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Weed Risk Assessment for *Phelipanche ramosa* (L.) Pomel (Orobanchaceae) – Branched broomrape

From left to right: branched broomrape in flower (source: O.P. Sharma, Bugwood.org), broomrape with haustoria (source: USDA APHIS PPQ – Oxford, NC, Bugwood.org), branched broomrape seeds (source: Julia Scher, USDA-APHIS, Bugwood.org).

AGENCY CONTACT

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

Executive Summary

The result of the weed risk assessment for *Phelipanche ramosa* (branched broomrape) is High Risk of becoming weedy or invasive in the United States. Branched broomrape is a fleshy, parasitic weed that lacks chlorophyll and depends entirely on its host for water and nutrients. It has a wide host range and can survive in six climate classes. It is native to 39 countries and has become naturalized in another 31. *Phelipanche ramosa* is naturalized in seven states and 35 counties in the United States and is registered as a Federal Noxious Weed. It is a prolific seed producer with almost invisible seeds that can be readily transported long distances in agricultural commodities. Seeds from *P. ramosa* have been intercepted at U.S. ports in general and permitted cargo. Climate models show that *Phelipanche* species have a high invasive potential in most of the United States. Once *P. ramosa* becomes established, it is almost impossible to eradicate due to the longevity of its seed bank.

Numerous weed control measures have been developed globally for *P. ramosa*. It is controlled in California tomato fields by rotating the tomato crop with pasture grass, and state contracts in Texas require power washing of roadside mowers to prevent its spread. The most promising control measures include cultural, mechanical methods, and induced resistance. Cultural methods for controlling *P. ramosa* include crop rotation with non-host species, use of false host crops that stimulate suicidal seed germination, flood irrigation, and soil fertilization. Control measures have focused on destroying seed bank populations with false hosts and crop rotation, and have made use of its phenology to time crop planting and soil flooding. Mechanical methods may include tilling the soil to expose the seed bank to ozone and/or ultraviolet light that can destroy the seeds. Another promising control tactic is to chemically induce resistance in host roots in order to inhibit *P. ramosa* haustoria attachment to the roots. Combining several methods into an integrative weed control strategy could achieve near complete control of *P. ramosa* in crop production systems. Such a strategy requires extensive planning and high costs, but multiple tactics are needed to ensure complete control and prevent the escape of plants that could produce enough seeds to negate any partial control measures.

1. Plant Information and Background

SPECIES: *Phelipanche ramosa* (L.) Pomel (GRIN, 2017).

FAMILY: Orobanchaceae

SYNONYMS: *Orobanche ramosa* L. (GRIN, 2017). *Phelipanche ramosa* is closely related to *O. aegyptiaca, O. nana,* and *O. mutelii*, and they have similar host ranges (Mohamed and Musselman, 2008). Some taxonomists treat *O. nana* and *O. mutelii* as subspecies of *P. ramosa* (Mohamed and Musselman, 2008).

COMMON NAMES: Branched broomrape, hemp broomrape (CABI, 2018).

BOTANICAL DESCRIPTION: *Phelipanche ramosa* is a non-photosynthetic root parasite that grows on a wide range of hosts in temperate and subtropical climates (Pieterse, 1979). The yellow, fleshy, leafless stems range from 4 to 12 inches tall, are either simple or branched, and produce blue flowers. The base of the stem attaches to a root of a host plant, and all of the water and nutrients for *P. ramosa* are supplied by the host plant. The leaves are reduced to triangular flaps on the stem. The seeds are about 0.3 mm long, with a tan or brown color that blackens with age. *Phelipanche ramosa* can be an annual or a perennial depending on the life cycle of the host. This species is self-pollinating and generally flowers from February to May in its native range. For a full botanical description see Kasasian (Kasasian, 1971; Musselman, 1980).

Phelipanche ramosa has a wide host range that includes many vegetable crops and weedy broadleaf plants. Host surveys for *P. ramosa* were conducted in Jordan and Australia, and a complete list of host plants is provided in Appendix B. Experimental hosts, tested in screening studies, are listed in Qasem and Foy (2007) and Virtue et al. (2014).

INITIATION: PPQ initiated this weed risk assessment to gain a better understanding of *P. ramosa* and its risk potential in order to support control activities in Texas.

WRA AREA[1]: United States and Territories.

FOREIGN DISTRIBUTION: *Phelipanche ramosa* is believed to be native to the European countries that border the Mediterranean sea (Mohamed et al., 2006). It is listed as native to 39 countries and has been introduced and become naturalized in another 31 (CABI, 2018). It has spread in northeastern and southern Africa, northern Europe, Australia, New Zealand, and North and South America (Fernandez-

[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).

Aparicio et al., 2016; Parker, 2012). Because *P. ramosa* is one of the worst parasitic weeds of agricultural crops, the species is unlikely to be cultivated in any of these countries (Parker, 2009, 2012).

U.S. DISTRIBUTION AND STATUS: Figure 1 shows the current U.S. distribution of *P. ramosa.* The species has known presence in seven states, including Alabama, California, Illinois, Kentucky, New Jersey, Texas, and Virginia, and has naturalized in 35 counties (EDDMapS, 2019; NRCS, 2019a). *Phelipanche ramosa* was introduced into the United States from Europe (Jain and Foy, 1989; Musselman, 1980) and was first discovered in 1890 on hemp crops in Kentucky, where it was probably brought in on packing material made of hay (Musselman, 1996). *Phelipanche ramosa* is on the U.S. Federal Noxious Weed List (NRCS, 2019b) and regulated in twelve states. It is classified as a prohibited noxious weed in Arizona, a noxious weed in Texas, and an A-list noxious weed in California (NRCS, 2019b). Members of the genus *Orobanche* (former genus classification of *Phelipanche*) are classified as class A noxious weeds in Alabama, North Carolina, and Vermont; quarantine weeds in California and Oregon; prohibited weeds in Massachusetts; noxious weeds in Florida; prohibited noxious weeds in Minnesota; and pest plants in South Carolina. Crop rotation with a grass species was used in an attempt to control *P. ramosa* in an infested California tomato field. This method failed: *P. ramosa* re-infested the field the first year tomatoes were regrown on the site, even though the field was in grass for over two decades (Jackson, 2014). Texas requires roadside contractors to power wash their mowers in order to remove *P. ramosa* seeds from the equipment and slow the movement of the weed along mowed roadsides (Motloch, 2019).

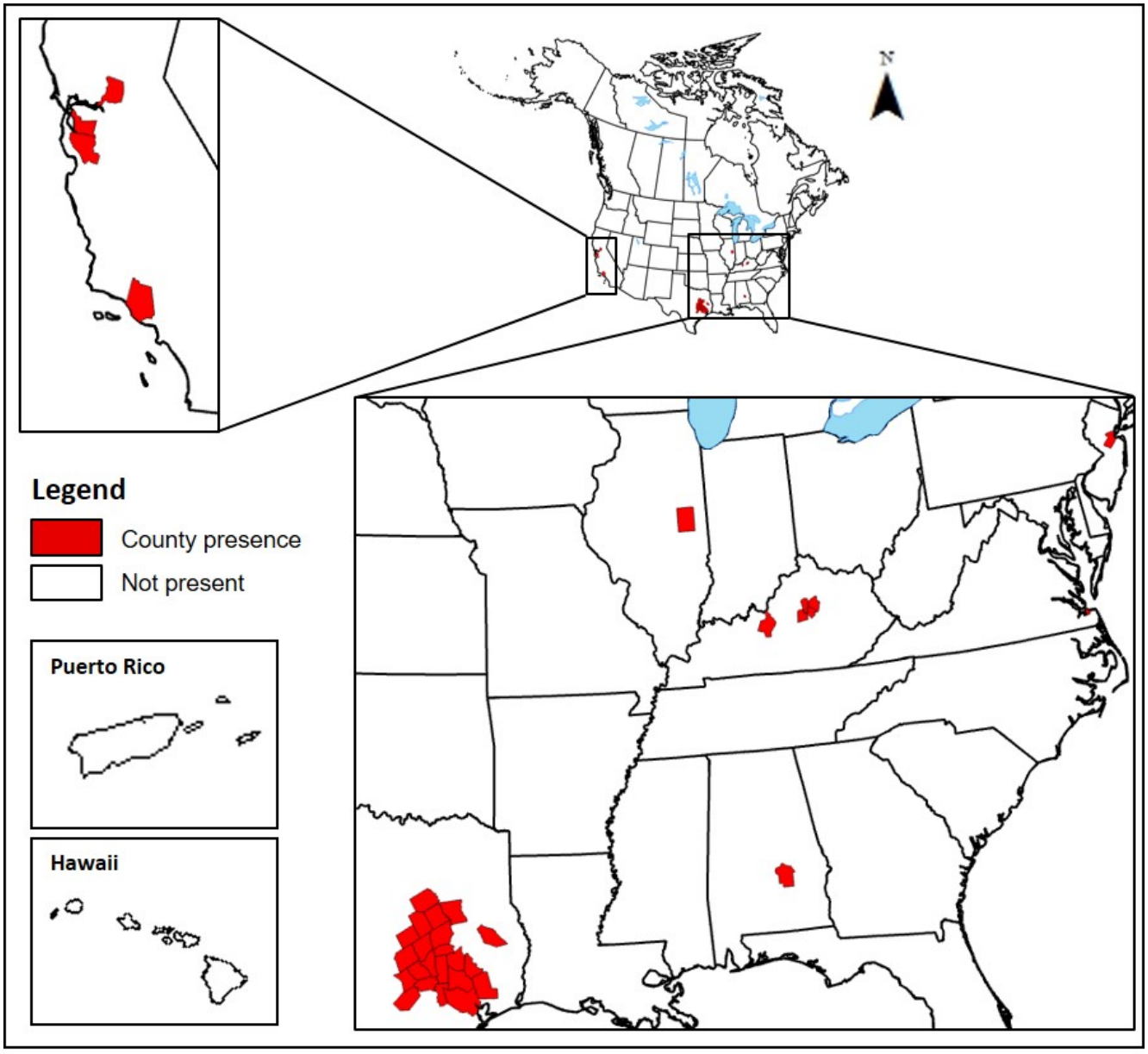

Figure 1. Known naturalized distribution of *Phelipanche ramosa* in the United States and Canada. The records shown here were obtained primarily from species distribution databases (EDDMapS, 2019; NRCS, 2019a) and herbarium records (Weakley, 2016). The Texas records were independently verified by the United States Department of Agriculture, Animal and Plant Health Inspection Service. Map insets are not to scale. This species is also located in Norfolk County, VA, but the county is difficult to see at this resolution.

2. Analysis

ESTABLISHMENT/SPREAD POTENTIAL

Phelipanche ramosa originated in the European countries that border the Mediterranean Sea but has since spread and naturalized in 31 other countries (Mohamed et al., 2006). It is a prolific seed producer, with small seeds that can be windblown or transported by animals, water, agricultural trade, or equipment (AQAS, 2019; Buschmann et al., 2005; Ginman, 2009). Once it becomes established, it is almost impossible to eradicate due to the longevity of its seed bank (Fernandez-Aparicio et al., 2016; Punia, 2014). The hard seed coat of *P. ramosa* ensures high seed viability rates, even when buried in soil for over 20 years (Pakeman et al., 2002). Because the seeds are only about 0.3 mm long, they can be transported in many agricultural commodities over long distances (Pakeman et al., 2002). *Phelipanche ramosa* also has a very wide host range that includes many weedy, vegetable, and ornamental plants and contributes to its spread and establishment potential (Qasem and Foy, 2007; Virtue et al., 2014). We had low uncertainty for this risk element due to the large amount of literature concerning the establishment and spread of *P. ramosa* and the fact that it has spread into 31 countries beyond its native range (Fernandez-Aparicio et al., 2016; Parker, 2012).

Risk score = 22 Uncertainty index = 0.11

IMPACT POTENTIAL

As a parasitic weed, *P. ramosa* siphons water and nutrients off of host plants, reducing their overall biomass and yield. It is ranked as one of the five worst parasitic weed species and results in crop yield losses and unmarketable fruits and vegetables (Pieterse, 1979; Longo et al., 2010). *Phelipanche ramosa* can reduce crop yields from 20 to 80 percent in Brassicaceae, Fabaceae, Solanaceae, and Cucurbitaceae crops, and in some cases may cause complete crop failure (Babiker, 2007; Buschmann et al., 2005; CABI, 2018). Host surveys show that *P. ramosa* can infest at least 22 vegetable, woody, and fiber crops (Qasem, 2009; Virtue et al., 2014)(See Appendix B for list of crop host species). A U.S. host plant screening study shows evidence that *P. ramosa* can occasionally attach to peanut and soybean (Jain and Foy, 1989). In anthropogenic systems, *P. ramosa* can infest at least 20 ornamental host species (Prider, 2019; Qasem and Foy, 2007) (See Appendix B for list of ornamental host species). In natural ecosystems, *P. ramosa* can infest several weed species (See Appendix B for list of weedy species). Weedy host species act as alternative hosts and could allow reservoir populations to re-infest treated sites. Southeastern Australia had a relatively new *P. ramosa* infestation over approximately 6,000 ha that resulted in a national quarantine and control program costing about $4 million USD per year (Warren, 2006). The control program operated for about 11 years before it was terminated due to lack of funding (Warren, 2006). Despite the decade-long, national program, *P. ramosa* has not been eradicated from Australia. We had low uncertainty for this risk element because *P. ramosa* is a holoparasitic weed, and a large body of evidence documents its negative impact on crops and ornamental plants.

Risk score = 3.1 Uncertainty index = 0.9

GEOGRAPHIC POTENTIAL

We estimate that about 65 percent of the United States is suitable for the establishment of *P. ramosa* (Fig. 2). This predicted distribution is based on the rainfall, temperature, and climate classes from its known distribution elsewhere in the world, using evidence from both point-referenced localities and general areas of occurrence. A predictive climate model by Mohamed et al. (2006) shows that *Orobanche* species have a high invasive potential in most of the United States, which is in agreement with our geopotential distribution map. Our map for *P. ramosa* represents the joint distribution of Plant Hardiness Zones 4-12, areas with 10-90 inches of annual precipitation, and the following Köppen-Geiger climate classes: tropical savanna, steppe, desert, Mediterranean, humid subtropical, marine west coast, humid continental warm summer, humid continental cool summer, subarctic, and tundra. It is not clear if *P. ramosa* occurs in tropical savanna because we found only one point in this climate class. For this analysis, we assumed that it could survive in tropical savannas in irrigated fields and on weedy hosts in moist lowlands or along stream sides.

The area of the United States shown to be climatically suitable (Fig. 2) for species establishment considered only three climatic variables. Other variables, such as soil and habitat type, novel climatic conditions, or plant genotypes, may alter the areas in which this species is likely to establish. *Phelipanche ramosa* originated in the Mediterranean region, which has mild, wet winters and hot, dry summers. In general, *P. ramosa* germinates under at temperatures of 10 to 20 °C, so it is not as prevalent in tropical countries with warm winter ecoregions (Musselman, 1996).

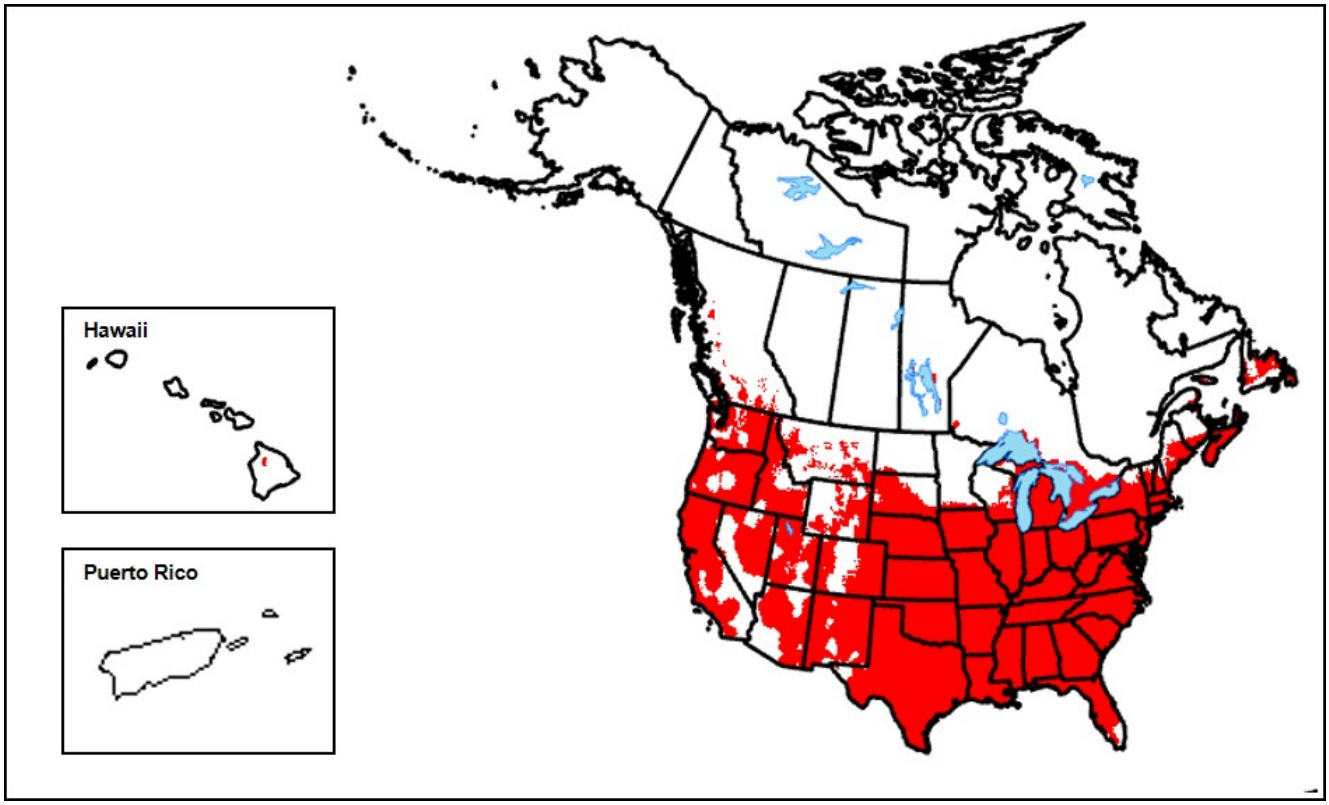

Figure 2. Potential geographic distribution of *Philepanche ramosa* in the United States and Canada. Map insets for Hawaii and Puerto Rico are not to scale. For additional information on the PPQ climate-matching process see Magarey et al. (2017).

ENTRY POTENTIAL

We did not assess the entry potential of *P. ramosa* because the species is already present in the United States (EDDMapS, 2019; Musselman, 1996).

3. Predictive Risk Model Results

Model Probabilities: P(Major Invader) = 94.8%
P(Minor Invader) = 5.0%
P(Non-Invader) = 0.2%
Risk Result = High Risk
Risk Result after Secondary Screening = Not Applicable

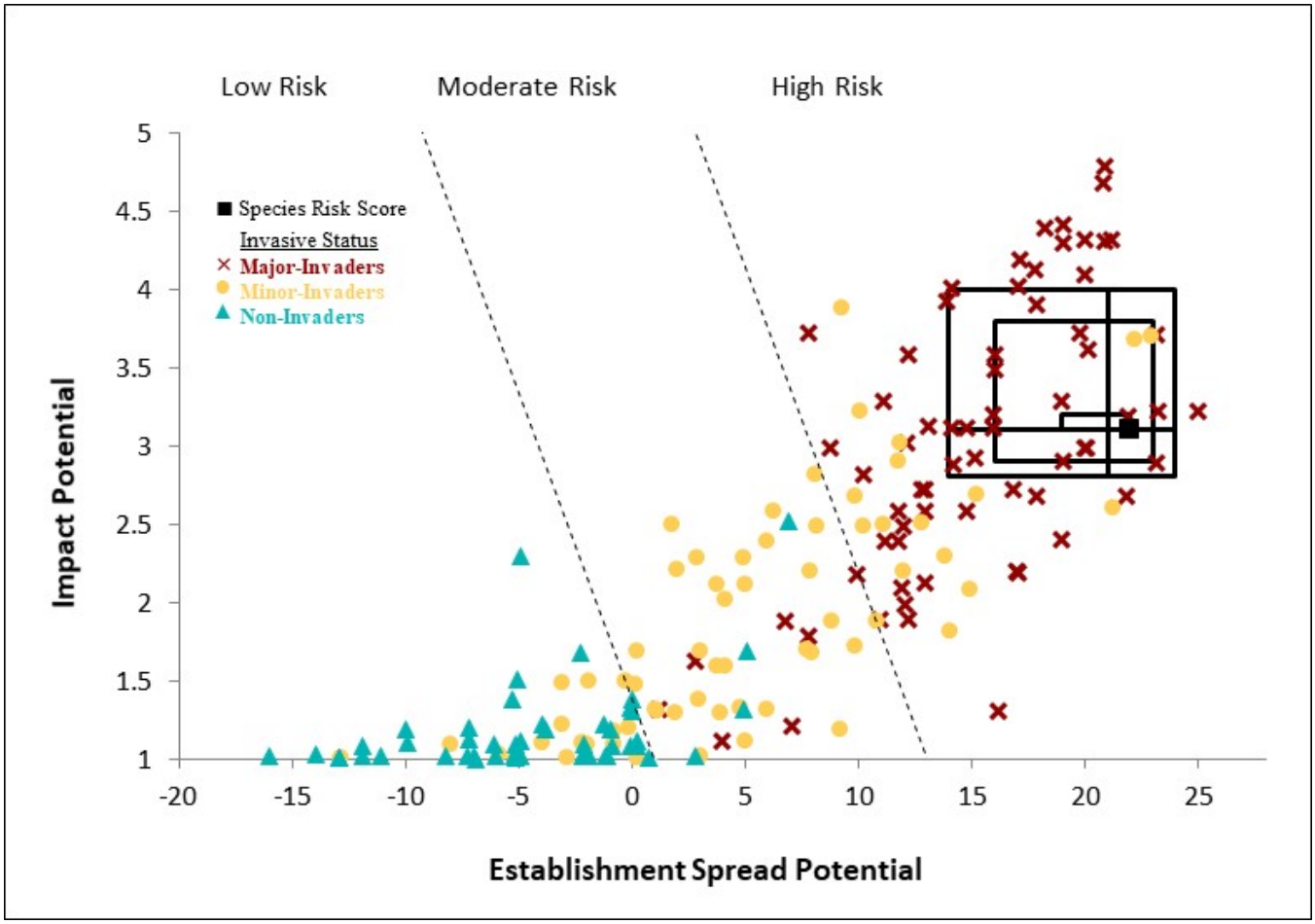

Figure 3. Risk and uncertainty results for *Phelipanche ramosa*. The risk score for *P. ramosa* (solid black symbol) is plotted relative to the risk scores of the species used to develop and validate the PPQ WRA model (Koop et al., 2012). The results from the uncertainty analysis are plotted around the risk score for *P. ramosa*. 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).

4. Discussion

The result of the weed risk assessment for *Phelipanche ramosa* is High risk of becoming weedy or invasive in the United States. The uncertainty score was low due to the numerous articles and books on this species, including journal articles referencing impacts of *P. ramosa* infestations in the United States. The 55 percent area increase in *P. ramosa*-infested rapeseed fields in western France over a four-year period shows that it can spread rapidly, even on a newly reported host species.

Phelipanche ramosa is a prolific seed producer with very small, almost invisible seeds that can readily attach to or be ingested by animals (Ginman, 2009). The seeds can also attach to equipment, agricultural commodities, or other materials and be transported long distances (Musselman, 1980).

The small size allows seeds to be windblown and carried by animals (Ginman, 2009). The seeds have a hard coat that allows them to remain viable in seed banks for 20 or 30 years, making seed bank management a critical element in any control strategy (Pakeman et al., 2002; Punia, 2014; Qasem and Foy, 2007). Because *P. ramosa* produces a large number of seeds with a long seedbank viability period, integrated weed management practices are probably the most effective control strategies (Habimana et al., 2014).

Surveys show that *P. ramosa* has a very wide host range, especially among vegetable crops. Losses in specialty crop yields in the United States could range from 20 to 100 percent, depending on environmental, weed, and crop conditions (Babiker, 2007; Parker, 2012). It can infest at least 24 ornamental species, and numerous commonly occurring weed species, such as red clover (*Trifolium pratense*), red sorrel (*Rumex acetosella*), cocklebur (*Xanthium strumarium*), and prostrate knotweed (*Polygonum aviculare*) (Prider, 2019; Qasem, 2009). Weedy hosts are generally ignored by farmers and road side managers and these hosts act as population reservoirs in disturbed areas such as crop edges and roadsides, from which it can re-infest treated crop fields. Roadside infestations are highly likely to spread over long distances due to routine mowing activity. (Musselman, 1996).

Hemp is a host crop for *P. ramosa,* so the weed may have been introduced into the United States during the period when hemp was commonly used to make ropes and cordage (Dewey, 1913). The use of hemp as a fiber crop for cordage and sail making in the 1800s may also have contributed to the spread of *P. ramosa* to seven states. In the 1913 USDA Yearbook, in the section titled “The Hemp Plant,” the author called branched broomrape “the only really serious enemy of hemp” (Dewey, 1913). The 2018 USDA Farm Bill legalized the production of hemp (Buschmann et al., 2005).

If *P. ramosa* becomes established in disturbed areas, pastures, or field edges, it is almost impossible to eradicate because the very expensive control treatments are not economically justified. Although *P. ramosa* is one of the worst parasitic weeds, most countries do not have a national control program or a budget to control infestations. Only Australia attempted an 11-year national eradication program for *P. ramosa*, but the country terminated the program due to lack of funding before reaching its eradication goal (Panetta and Lawes, 2007).

Control methods for *P. ramosa* include cultural, mechanical, chemical, biological, biotechnology, and chemically induced resistance methods. The most common cultural method is rotation with a non-host crop species, most often corn or another grass (Habimana et al., 2014). A very promising cultural method of control is the use of a trap crop, or false host, which stimulates germination of *P. ramosa* seeds that then die because they cannot attach to the roots of that particular crop (Qasem, 2019). Other cultural methods may include irrigation, fertilization, and deep tillage to inhibit seed germination or lower seed viability by accelerating natural seed decay processes (Karkanis et al., 2007). Biological agents such as *Fusarium* spp. have been evaluated for their effect on *P. ramosa* seed bank germination rates (Boari and Vurro, 2004). Herbicides have also been extensively evaluated for their effects on seedlings germinating from seed banks (Habimana et al., 2014; Punia, 2014). Soil fumigation methods have also been evaluated, though fumigation methods are too expensive for most crop producers

(Matthews et al., 2006). Fernadez-Aparico et al. (2016) conducted a review of the seed bank control strategies for *P. ramosa*.

Two new technologies show promise for inactivating *P. ramosa* seeds in the seed bank and for inducing natural plant resistance in crop species. A novel soil tillage system that was patented in 2013 combines soil tillage with ultraviolet light and ozone gas (Underwood, 2013). Previous research has shown that ultraviolet light may negatively affect seed germination rates, depending on the length of the exposure (Shaukat et al., 2013). When ozone is exposed to ultraviolet light, free radical hydroxyls are formed which could rapidly degrade seed coats and thereby reduced seed viability (Liszkay et al., 2004; Siddhuraju and Becker, 2007). This soil tillage system should be evaluated for its effectiveness at inactivating seed banks because of its potential to lower treatment costs and significantly reduce health and safety issues associated with soil fumigation. A second promising technology, with a longer research history, is the induction of natural plant resistance to parasitic weed attachment (Fernandez-Aparicio et al., 2016). Application of salicylic acid to seeds, or acibenzolar-S-methyl to leaves, reduces *P. ramosa* haustorium attachment rate to host roots by inducing plant defenses such as increased lignification which reduce root penetration ability of haustoria (Al-Wakeel et al., 2013; Véronési et al., 2009). Seed treatment with salicylic acid should be field evaluated, as it would be an inexpensive method of *P. ramosa* control.

SUGGESTED CITATION

PPQ. 2019. Weed risk assessment for *Phelipanche ramosa (L.) Pomel* (Orobanchaceae) – Branched broomrape. United States Department of Agriculture, Animal and Plant Health Inspection Service, Plant Protection and Quarantine (PPQ), Raleigh, NC. 28 pp.

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Appendix A. Weed risk assessment for Phelipanche ramosa (L.) Pomel (Orobanchaceae).

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

Question ID	Answer - Uncertainty	Score	Notes (and references)
ESTABLISHMENT/SPREAD POTENTIAL			
ES-1 [What is the taxon's establishment and spread status outside its native range? (a) Introduced elsewhere =>75 years ago but not escaped; (b) Introduced <75 years ago but not escaped; (c) Never moved beyond its native range; (d) Escaped/Casual; (e) Naturalized; (f) Invasive; (?) Unknown]	f - mod	5	*Phelipanche ramosa* is believed to be native to 39 countries in the Mediterranean region of Europe (Mohamed et al., 2006; CABI, 2018). The taxon has become naturalized in 31 countries in northeastern and southern Africa, northern Europe, Australia, New Zealand, and North and South America (Fernandez-Aparicio et al., 2016; Parker, 2012). After the discovery of *P. ramosa* in rapeseed crops in western France, four field

Question ID	Answer - Uncertainty	Score	Notes (and references)
			surveys were conducted between 1999 and 2002. The survey results show that the area of rapeseed fields infested with *P. ramosa* increased from 35 to 90 percent between the 1999 and 2002 surveys (Gibot-Leclerc et al., 2001). Evidence from Texas suggests that this species can spread rapidly. For example, in the spring of 2000, ten central Texas counties reported *P. ramosa*, but in 2001, 22 counties reported it (Ketchersid, 2007). For the uncertainty simulation, both alternative answers were e.
ES-2 (Is the species highly domesticated)	n - negl	0	We found no evidence that *P. ramosa* has been domesticated. *Phelipanche ramosa* is a parasitic weed that has no foliage or chlorophyll and requires a host plant, so it is highly unlikely to be domesticated (Pieterse, 1979; Punia, 2014).
ES-3 (Significant weedy congeners)	y - low	1	Estimates for the number of *Phelipanche* (or *Orobanche* as the previous genus name) have ranged as high as 150 to 212 species, due to subtle differences in floral traits that cause confusion in species differentiation (Mohamed and Musselman, 2008; Pieterse, 1979). About five species cause significant crop damage or injury (Pieterse, 1979).
ES-4 (Shade tolerant at some stage of its life cycle)	y - high	1	*Phelipanche ramosa* is a parasitic weed with no chlorophyll (Musselman, 1980; Pieterse, 1979), indicating it derives all of its carbohydrates from its host plant. Therefore, it is neither a sun-loving nor shade tolerant plant due to a lack of photosynthetic ability. Although its host plants are generally found only in open, or disturbed habitats (Virtue et al., 2014), we answered yes with high uncertainty because it does not depend on sunlight, and it is possible it may have some hosts which are shade-adapted.
Host ES-5 (Plant a vine or scrambling plant, or forms tightly appressed basal rosettes)	n - negl	0	*Phelipanche ramosa* is not a vine or scrambling plant, nor does it form basal rosettes of leaves (Kasasian, 1971; Mitich, 1993; Punia, 2014).
ES-6 (Forms dense thickets, patches, or populations)	n - low	0	We found no evidence that this taxon forms dense thickets or patches (Habimana et al., 2014; Musselman, 1980). Because we found no evidence and because it is a parasitic weed that depends on host plants, we answered no with low uncertainty.
ES-7 (Aquatic)	n - negl	0	The taxon is not an aquatic species GPDD, 2009). It is a terrestrial plant.
ES-8 (Grass)	n - negl	0	The taxon is not a grass species (GPDD, 2009). It is in the *Orobanchaceae* family.
ES-9 (Nitrogen-fixing woody plant)	n - negl	0	We found no evidence that this species fixes nitrogen. Because it is not a woody plant (CABI, 2018), it would not score a yes for this question.

Question ID	Answer - Uncertainty	Score	Notes (and references)
ES-10 (Does it produce viable seeds or spores)	y - negl	1	*Phelipanche ramosa* produces viable seeds (Musselman, 1980; Punia, 2014).
ES-11 (Self-compatible or apomictic)	y - low	1	*Phelipanche ramosa* is a self-fertilizing species (Gibot-Leclerc et al., 2012; Le Corre et al., 2014).
ES-12 (Requires specialist pollinators)	n - mod	0	We found no evidence that this species requires specialized pollinators. It is pollinated by generalist pollinators (Benharrat et al., 2005; Fernandez-Aparicio et al., 2016).
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 - mod	1	*Phelipanche ramosa* generally parasitizes annual crops and weeds, so its life cycle matches that of the crop, and the most likely answer is b (Musselman, 1980). We found evidence that *P. ramosa* can adjust its life cycle to that of its host (Gibot-Leclerc et al., 2013; Gibot-Leclerc et al., 2012). Tomatoes can be perennials if grown under suitable conditions (NRCS, 2019a) and are hosts for *P. ramosa*. For the uncertainty simulation, both the alternative answers were c.
ES-14 (Prolific seed producer)	y - low	1	The taxon is a prolific seed producer. Each plant produces from 100,000 to 500,000 dust-like seeds (0.3 mm long) per year (Buschmann et al., 2005; Pieterse, 1979). The viability of *P. ramosa* seeds is approximately 74-78 percent (Buschmann et al., 2005). Assuming plants produce only 100,000 seeds, and they have a viability rate of 74 percent, plants will produce 74,000 viable seeds per square meter, which is well above our threshold of 5,000.
ES-15 (Propagules likely to be dispersed unintentionally by people)	y - low	1	*Phelipanche ramosa* produces very small seeds that are likely to be unintentionally dispersed by humans, for example in mud that sticks to farm machinery. The seeds of *P. ramosa* are virtually invisible to the human eye but have been intercepted in baggage at U.S. ports (AQAS, 2019).
ES-16 (Propagules likely to disperse in trade as contaminants or hitchhikers)	y - mod	2	Inspectors at U.S. ports have intercepted *P. ramosa* seeds in general cargo and permit cargo (AQAS, 2019. It is likely that the small seeds could be lodged in any type of micro-surface in materials or commodities and dispersed in trade.
ES-17 (Number of natural dispersal vectors)	4	4	*Philepanche ramosa* seeds are about 0.3 mm long and 0.2 mm wide and weigh approximately 3 to 6 µg. Seeds have a secondary dormancy mechanism, so they will only germinate under favorable soil conditions and when stimulated by nearby host roots. Their controlled dormancy allows seeds to survive for several decades in the seed bank (Pakeman et al., 2002).
ES-17a (Wind dispersal)	y - low		*Phelipanche ramosa* seeds can be windblown due to their small size (Ginman, 2009).
ES-17b (Water dispersal)	y - low		*Phelipanche ramosa* seeds can be transported by water due to their small size (Ginman, 2009; Pieterse, 1979).

Question ID	Answer - Uncertainty	Score	Notes (and references)
ES-17c (Bird dispersal)	n - high		We found no evidence that birds disperse the seeds or any evidence that the fruit would be attractive to birds. Because it is possible that some birds could eat the seeds from the seed pods, we answered no with high uncertainty.
ES-17d (Animal external dispersal)	y - low		*Phelipanche ramosa* seeds can be carried by animals such as sheep on their feet and in their wool (Ginman, 2009).
ES-17e (Animal internal dispersal)	y - low		*Phelipanche ramosa* seeds can be ingested by sheep and excreted within days (Ginman, 2009). *Orobanche* spp. seeds were viable after being excreted from sheep (Jacobsohn et al., 1987). Seeds with durable coats that allow them to remain viable in seed banks for up to 20 years are also very likely to remain viable after being excreted by animals (Pakeman et al., 2002).
ES-18 (Evidence that a persistent (>1yr) propagule bank (seed bank) is formed)	y - negl	1	The taxon has a persistent seed bank with seeds that are viable up to 20 years (Punia, 2014; Qasem and Foy, 2007). A California field was re-infested with *P. ramosa* when it was rotated back into tomato after about 24 years of of grass production (Jackson, 2014).
ES-19 (Tolerates/benefits from mutilation, cultivation or fire)	y - mod	1	We found no evidence that *P. ramosa* is tolerant to mechanical control or can resprout after hand weeding, disking, or harrowing.
ES-20 (Is resistant to some herbicides or has the potential to become resistant)	n - negl	0	We found no evidence that this species has developed a tolerance to any herbicides. Furthermore, no member of the genus is listed as resistant to herbicides (Heap, 2019).
ES-21 (Number of cold hardiness zones suitable for its survival)	7	0	
ES-22 (Number of climate types suitable for its survival)	6	2	
ES-23 (Number of precipitation bands suitable for its survival)	8	1	
IMPACT POTENTIAL			
General Impacts			
Imp-G1 (Allelopathic)	n - low	0	We found no evidence that *P. ramosa* is allelopathic. The species is a holoparasitic weed that depends entirely on its host to supply nutrients and water, so generating allelopathic chemicals would be counterproductive to meeting its resource needs (Musselman, 1980; Pieterse, 1979).
Imp-G2 (Parasitic)	y - negl	0.1	*Phelipanche ramosa* is a well characterized parasitic weed (Musselman, 1980; Punia, 2014).
Impacts to Natural Systems			
Imp-N1 (Changes ecosystem processes and parameters that affect other species)	n - low	0	We found no evidence that this species changes ecosystem processes. The taxon is unlikely to change ecosystem processes due to its low

Question ID	Answer - Uncertainty	Score	Notes (and references)
			likelihood of establishment in natural areas. *Phelipanche ramosa* occurs across a range of habitat types, from natural areas to cropland; however, its primary habitats are agricultural land and disturbed areas (CABI, 2018). An extensive host survey in Jordan found 19 weed species as hosts for *P. ramosa*, but the survey provided no evidence that it can invade natural areas containing these weed species (Qasem, 2009). Another host range survey in southern Australia found four native plant host species and 19 weedy host species, but it also provides no evidence that *P. ramosa* can invade undisturbed, natural areas (Prider, 2019; Virtue et al., 2014).
Imp-N2 (Changes habitat structure)	n - low	0	We found no evidence that *P. ramosa* can change habitat structure.
Imp-N3 (Changes species diversity)	n - low	0	We found no evidence that *P. ramosa* can change species diversity in natural ecosystems.
Imp-N4 (Is it likely to affect federal Threatened and Endangered species?)	y - high	0	We found no direct evidence that *P. ramosa* can parasitize Federal Threatened and Endangered species. Three species in the genus *Solanum*, however, are hosts for *P. ramosa* (Qasem, 2009). Several Threatened and Endangered species are also in the genus *Solanum*, so it is likely that *P. ramosa* could parasitize a Federal Threatened or Endangered species.
Imp-N5 (Is it likely to affect any globally outstanding ecoregions?)	n - low	0.1	It is unlikely that *P. ramosa* could affect any globally outstanding ecoregions. The taxon is primarily associated with agricultural and disturbed ecosystems (CABI, 2018; Virtue et al., 2014.
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]	a - mod	0.2	We found no evidence that *P. ramosa* is a weed in natural ecosystems. For the uncertainty simulation, the alternative answers were both "b"
Impact to Anthropogenic Systems (e.g., cities, suburbs, roadways)			
Imp-A1 (Negatively impacts personal property, human safety, or public infrastructure)	n - low	0.1	We found no evidence that *P. ramosa* negatively impacts personal property, human safety, or public infrastructure. Because it is unlikely that a small herbaceous, parasitic plant would have these impacts, we used low uncertainty.
Imp-A2 (Changes or limits recreational use of an area)	n - low	0	We found no evidence that *P. ramosa* changes or limits recreational use of an area.
Imp-A3 (Affects desirable and ornamental plants, and vegetation)	y - mod	0	In a host plant survey in Jordan, the taxon was found to parasitize approximately 14 ornamental species (Qasem, 2009), and in a survey in Australia, it was found to parasitize approximately 10 ornamental species (Virtue et al., 2014).

Question ID	Answer - Uncertainty	Score	Notes (and references)
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]	c - mod	0.1	*Phelipanche ramosa* is a weed on roadsides in Texas, and we found evidence of control by the Texas Department of Transportation (DOT), so our answer is c. *Phelipanche ramosa* is present on roadsides in Texas, and roadside mowers have spread the seeds with their mowing equipment (Musselman, 1996). Texas DOT officials requested that state contracts with roadside mowers include cleaning of equipment with power washers in order to remove *P. ramosa* seeds (Motloch, 2019). For the uncertainty simulation, both alternative answers were "b"
Impact to Production Systems (agriculture, nurseries, forest plantations, orchards, etc.)			
Imp-P1 (Reduces crop/product yield)	y - negl	0.4	*Phelipanche ramosa* can significantly reduce the yields of many crops (Buschmann et al., 2005; CABI, 2018). Tomato yield losses can range from 50 to 72 percent (Mauromicale et al., 2017), and tobacco yields losses can range from 50 to 60 percent (Punia, 2014).
Imp-P2 (Lowers commodity value)	y - negl	0.2	The taxon reduces the quality of vegetables that it parasitizes (Longo et al., 2010). It causes economic damage by reducing crop yields and also causes farmers to rotate infested fields out of vegetable production and into crops of lesser value (Fernandez-Aparicio et al., 2016; Jain and Foy, 1989; Punia, 2014).
Imp-P3 (Is it likely to impact trade?)	y - negl	0.2	This taxon is likely to impact trade. *Orobanche* seeds have been intercepted at U.S. ports in general cargo (AQAS, 2019). Australia had a national program to eradicate *P. ramosa* (Panetta et al., 2011; Prider et al., 2012).
Imp-P4 (Reduces the quality or availability of irrigation, or strongly competes with plants for water)	n - mod	0	We found no evidence that this taxon would affect the quality or availability of irrigation water. *Philepanche ramosa* is a parasitic plant that receives all its water needs from the host plant.
Imp-P5 (Toxic to animals, including livestock/range animals and poultry)	n - low	0	We found no evidence that this species or genus is toxic (Burrows and Tyrl, 2013). Sheep and goats graze on *P. ramosa* without any toxicity issues (Ginman, 2009).

Question ID	Answer - Uncertainty	Score	Notes (and references)
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	The taxon is a major parasitic weed in crop production systems, and we found evidence of control, so we chose "c" for this question. *Phelipanche ramosa* parasitizes the following crop hosts: tomato, brassica crops, bell pepper, potato, eggplant, cabbage, coleus, onion, broad bean, common bean, celery, carrot, hemp, lettuce, safflower, tobacco, and sunflower (Bagavathiannan, 2015; Kasasian, 1971; Pieterse, 1979). *Phelipanche ramosa* is under unofficial control in many countries (Babiker, 2007). Control methods for *P. ramosa* include cultural methods such as trap crops, mechanical methods such as deep plowing, and chemical methods such as herbicides and fumigation (Habimana et al., 2014; Punia, 2014). For the uncertainty simulation, both alternative answers were b.
GEOGRAPHIC POTENTIAL			Unless otherwise indicated, the following evidence represents geographically referenced points obtained from the Global Biodiversity Information Facility.
Plant hardiness zones			
Geo-Z1 (Zone 1)	n - negl	N/A	We found no evidence it occurs in this Zone (e.g., Mohamed et al., 2006).
Geo-Z2 (Zone 2)	n - negl	N/A	We found no evidence it occurs in this Zone (e.g., Mohamed et al., 2006).
Geo-Z3 (Zone 3)	n - negl	N/A	We found no evidence it occurs in this Zone (e.g., Mohamed et al., 2006).
Geo-Z4 (Zone 4)	n - high	N/A	Five points in Austria. These are old records, near Zone 5, and sites are located in the Alps, a mountainous region that may have be a lot of mapping error.
Geo-Z5 (Zone 5)	y - high	N/A	One point in Russia, one point in Austria.
Geo-Z6 (Zone 6)	y - negl	N/A	Germany, two points in Austria, two points in France, one point in Russia, one point in Ukraine.
Geo-Z7 (Zone 7)	y - negl	N/A	Germany, many points in France, a few points in Spain.
Geo-Z8 (Zone 8)	y - negl	N/A	France, Spain, Germany.
Geo-Z9 (Zone 9)	y - negl	N/A	Spain, France, Portugal.
Geo-Z10 (Zone 10)	y - negl	N/A	Spain, a few points in Portugal and Italy, three points in Morocco, two points in Ethiopia, a few points in South Africa.
Geo-Z11 (Zone 11)	y - negl	N/A	Some points in Spain, Portugal, and Italy; a few points in South Africa; two points in Sudan; a few points in Ethiopia.

Question ID	Answer - Uncertainty	Score	Notes (and references)
Geo-Z12 (Zone 12)	n - mod	N/A	Three points in South Africa, but these are on the coast and near Zone 11.
Geo-Z13 (Zone 13)	n - negl	N/A	We found no evidence it occurs in this Zone (e.g., Mohamed et al., 2006).
Köppen -Geiger climate classes			
Geo-C1 (Tropical rainforest)	n - negl	N/A	We found no evidence it occurs in this climate class.
Geo-C2 (Tropical savanna)	n - low	N/A	One in point Tanzania. Seems unlikely the species can survive well in this climate type because of one point in this climate class.
Geo-C3 (Steppe)	y - negl	N/A	Many points in Spain, five points in Ethiopia, a few points in South Africa, two points in Namibia.
Geo-C4 (Desert)	n - high	N/A	Six points in South Africa, one point in Morocco but on edge with Steppe, some points in Spain and in Canary Islands, three points in Sudan. Although these desert regions have some points, we answered no with high uncertainty because they may be growing in microclimates along rivers or canals.
Geo-C5 (Mediterranean)	y - negl	N/A	Italy, Portugal, Spain, a few points in Morocco.
Geo-C6 (Humid subtropical)	y - negl	N/A	A few points in France, Germany, and Italy; five points in Russia, five points in Bulgaria, one point in Greece, one point in Ethiopia, one point in South Africa, many points in the United States (Texas).
Geo-C7 (Marine west coast)	y - negl	N/A	Germany, France, and Spain.
Geo-C8 (Humid cont. warm sum.)	y - high	N/A	One point in Russia, one point in Armenia. Although we had only two points, we answered yes because this species occurs in continental cool summer regions and warmer regions of the world, which is next to climate class C9 (cool summers) with many points.
Geo-C9 (Humid cont. cool sum.)	y - negl	N/A	Germany, many points in France, two points in Spain, five points in Austria.
Geo-C10 (Subarctic)	n - high	N/A	Nine points in France, two points in Germany, three points in Spain. Although we found a few points in this climate class in Europe, this species is generally distributed in warmer climates of Europe. These few points maybe due to seasonal transients that are continually re-introduced from surrounding warmer regions. We found no other evidence to indicate that this species can survive in subarctic regions.
Geo-C11 (Tundra)	n - high	N/A	One point in Spain, two points in Austria, one point in Liechtenstein. These few points are in mountainous regions in Europe where rapid elevational changes may contribute to mapping error.
Geo-C12 (Icecap)	n - negl	N/A	
10-inch precipitation bands			

Question ID	Answer - Uncertainty	Score	Notes (and references)
Geo-R1 (0-10 inches; 0-25 cm)	y - mod	N/A	Five points in South Africa, one in Namibia, two in Ethiopia, two in Sudan, a few in Spain. It is likely that *P. ramosa* in this rainfall zone is growing in riparian areas or irrigated fields (Babiker, 2007
Geo-R2 (10-20 inches; 25-51 cm)	y - negl	N/A	Spain, a few points in Italy, four points in Morocco.
Geo-R3 (20-30 inches; 51-76 cm)	y - negl	N/A	France, Germany, and Spain.
Geo-R4 (30-40 inches; 76-102 cm)	y - negl	N/A	France and Germany, some points in Italy, many points in the United States (Texas).
Geo-R5 (40-50 inches; 102-127 cm)	y - negl	N/A	France and Germany.
Geo-R6 (50-60 inches; 127-152 cm)	y - negl	N/A	Some points in France and Germany.
Geo-R7 (60-70 inches; 152-178 cm)	y - low	N/A	A few points in mountainous regions of France and Germany.
Geo-R8 (70-80 inches; 178-203 cm)	y - high	N/A	A few points in mountainous regions of France and Germany.
Geo-R9 (80-90 inches; 203-229 cm)	n - high	N/A	Five points in the German Alps.
Geo-R10 (90-100 inches; 229-254 cm)	n - negl	N/A	We found no evidence.
Geo-R11 (100+ inches; 254+ cm)	n - negl	N/A	We found no evidence.
ENTRY POTENTIAL			
Ent-1 (Plant already here)	y - negl	1	The taxon is already present in eight U.S. states (CABI, 2018).
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 other evidence of trade or resale]	-	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	

Question ID	Answer - Uncertainty	Score	Notes (and references)
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. Host list for *Phelipanche ramosa* (L.) Pomel (Orobanchaceae).

Family	*Species*	Common name	Basis of host status*	Reference
Acanthaceae	*Thunbergia alata*	black-eyed Susan vine	Survey	Qasem 2009
Aizoaceae	*Mesebryanthemum sp.*	ice plant	Survey	Qasem 2009
Amaranthaceae	*Atriplex semibaccata*	creeping saltbush	Experimental	Virtue et al., 2014
Amaranthaceae	*Enchylaena tomentosa*	ruby saltbush	Experimental	Virtue et al., 2014
Amaranthaceae	*Rhagodia spinescens*	spiny saltbush	Experimental	Virtue et al., 2014
Amaryllidaceae	*Allium cepa*	onion	Survey	Qasen 2009
Apiaceae	*Ammi majus*	Bishop weed	Survey	Qasem 2009
Apiaceae	*Anethum graveolens*	dill	Survey	Qasem 2009
Apiaceae	*Apium raveolens*	celery	Survey	Qasem 2009
Apiaceae	*Carum carvi*	caraway	Survey	Qasem 2009
Apiaceae	*Coriandrum sativum*	coriander	Survey	Qasem 2009
Apiaceae	*Cuminum cyminum*	cumin	Survey	Qasem 2009
Apiaceae	*Daucus carota*	Queen Anne's lace	Survey	Qasem 2009

Family	*Species*	Common name	Basis of host status*	Reference
Apiaceae	*Eryngium creticum*	Eryngo	Survey	Qasem 2009
Apiaceae	*Falcaria vulgaris*	sickleweed	Survey	Qasem 2009
Apiaceae	*Ferula communis*	giant fennel	Survey	Qasem 2009
Apiaceae	*Foeniculum vulgare*	common fennel	Survey	Qasem 2009
Apiaceae	*Petroselinum sativum*	parsley	Survey	Qasem 2009
Apiaceae	*Pimpinella anisum*	anise	Survey	Qasem 2009
Apiaceae	*Torolis arvensis*	spreading hedgeparlsey	Survey	Qasem 2009
Apiaceae	*Trachyspermum ammi*	Bishop's weed	Survey	Qasem 2009
Asteraceae	*Anthemis cotula*	Mayweed	Survey	Qasem 2009
Asteraceae	*Arctotheca calendula*	capeweed	Survey	Virtue et al., 2014
Asteraceae	*Brachyscome ciliaris*	variable daisy	Survey	Virtue et al., 2014
Asteraceae	*Brachyscome multifidi*	cut-leaf daisy	Experimental	Virtue et al., 2014
Asteraceae	*Calendula arvensis*	field marigold	Survey	Qasem 2009
Asteraceae	*Calendula officinalis*	pot marigold	Survey	Qasem 2009
Asteraceae	*Carduus pycnocephalus*	Italian thistle	Survey	Qasem 2009
Asteraceae	*Carthamus tinctorius*	safflower	Survey	Qasem 2009
Asteraceae	*Chondrilla juncea*	skeleton weed	Survey	Virtue et al., 2014
Asteraceae	*Chrysocephalum apiculatum*	common everlasting	Experimental	Virtue et al., 2014
Asteraceae	*Cichorium intybus*	chicory	Survey	Qasem 2009
Asteraceae	*Crepis aspera*	hawksbeard	Survey	Qasem 2009
Asteraceae	*Dahlia pinnata Cav.*	Dahlia	Survey	Qasem 2009
Asteraceae	*Gazania sp.*	gazania	Experimental	Virtue et al., 2014
Asteraceae	*Gazania splendens*	treasure flower	Survey	Qasem 2009
Asteraceae	*Hedypnois rhagadioloides*	Cretan weed	Survey	Virtue et al., 2014
Asteraceae	*Helianthus annuus*	sunflower	Experimental	Virtue et al., 2014
Asteraceae	*Hypochaeris radicata*	smooth catsear	Survey	Virtue et al., 2014
Asteraceae	*Hypochoeris glabra*	flatweed	Survey	Virtue et al., 2014
Asteraceae	*Lactuca sativa*	lettuce	Survey	Qasem 2009
Asteraceae	*Matricaria chamomilla*	German chamomile	Survey	Qasem 2009
Asteraceae	*Notobasis syriaca*	Syrian thistle	Survey	Qasem 2009
Asteraceae	*Olearia pimeleoides*	showy daisy bush	Experimental	Virtue et al., 2014
Asteraceae	*Onopordum acaulon*	stemless thistle	Survey	Virtue et al., 2014
Asteraceae	*Picnomon acarna*	solider thistle	Survey	Qasem 2009
Asteraceae	*Polycalymma stuartii*	poached egg daisy	Survey	Virtue et al., 2014
Asteraceae	*Reichardia tingitana*	false sowthistle	Survey	Virtue et al., 2014
Asteraceae	*Rhagadiolus stellatus*	Endive daisy	Survey	Qasem 2009
Asteraceae	*Senecio pinnatifolius*	variable groundsel	Survey	Virtue et al., 2014
Asteraceae	*Silybum marianum*	milk thistle	Survey	Qasem 2009

Family	*Species*	Common name	Basis of host status*	Reference
Asteraceae	*Sonchus oleraceus*	sow thistle	Survey	Virtue et al., 2014
Asteraceae	*Tolpis barbata*	European umbrella milkwort	Survey	Virtue et al., 2024
Asteraceae	*Tragopogon coelesyriacus*	goatsbeard	Survey	Qasem 2009
Asteraceae	*Vittadinia sp.*	New Holland daisy	Survey	Virtue et al., 2014
Asteraceae	*Xanthium spinosum*	Bathurst burr	Survey	Virtue et al., 2014
Asteraceae	*Xanthium strumarium*	rough cocklebur	Survey	Qasem 2009
Asteraceae	*Xerochrysum bracteatum*	golden everlasting	Experimental	Virtue et al., 2014
Boraginaceae	*Buglossoides arvensis*	sheepweed	Survey	Virtue et al., 2014
Boraginaceae	*Echium plantagineum*	salvation Jane	Survey	Virtue et al., 2014
Boraginaceae	*Heliotropium europaeum*	common heliotrope	Survey	Virtue et al., 2014
Brassicaceae	*Brassica campestris*	field mustard	Survey	Qasem 2009
Brassicaceae	*Brassica juncea*	Indian mustard	Experimental	Virtue et al., 2014
Brassicaceae	*Brassica napus*	canola	Experimental	Virtue et al., 2014
Brassicaceae	*Brassica nigra*	black mustard	Survey	Qasem 2009
Brassicaceae	*Brassica oleracea var. botrytis*	cauliflower	Survey	Qasem 2009
Brassicaceae	*Brassica oleracea var. capitata*	cabbage	Survey	Qasem 2009
Brassicaceae	*Brassica oleracea var. gongylades*	Kohlrabi	Survey	Qasem 2009
Brassicaceae	*Brassica oleracea var. italica*	broccoli	Experimental	Virtue et al., 2014
Brassicaceae	*Brassica rapa*	forage turnip	Experimental	Virtue et al., 2014
Brassicaceae	*Brassica tournefortii*	long fruited turnip	Survey	Virtue et al., 2014
Brassicaceae	*Cardaria draba*	hoary cress	Survey	Qasem 2009
Brassicaceae	*Diplotaxis erucoides*	white rocket	Survey	Qasem 2009
Brassicaceae	*Diplotaxis tenuifolia*	Lincoln weed	Survey	Virtue et al., 2014
Brassicaceae	*Eruca sativa Miller*	arugula	Survey	Qasem 2009
Brassicaceae	*Lepidium sativum*	pepperweed	Survey	Qasem 2009
Brassicaceae	*Lobularia maritima*	alyssum	Experimental	Virtue et al., 2014
Brassicaceae	*Matthiola annua*	evening stock	Survey	Qasem 2009
Brassicaceae	*Sinapis alba*	white mustard	Experimental	Virtue et al., 2014
Brassicaceae	*Sinapis hirta*	yellow mustard	Experimental	Virtue et al., 2014
Brassicaceae	*Sisymbrium orientale*	Indian hedge mustard	Survey	Virtue et al., 2014
Carophyllaceae	*Dianthus barbatus*	sweet William	Experimental	Virtue et al., 2014
Caryophyllaceae	*Dianthus caryophyllus*	carnation	Survey	Qasem 2009
Caryophyllaceae	*Spergula arvensis*	corn spurry	Survey	Qasem 2009
Convolvulaceae	*Convolvulus arvensis*	field bindweed	Survey	Qasem 2009
Cucurbitaceae	*Citrullus colocynthis*	colocynth	Survey	Qasem 2009
Cucurbitaceae	*Citrullus lanatus*	watermelon	Experimental	Virtue et al., 2014

Family	*Species*	Common name	Basis of host status*	Reference
Cucurbitaceae	*Citrullus vulgaris*	citrullus	Survey	Qasem 2009
Cucurbitaceae	*Cucumis melo var. flexuosus*	muskmelon	Survey	Qasem 2009
Cucurbitaceae	*Cucumis melo subsp. melo*	rockmelon	Experimental	Virtue et al., 2014
Cucurbitaceae	*Cucumis sativus*	cucumber	Experimental	Virtue et al., 2014
Cucurbitaceae	*Cucurbita maxima*	pumpkin	Experimental	Virtue et al., 2014
Cucurbitaceae	*Cucurbita pepo*	summer squash	Survey	Qasem 2009
Cucurbitaceae	*Luffa cylindrica*	sponge gourd	Survey	Qasem 2009
Fabaceae	*Acacia pycnantha*	golden wattle	Experimental	Virtue et al., 2014
Fabaceae	*Cicer arietinum*	chickpea	Experimental	Virtue et al., 2014
Fabaceae	*Hardenbergia violacea*	native lilac	Experimental	Virtue et al., 2014
Fabaceae	*Kennedia prostrata*	running postman	Experimental	Virtue et al., 2014
Fabaceae	*Lathyrus cicera*	lathyrus	Experimental	Virtue et al., 2014
Fabaceae	*Lathyrus odoratus*	sweet pea	Experimental	Virtue et al., 2014
Fabaceae	*Lens culinaris*	lentil	Survey	Qasem 2009
Fabaceae	*Lupinus angustifolius*	narrowleaf lupin	Experimental	Virtue et al., 2014
Fabaceae	*Lupinus polyphyllus*	large-leaved lupine	Experimental	Virtue et al., 2014
Fabaceae	*Medicago littoralis*	strand medic	Experimental	Virtue et al., 2014
Fabaceae	*Medicago minima*	small burr medic	Experimental	Virtue et al., 2014
Fabaceae	*Medicago polymorpha*	annual burr medic	Experimental	Virtue et al., 2014
Fabaceae	*Medicago sativa*	lucerne	Survey	Qasem 2009
Fabaceae	*Medicago tornata*	disc medic	Experimental	Virtue et al., 2014
Fabaceae	*Medicago truncatula*	barrel medic	Experimental	Virtue et al., 2014
Fabaceae	*Melilotus albus*	white sweedclover	Survey	Qasem 2009
Fabaceae	*Melilotus indicus*	annual yellow sweetclover	Survey	Qasem 2009
Fabaceae	*Pisum sativum*	field pea	Experimental	Virtue et al., 2014
Fabaceae	*Senna artemisioides*	desert cassia	Experimental	Virtue et al., 2014
Fabaceae	*Swainsona formosa*	Sturt's desert pea	Experimental	Virtue et al., 2014
Fabaceae	*Trifolium michelanium*	balansa clover	Experimental	Virtue et al., 2014
Fabaceae	*Trifolium pratense*	red clover	Survey	Qasem 2009
Fabaceae	*Trifolium repens*	white clover	Experimental	Virtue et al., 2014
Fabaceae	*Trifolium resupinatum*	Persian clover	Experimental	Virtue et al., 2014
Fabaceae	*Trifolium subterraneum*	subterranean clover	Experimental	Virtue et al., 2014
Fabaceae	*Vicia benghalensis*	purple vetch	Experimental	Virtue et al., 2014
Fabaceae	*Vicia faba*	faba bean	Survey	Qasem 2009
Fabaceae	*Vicia narbonensis*	Narbon vetch	Survey	Qasem 2009
Fabaceae	*Vicia palaestina*	vetch	Survey	Qasem 2009
Fabaceae	*Vicia peregrina*	wandering vetch	Survey	Qasem 2009
Fabaceae	*Vicia sativa*	vetch	Experimental	Virtue et al., 2014
Geraniaceae	*Pelargonium grandiflorum*	geranium	Survey	Qasem 2009

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Geraniaceae	*Pelargonium x domesticum*	garden geranium	Experimental	Virtue et al., 2014
Geraniaceae	*Pelargonium zonale*	zonal geranium	Survey	Qasem 2009
Goodeniaceae	*Dampiera rosmarinifolia*	wild rosemary	Experimental	Virtue et al., 2014
Goodeniaceae	*Goodenia varia*	variable goodenia	Experimental	Virtue et al., 2014
Hemerocallidaceae	*Dianella revolta*	black anther flax lily	Experimental	Virtue et al., 2014
Lamiaceae	*Ajuga australis*	austral bugle	Experimental	Virtue et al., 2014
Lamiaceae	*Lavandula stoechas*	Italian lavender	Experimental	Virtue et al., 2014
Lamiaceae	*Ocimum basilicum*	basil	Survey	Qasem 2009
Lamiaceae	*Piectranthus scutellariodes*	coleus	Survey	Qasem 2009
Lamiaceae	*Prostanthera aspalathoides*	scarlet mintbush	Experimental	Virtue et al., 2014
Lamiaceae	*Salvia splendens*	scarlet sage	Survey	Qasem 2009
Lamiaceae	*Thymus serpyllum*	thyme	Survey	Qasem 2009
Lamiaceae	*Thymus syriaca*	thyme	Survey	Qasem 2009
Linaceae	*Linum usitatissimum*	flax	Survey	Qasem 2009
Lythraceae	*Punica granatum*	promegranate	Survey	Qasem 2009
Malvaceae	*Corchorus olitorius*	jute mallow	Survey	Qasem 2009
Malvaceae	*Hibiscus sabdariffa*	carcade	Survey	Qasem 2009
Malvaceae	*Malva sylvestris*	mallow	Survey	Qasem 2009
Myrtaceae	*Callistemon rugulosus*	scarlet bottlebrush	Experimental	Virtue et al., 2014
Myrtaceae	*Eucalyptus gracilis*	yorrell	Experimental	Virtue et al., 2014
Myrtaceae	*Eucalyptus socialis*	summer red mallee	Experimental	Virtue et al., 2014
Myrtaceae	*Kunzea pomifera*	muntries	Experimental	Virtue et al., 2014
Myrtaceae	*Melaleuca lanceolata*	dryland tea tree	Experimental	Virtue et al., 2014
Onagraceae	*Oenothera stricta*	evening primrose	Survey	Virtue et al., 2014
Oxalidaceae	*Oxalis corniculata*	creeping woodsorrel	Survey	Qasem 2009
Papaveraceae	*Papaver hybridum*	rough poppy	Survey	Virtue et al., 2014
Papaveraceae	*Papaver rhoeas*	common poppy	Survey	Qasem 2009
Pittosporaceae	*Billardiera cymosa*	sweet apple berry	Experimental	Virtue et al., 2014
Poaceae	*Avena sativa*	oats	Experimental	Virtue et al., 2014
Poaceae	*Hordeum vulgare*	barley	Experimental	Virtue et al., 2014
Poaceae	*Triticum sp.*	wheat	Experimental	Virtue et al., 2014
Polygonaceae	*Polygonum aviculare*	prostrate knotweed	Survey	Qasem 2009
Polygonaceae	*Rumex acetosella*	red sorrel	Survey	Qasem 2009
Portulacaceae	*Portulaca oleracea*	common purslane	Survey	Qasem 2009
Proteaceae	*Grevillea lavandulacea*	lavender grevillea	Experimental	Virtue et al., 2014
Ranunculaceae	*Nigella sativa*	black caraway	Survey	Qasem 2009
Ranunculaceae	*Ranunculus arvensis*	corn buttercup	Survey	Qasem 2009
Rosaceae	*Rosa damascena*	Damask rose	Survey	Qasem 2009
Rubiaceae	*Galium verrucosum*	warty bedstraw	Survey	Qasem 2009

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Rutaceae	*Correa glabra*	rock correa	Experimental	Virtue et al., 2014
Scrophulariaceae	*Eremophila divaricata*	spreading emu bush	Experimental	Virtue et al., 2014
Scrophulariaceae	*Misopates orontium*	weasel's snout	Survey	Qasem 2009
Scrophulariaceae	*Myoporum parvifolium*	creeping boobialla	Experimental	Virtue et al., 2014
Solanaceae	*Capsicum annuum*	capsicum	Survey	Qasem 2009
Solanaceae	*Capsicum fruitisence*	Bell pepper	Survey	Qasem 2009
Solanaceae	*Datura metel*	devil's trumpet	Survey	Qasem 2009
Solanaceae	*Datura stramonium*	jimsonweed	Survey	Qasem 2009
Solanaceae	*Hyoscyamus aureus*	golden henbane	Survey	Qasem 2009
Solanaceae	*Nicotiana tabaccum*	tobacco	Survey	Qasem 2009
Solanaceae	*Petunia hybrida*	petunia	Survey	Qasem 2009
Solanaceae	*Solanum angustifolium*	nightshade	Survey	Qasem 2009
Solanaceae	*Solanum incanum*	thorn apple	Survey	Qasem 2009
Solanaceae	*Solanum lycopersicum*	tomato	Experimental	Virtue et al., 2014
Solanaceae	*Solanum melongena*	eggplant	Survey	Qasem 2009
Solanaceae	*Solanum nigrum*	black nightshade	Survey	Qasem 2009
Solanaceae	*Solanum tuberosum*	potato	Survey	Qasem 2009
Solanaceae	*Withania somnifera*	ashwagandha	Survey	Qasem 2009
Tropaeolaceae	*Tropaeolum majus*	garden nasturtium	Survey	Qasem 2009
Urticaceae	*Urtica pilulifera*	Roman nettle	Survey	Qasem 2009
Verbenaceae	*Verbena officinalis*	common verbena	Natural	Qasem 2009
Violaceae	*Viola arvensis*	pansy	Experimental	Virtue et al., 2014

* Based on a literature review, host status was determined either through field surveys or experimental testing.