prevented the growth of microbes more than extracts from other *Euphorbia* subsp.

Question ID	Answer - Uncertainty	Score	Notes (and references)
			(Kirbag et al., 2013). *Euphorbia falcata* subsp. *falcata* var. *falcata* is reported as a medicinal plant to treat eczema and fungal infections in Turkey (Özbïlgïn and Çïtoğl, 2012). Latex of plant is used for medicinal purposes (Mahmoudi et al., 2012). Considered a medicinal plant in Morocco (Gharnit and Ennabili, 2000) and may be used as a laxative ({Leporatti, 1985 #2090}).
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	