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Version 1

Weed Risk Assessment for *Phelipanche aegyptiaca* (Pers.) Pomel (Orobanchaceae) – Egyptian broomrape

Left: *Phelipanche aegyptiaca* parasitizing carrot (Dr. Reuven Jacobsohn, Agricultural Research Organization, Bugwood.org); Right (top): *P. aegyptiaca* seeds (source: Julia Scher, Federal Noxious Weed Disseminules, USDA APHIS ITP, Bugwood.org); (bottom): carrot field infested with *P. aegyptiaca*, left treated with soil solarization, right untreated with crop completely destroyed (source: Jaacov Katan, University of Jerusalem, Bugwood.org).

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1. 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 or weedy potential of a plant species using information related to its ability to establish, spread, and cause harm in natural and anthropogenic systems, including production systems (Koop et al., 2012). Because the predictive model is geographically and climatically neutral, it can be used to evaluate the risk of a plant species for the entire United States or for any area within it. We use a stochastic simulation to evaluate how much the uncertainty associated with the risk analysis affects the possible outcomes from the predictive model. The simulation essentially evaluates what other risk scores might result if any factors in the predictive model were to change. Finally, we use Geographic Information System (GIS) overlays to identify 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 *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 for the assessment, which results in a very broad evaluation. This is appropriate for the types of actions considered by our agency, such as Federal regulation. Furthermore, risk assessment and risk management are distinctly different phases of pest risk analysis (IPPC, 2016). 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.

2. Plant Information and Background

SPECIES: *Phelipanche aegyptiaca* (Pers.) Pomel (NGRP, 2018)

FAMILY: Orobanchaceae

SYNONYMS: *Orobanche aegyptiaca* Pers.; *Orobanche indica* Buch.-Ham. Ex Roxb. (NGRP, 2018)

COMMON NAMES: Egyptian broomrape (Robson et al., 1991)

BOTANICAL DESCRIPTION: *Phelipanche aegyptiaca* is an annual or perennial root parasite. The stems are slender (15-50 cm x 0.4-0.6 cm), branched, glandular, and hairy. The leaves are reduced to colorless bracts up to 12 mm long. The flower is a corolla, 20-35 mm long, distinctly funnel-shaped, constricted above the ovary, and pale violet to blue, with shaggy anthers. The calyx is four-lobed and bell-shaped, extending to the constriction of the corolla. Plants flower from February to October (Robson et al., 1991), and seeds measure between 0.25 and 0.3 mm long (Joel and Losner-Goshen, 1994).

Phelipanche aegyptiaca parasitizes *Achillea santolina*, *Apium graveolens* (celery), *Arachis hypogaea* (peanut), *Artensia maritima, Aster altaicus*, *Brassica campestris* var. *rapa* (turnip), *Brassica campestris* var. *sarson*, *Brassica campestris* var. *toria* (toria), *Brassica juncea* (mustard), *Brassica napus* (rapeseed), *Brassica nigra* (black mustard), *Brassica oleracea* (syn.: *B. caulorapa*) (cabbage), *Brassica oleracea* var. *botrytis* (broccoli), *Brassica oleracea* var. *capitata* (cabbage), *Brassica rapa* (field mustard), *Capsicum annuum* (pepper), *Capsicum frutescens* (red chillies), *Chenopodium album* (goose foot), *Cicer arietinum* (chickpea), *Citrullus lanatus* (watermelon), *Citrullus vulgaris* var. *fistulosus* (Indian summer squash), *Convolvulus arvensis* (field bindweed), *Cucumis melo* (melon), *Cucumis sativus* (cucumber), *Cucurbita moschata* (squash), *Cucurbita pepo* (pumpkin, squash), *Daucus carota* (carrot), *Eruca vesicaria* (purple-vein rocket), *Euphorbia helioscopia* (sun spurge), *Foeniculum vulgare* (fennel), *Gerapogon hybridus* (hairless goatsbeard), *Helianthus annuus* (sunflower), *Heliotropium europaeum* (European heliotrope), *Hibiscus cannabinus* (kenaf), *Hibiscus trionum* (flower of an hour), *Hordeum vulgare* (barley), *Hyoscyamus niger* (common henbane), *Kalanchoe blossfeldiana* (flaming katy), *Lactuca sativa* (lettuce), *Lagenaria vulgaris* (bottle gourd), *Lens culinaris* subsp. *culinaris* (lentil), *Lepidium draba* (hoary cress), *Luffa acutangula* (sinkwa towelsponge), *Lycopersicon esculentum* (syn.: *Solanum lycopersicum*) (tomato), *Malva sylvestris* (high mallow), *Medicago sativa* (alfalfa), *Momordica charantia* (bitter melon), *Nicotiana tabacum* (tobacco), *Ocimum basilicum* (basil), *Ocimum sanctum* (holy basil), *Olea europaea* subsp. *europaea* (European olive), *Pastinaca sativa* (parsnip), *Pelargonium grandiflorum* (regal pelargonium), *Petroselinum crispum* (parsley), *Petunia* x *hybrida* (petunia), *Peucedanum graveolens* (dill), *Pisum sativum* (pea), *Prunus amygdalus* (almond), *Prunus armeniaca* (apricot), *Prunus persica* (peach), *Punica granatum* (pomegranate), *Raphanus sativus* (radish), *Sesamum indicum* (sesame), *Solanum melongena* (eggplant), *Solanum nigrum* (nightshade), *Solanum tuberosum* (potato), *Sonchus oleraceus* (common sowthistle), *Spinacia oleracea* (spinach), *Tanacetum gracile, Taxaracum* sp., *Tropaeolum majus* (garden nasturtium), *Vicia faba* (faba bean), *Vicia sativa* (common vetch), *Xanthium spinosum* (spiny cocklebur), and *Zinnia elegans* (common zinnia) (Abu-

Irmaileh, 1991; Aksoy and Arslan, 2013; Bernhard et al., 1998; CABI, 2014; Ghotbi et al., 2012; Goldwasser, 1995; Haidar and Shdeed, 2015; Hershenhorn et al., 2009; Hershenhorn et al., 1996; Jafar, 1978; Joel et al., 2007; Khatri et al., 1989; Qasem, 2009; Rubiales et al., 2009; Sadidi et al., 2011; Jafar and Shafique, 1975).

INITIATION: During the development of a pathway-initiated pest risk assessment for global *Spinacia oleracea* (spinach) seed for planting, PPQ identified *Phelipanche aegyptiaca* as a potential contaminant of spinach seed. Because this species poses a potential risk to U.S. agricultural and natural resources, the PPQ Cross Functional Working Group (CFWG) for Noxious Weeds requested that a full weed risk assessment be conducted. The CFWG specifically requested information on impacts on agricultural production, costs to the agricultural industry, impacts on trade, challenges to eradication, and documentation of eradication efforts in other countries. In this assessment, PERAL evaluates the risk potential of this species to the United States and addresses the specific concerns of the CFWG.

WRA AREA[1]: United States and Territories.

FOREIGN DISTRIBUTION: The native range of *Phelipanche aegyptiaca* includes Africa (Algeria, Egypt, Ethiopia, Mauritius, Morocco, and Tunisia), temperate Asia [Afghanistan, Armenia, China (Xinjiang), Cyprus, Egypt (Sinai), Iran, Iraq, Israel, Jordan, Kazakhstan, Kuwait, Kyrgyzstan, Lebanon, Saudi Arabia, Syria, Tajikistan, Turkey, Turkmenistan, and United Arab Emirates], tropical Asia (Bangladesh, Bahrain, India, Nepal, and Pakistan), and Europe (Bulgaria, Italy, Russian Federation, and Ukraine) (Holm et al., 1979; NGRP, 2018; Parker and Wilson, 1987; Vagelas and Gravanis, 2014). We found no evidence that this species has spread outside its native range. It is reported to have been introduced into Cuba (Oviedo et al., 2012), but we were unable to confirm this. In Cuba, it is synonymized with *Orobanche ramosa* (Oviedo et al., 2012), which is a similar plant but is considered a separate species (NGRP, 2018). We found no evidence that this species is cultivated. *Orobanche* spp. are specifically regulated by 16 countries (APHIS, 2018). *Phelipanche aegyptiaca* is considered a severe pest and is aggressively controlled as an “invasive” weed throughout its range (Haidar and Shdeed, 2015). In some cases, infestations have caused farmers to abandon production of host plants in favor of less profitable non-host crops (Hershenhorn et al., 2009; Sadidi et al., 2011).

U.S. DISTRIBUTION AND STATUS: *Phelipanche aegyptiaca* is not listed in the BONAP (Kartesz, 2017) or EDDMapS (2017) databases, but it is listed as “introduced” in Solano County, CA within the PLANTS database (NRCS, 2017). The term “introduced” suggests that the organism is established, but when it was detected in a processing tomato field in 2014, the landowner, farmer associations, and others instituted an eradication program and established best management practices (BMP) for preventing further incursion of this parasitic plant. These efforts were supported by the California Department of Food and Agriculture (CDFA) and the United States Department of Agriculture (USDA) (Condos and Wright, 2016; Miyao, 2017). The eradication plan included: 1) application of glyphosate to

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

the parasite and host plants, 2) hand removal of parasitic shoots, 3) flaming with propane, 4) restriction of access to the field, and 5) fumigation of the field. This was followed by a succession of three host crops to monitor the effectiveness of the treatments (Miyao, 2017). The fields were fumigated with methyl bromide, which is a broad-spectrum herbicide historically used for killing weeds prior to planting (Hanson and Shrestha, 2006). The field was closely monitored for two years, and at that time the eradication was considered successful (Condos and Wright, 2016; Miyao, 2017). The weed was detected in an adjacent tomato field in 2016 and is under a similar eradication effort (Kelch, 2018; Mullaly, 2016). The prior success of eradication and the ongoing efforts to eliminate the species from this new field indicate that it is not considered to be established in the United States. We found no evidence that the plant is cultivated in the United States. It is regulated as a Federal Noxious Weed (7 CFR § 360, 2010; 7 CFR § 361, 2014) and is listed as a noxious weed or otherwise regulated (prohibited or quarantined) in nine states: Alabama, California, Florida, Massachusetts, Minnesota, North Carolina, Oregon, South Carolina, and Vermont (NRCS, 2017).

3. Analysis

ESTABLISHMENT/SPREAD POTENTIAL

Phelipanche aegyptiaca is a prolific producer of tiny seeds (Rubiales et al., 2009), which spread on animals, through wind and water, and through cultivation practices (Jacobsohn et al., 1987; Rubiales et al., 2009). The seeds easily spread from field to field, and the species has been characterized as a “fast-spreading parasite” (Hershenhorn et al., 2009). The tiny seeds are “difficult to detect in harvested crop seeds and in soil” (Rathore et al., 2014). The species can establish a long-term seed bank. One report from a field in Israel suggests that seeds can survive more than 40 years (Joel et al., 2007). We had low uncertainty for this risk element because the biology of this species is well known.

Risk score = 16 Uncertainty index = 0.10

IMPACT POTENTIAL

It is well established that *Phelipanche aegyptiaca* is a pest of production systems. In some systems it has caused total yield loss (Bernhard et al., 1998; Cochavi et al., 2015). In some regions of its native range, farmers have either abandoned highly fertile infested fields or have switched to less profitable non-host crops (Hershenhorn et al., 2009). Controls for this species include fumigation (Miyao, 2017), crop rotation (Babaei et al., 2010), crop substitution (Bernhard et al., 1998), biological control with agromyzid flies (CABI, 2014), soil solarization (Robson et al., 1991), use of resistant plants (Goldwasser et al., 1997), application of herbicides (Cochavi et al., 2015; Cochavi et al., 2016; Eizenberg et al., 2012; Haidar and Shdeed, 2015), and use of trap crops and false hosts (Jervekani et al., 2016). Controls, however, often fail to provide adequate management (Hershenhorn et al., 2009; Sadidi et al., 2011). Despite the clear impacts in production systems, we found no evidence that this organism causes impacts to natural systems, and it is unclear if it has any impacts on other anthropogenic systems. Sixteen countries, including Canada and Mexico, regulate *Orobanche* spp. as pests (APHIS, 2018). We had high uncertainty for this risk element because of the lack of information reported from natural and anthropogenic systems.

Risk score = 2.6 Uncertainty index = 0.20

GEOGRAPHIC POTENTIAL

Based on three climatic variables, we estimate that about 41 percent of the United States is suitable for the establishment of *P. aegyptiaca* (Fig. 1). This predicted distribution is based on the known distribution of the species elsewhere in the world and includes point-referenced localities and general areas of occurrence. The map for *P. aegyptiaca* represents the overlap of Plant Hardiness Zones (PHZs) 7-12, areas with 0-60 inches of annual precipitation, and the following Köppen-Geiger climate classes: Mediterranean, desert, steppe, humid subtropical, marine west coast, humid continental warm summers, and humid continental cool summers. Note that, it was not clear if *P. aegyptiaca* occurs in PHZs 5, 6, and 13. For this assessment, we assumed that these PHZs are not suitable.

The area of the United States shown to be climatically suitable (Fig. 1) 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. It is unlikely to be limited by host availability because hosts are found in every U.S. state and territory (Clark, 2009; Vilsack, 2014; Vilsack and Clark, 2014).

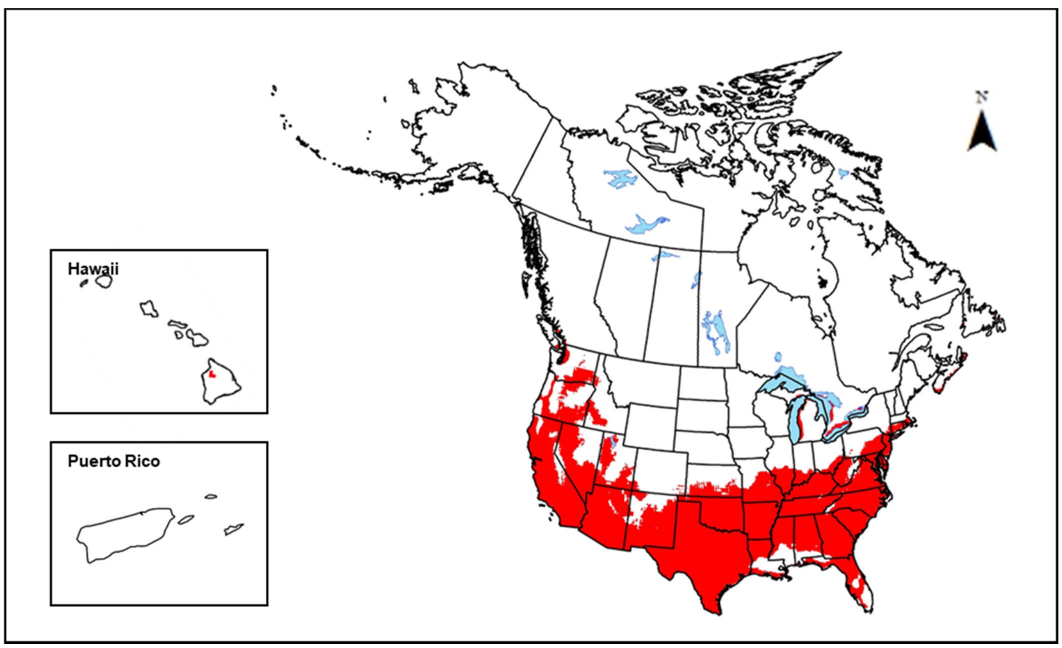

Figure 1. Potential geographic distribution of *P. aegyptiaca* in the United States and Canada. Map insets for Hawaii and Puerto Rico are not to scale.

ENTRY POTENTIAL

Phelipanche aegyptiaca has not naturalized in the United States, but it has previously been detected in California, suggesting there is an open pathway for this organism to enter. Trace backs to the seed sources that were planted in California failed to detect contaminated seed. It is unlikely that this species would be brought into the country specifically for cultivation since it has adverse effects on other species. Rather, the abundance of tiny seeds produced by this species and the ease with which they are dispersed suggest that it is more likely to enter the United States as a contaminant. Long-distance (local, national, and international) dispersal of *Orobanchaceae* spp. has been attributed to the trade of contaminated seed (Joel, 2013).

Risk score = 0.14 Uncertainty index = 0.09

4. Predictive Risk Model Results

Model Probabilities: P(Major Invader) = 76.8%
P(Minor Invader) = 22.3%
P(Non-Invader) = 0.9%
Risk Result = High Risk
Secondary Screening = Not Applicable

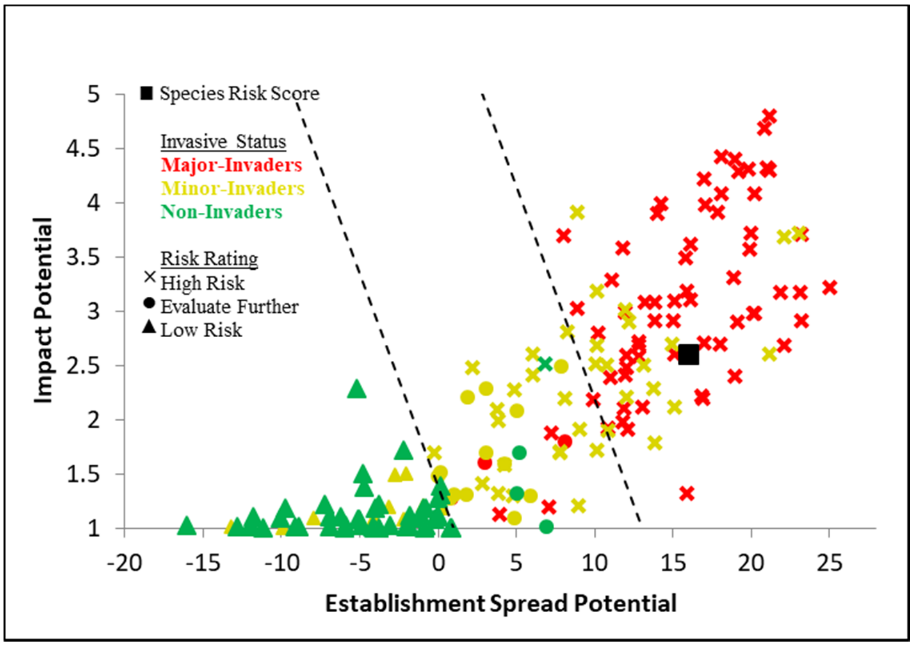

Figure 2. *Phelipanche aegyptiaca* risk score (black box) relative to the risk scores of species used to develop and validate the PPQ WRA model (other symbols). See Appendix A for the complete assessment.

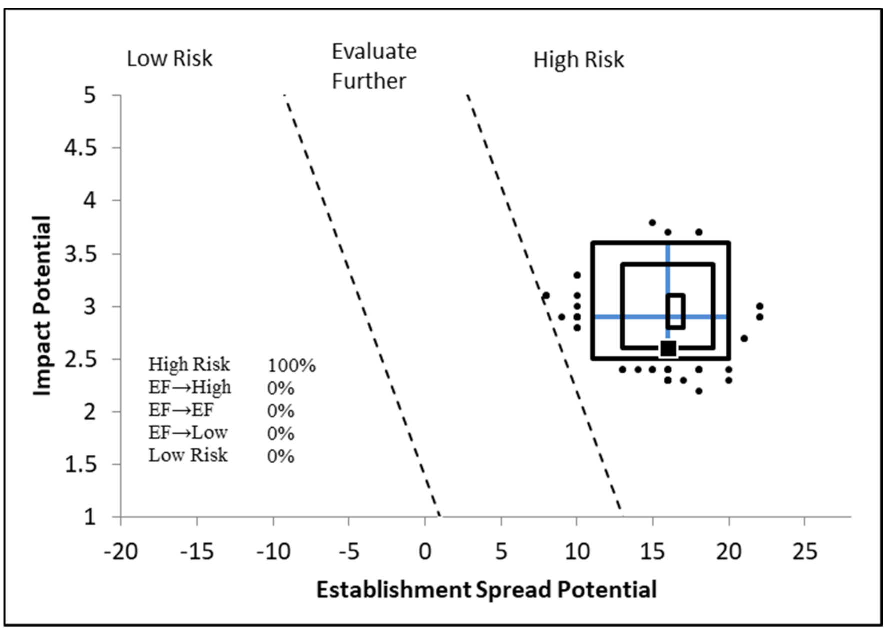

Figure 3. Model simulation results (N=5,000) for uncertainty around the risk score for *P. aegyptiaca*. The blue "+" symbol represents the medians of the simulated outcomes. The smallest box contains 50 percent of the outcomes, the second 95 percent, and the largest 99 percent.

5. Discussion

The result of the weed risk assessment for *Phelipanche aegyptiaca* is High Risk (Fig. 2). All the simulated data in the uncertainty analysis agree with a prediction of High Risk (Fig. 3), indicating that this prediction is robust despite the few areas of uncertainty. *Phelipanche aegyptiaca* is a parasitic plant that produces a large number of tiny (0.25 – 0.3 mm long) seeds that are easily dispersed. It is a weed of production systems, where it causes damage or yield loss to several types of crops. Within the United States, the species has only been reported from two adjacent fields in Solano County, CA, where eradication efforts are ongoing. *Phelipanche aegyptiaca* is listed on the Federal Noxious Weed List and is regulated by nine states.

We found only two reports of *P. aegyptiaca* outside its native range, one in Cuba and one in the United States. It is not clear if the report from Cuba is a report of *P. aegyptiaca* or the closely related *P. ramosa*, since the publication synonymized the two. The report from the United States has been confirmed to be *P. aegyptiaca*. Parasitic plant seeds commonly contaminate seed crops, allowing them to spread long distances (Joel, 2013), but we found little direct evidence suggesting that this species is a highly mobile organism in global trade. The detection in the United States indicates an open pathway for this organism into the country. The literature includes numerous reports of negative impacts of this species (Bernhard et al., 1998; Cochavi et al., 2015; Hershenhorn et al., 2009). Most alarming of these is a report that it produces a seedbank that can survive up to 40 years (Joel et al., 2007). Many management strategies are used to control parasitic plants, but these methods are often complicated and expensive and may not completely eradicate the plant (Hershenhorn et al., 2009; Sadidi et al., 2011). This has caused growers in some regions to abandon their infested fertile fields or switch to less profitable crops that are not hosts.

6. Acknowledgements

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SUGGESTED CITATION

PPQ. 2018. Weed risk assessment for *Phelipanche aegyptiaca* (Pers.) Pomel (Orobanchaceae) – Egyptian broomrape. United States Department of Agriculture, Animal and Plant Health Inspection Service, Plant Protection and Quarantine (PPQ), Raleigh, NC. 25 pp.

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Appendix A. Weed risk assessment for *Phelipanche aegyptiaca* (Pers.) Pomel (Orobanchaceae)

In the following table are the evidence and associated references used to evaluate the risk potential of *P. aegyptiaca*. We 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]	d - mod	5	Although Orobanchaceae species are commonly thought to travel in international trade (Joel, 2013), we found few reports of this organism outside its native range. *Phelipanche aegyptiaca* was found growing in a California field for at least two years prior to the initiation of eradication efforts (Kelch, 2018). It is unclear if the plant had naturalized in California since we are not sure when the species first started growing in the field. The species was also reported as invasive in Cuba (Oviedo et al., 2012); however, it is not clear if the Cuban report referes to *P. aegyptiaca* or *Orobanche ramosa*. Despite the lack of evidence for international spread, the plant has been characterized as a "fast-spreading parasite" (Hershenhorn et al., 2009), and its small seeds allow it to spread easily "from one field to another" (Rubiales et al., 2009). The alternate answers for this question were both 'e'.
ES-2 (Is the species highly domesticated)	n - low	0	We found no evidence of cultivation.
ES-3 (Significant weedy congeners)	y - negl	1	The genus *Phelipanche* is closely related to *Orobanche*, and some researchers recognize them as a single genus (Nemli et al., 2011). With about 20 species, the genus *Orobanche* includes some of the "most devastating weeds in agriculture" (Joel et al., 2007). In Turkey, three *Orobanche* spp. are widespread and are considered serious problems for agricultural crops: *O. crenata*, *O. cernua*, and *O. ramosa* (Nemli et al., 2011).
ES-4 (Shade tolerant at some stage of its life cycle)	y - negl	1	*Phelipanche aegyptiaca* lacks chlorophyll (Cochavi et al., 2015; Joel et al., 2007; Sadidi et al., 2011), so it has

Question ID	Answer - Uncertainty	Score	Notes (and references)
			no need for sunlight. It exploits other flowering plants for water and nutrients (Rubiales and Heide-Jorgensen, 2011).
ES-5 (Plant a vine or scrambling plant, or forms tightly appressed basal rosettes)	n - negl	0	This species is not a vine, nor does it form tightly appressed basal rosettes. The stems are slender branches (Robson et al., 1991).
ES-6 (Forms dense thickets, patches, or populations)	n - mod	0	We found no written descriptions of the density of *P. aegyptiaca* populations. Photos of *P. aegyptiaca* infestations show the parasite forming small dense patches throughout the field (Eizenberg and Goldwasser, 2018). As a parasitic plant, it is unlikely that the species would densely occupy large areas of a field since the host plant would still require some space to grow in order to sustain the parasitic population.
ES-7 (Aquatic)	n - negl	0	*Phelipanche aegyptiaca* is not an aquatic plant; it is an obligate root parasite of field crops and vegetables (Robson et al., 1991).
ES-8 (Grass)	n - negl	0	This species is not a grass; it is an obligate root parasite in the family Orobanchaceae (Robson et al., 1991).
ES-9 (Nitrogen-fixing woody plant)	n - negl	0	*Phelipanche aegyptiaca* is not a woody plant. We found no evidence that it can fixnitrogen, and it does not belong to a family known to contain any nitrogen-fixing species (Martin and Dowd, 1990).
ES-10 (Does it produce viable seeds or spores)	y - negl	1	Broomrapes propagate via seeds (Rubiales et al., 2009). The seeds germinate in the soil only after a preconditioning period and only in response to a specific chemical (xenognosin) exuded by the root of the host plant, which acts as a germination stimulant (Ghotbi et al., 2012).
ES-11 (Self-compatible or apomictic)	y - low	1	*Phelipanche aegyptiaca* will self-pollinate if not visited by insects (Joel et al., 2007; Rubiales et al., 2009).
ES-12 (Requires specialist pollinators)	n - negl	0	This species is believed to be pollinated by insects (Rubiales et al., 2009); however, because it will self-pollinate without insects, we answered no with negligible uncertainty.

Question ID	Answer - Uncertainty	Score	Notes (and references)
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]	a - mod	1	We found no specific reports that the organism produces multiple generations in a single year, but based on the biology, this may be possible. Seeds of *Phelipanche* spp. require specific moisture, temperature, and chemical cues for emergence (Joel, 2000), but it does not appear that the seeds go through an extended seed dormancy. After planting, seeds of *P. aegyptiaca* can be ready to emerge in a few days and flowering may occur as early as 27 days post planting (Jervekani et al., 2016). It is not clear how long it might take for seeds to develop after flowering, but it is plausible that several generations of *P. aegyptiaca* could occur in a single year. Both alternate choices for this question were 'b'.
ES-14 (Prolific seed producer)	y - negl	1	The number of seeds produced by a healthy *P. aegyptiaca* plant can exceed 200,000 (Joel et al., 2007; Rubiales et al., 2009). Egyptian broomrape can produce hundreds of thousands of small (0.1 to 0.2 mm) seeds (Cochavi et al., 2016). Under laboratory conditions, where germination is likely optimized, germination rates greater than 80 percent have been reported for *P. aegyptiaca* (Westwood and Foy, 1999).
ES-15 (Propagules likely to be dispersed unintentionally by people)	y - negl	1	The minute seeds may be easily dispersed by vehicles and farming machines (Rubiales et al., 2009). Local, global, and international dispersal has been attributed to the movement of contaminated seed lots (Joel et al, 2013).
ES-16 (Propagules likely to disperse in trade as contaminants or hitchhikers)	y - mod	2	The minute seeds may easily be transferred from one field to another and crop contaminated seeds (Rubiales et al., 2009). Local, global, and international dispersal of Orobanchaceae has been attributed to the movement of contaminated seed lots (Joel, 2013).
ES-17 (Number of natural dispersal vectors)	4	4	Plant propagule traits for questions ES-17a through ES-17e. From Rubiales et al., 2009): Seeds are very small, approximately 0.1-0.2 mm long (Cochavi et al., 2016).

Question ID	Answer - Uncertainty	Score	Notes (and references)
ES-17a (Wind dispersal)	y - negl		This species is dispersed by wind (Hershenhorn et al., 2009; Rubiales et al., 2009). *Phelipanche aegyptiaca* seeds were blown from an infested tomato field a distance of at least 90 m by harvesting machinery (Cohen et al., 2017).
ES-17b (Water dispersal)	y - low		Water, particularly run-off, is proposed as a mechanism for dispersal of this (Hershenhorn et al., 2009; Rubiales et al., 2009) and related species (Joel, 2013). We found no direct evidence, so we used 'low' uncertainty.
ES-17c (Bird dispersal)	n - mod		We found no evidence of dispersal by birds.
ES-17d (Animal external dispersal)	y - low		Seeds may be transferred from one field to another by animals (Rubiales et al., 2009).
ES-17e (Animal internal dispersal)	y - negl		Experimental tests demonstrated the ability of *P. aegyptiaca* (*O. aegyptiaca*) seeds to survive and parasitize host plants after the seeds passed through the digestive system of a ram (Jacobsohn et al., 1987). Accidental harvesting of plant shoots (*O. crenata* or *O. aegyptiaca*) in lentil straw and forage crops may spread the seeds if the crops are used to feed animals because the manure may be contaminated with seeds, which remain viable after passing through the alimentary system of animals (Rubiales et al., 2009). Adequately composted manure, however, is considered safe (Yaacoby et al., 2015).
ES-18 (Evidence that a persistent (>1yr) propagule bank (seed bank) is formed)	y - negl	1	Broomrape seeds may remain viable in soil for decades (Rubiales et al., 2009). The seeds germinate in the soil only after a preconditioning period and only in response to a specific chemical (xenognosin) exuded by the root of the host plant, which acts as a germination stimulate (Ghotbi et al., 2012). Seeds are hard to detect in the soil and can remain viable for many years (Cochavi et al., 2016). Extreme cases were documented in Israel, where the seeds survived in the soil for more than 40 years (Joel et al., 2007).

Question ID	Answer - Uncertainty	Score	Notes (and references)
ES-19 (Tolerates/benefits from mutilation, cultivation or fire)	n - mod	-1	We found no evidence that this species tolerates or would benefit from mutilation, cultivation, or fire. Fire has been used as a tool for eradicating populations of *P. aegyptiaca* (Miyao, 2017).
ES-20 (Is resistant to some herbicides or has the potential to become resistant)	n - low		Neither *Phelipanche aegyptiaca* nor any of its close relatives are listed as herbicide-resistant weeds (Heap, 2018).
ES-21 (Number of cold hardiness zones suitable for its survival)	6	0	
ES-22 (Number of climate types suitable for its survival)	7	2	
ES-23 (Number of precipitation bands suitable for its survival)	6	0	
IMPACT POTENTIAL			
General Impacts			
Imp-G1 (Allelopathic)	n - high		We did not find specific evidence that *P. aegyptiaca* is allelopathic; however, in a study with other *Phelipanche* spp., the biomass from the parasitic weeds was added to petri plates and showed an allelopathic effect on the germination and initial development of lettuce (*Lactuca sativa*) under laboratory conditions (Marinov-Serafimov et al., 2017).
Imp-G2 (Parasitic)	y - negl	0.1	*Phelipanche aegyptiaca* is a destructive root parasitic plant, causing serious damage to multiple crop species (Babaei et al., 2010; Parker, 2009; Rubiales et al., 2009; Rubiales and Heide-Jorgensen, 2011).
Impacts to Natural Systems			
Imp-N1 (Changes ecosystem processes and parameters that affect other species)	n - mod	0	We found no evidence for impacts on ecosystem processes. Because this species is not considered a weed of natural systems, we answered most of the questions in this risk sub-element as no with moderate uncertainty. We did not use low uncertainty because this species has not become widely naturalized outside of its native range.
Imp-N2 (Changes habitat structure)	n - mod	0	We found no evidence for impacts on habitat structure.
Imp-N3 (Changes species diversity)	? - max		The California pest risk assessment suggests that this is a possibility (Kelch, 2015); however, we found no supporting evidence.

Question ID	Answer - Uncertainty	Score	Notes (and references)
Imp-N4 (Is it likely to affect federal Threatened and Endangered species?)	? - max		*Phelipanche aegyptiaca* is described as a parasite of crop plants, and we found no reports of it in natural systems. The California pest risk assessment, however, suggests that threatened and endangered species in the state could be affected (Kelch, 2015).
Imp-N5 (Is it likely to affect any globally outstanding ecoregions?)	n - mod	0	*Phelipanche aegyptiaca* is a parasite of crop plants, and we found no reports of it in natural systems.
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 - low	0	We found no evidence that *P. aegyptiaca* is a weed in natural systems. Both alternate answers for this question were 'b'.
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 impacts on personal property. Because this impact seems unlikely for a small, herbaceous species, we used low uncertainty.
Imp-A2 (Changes or limits recreational use of an area)	n - low	0	We found no evidence of impacts on recreational areas. Because this impact seems unlikely for a small, herbaceous species, we used low uncertainty.
Imp-A3 (Affects desirable and ornamental plants, and vegetation)	y - low	0	We found several reports of this taxon parasitizing ornamental host plants (Jafar, 1978; Qasem, 2009). It is unclear, however, how severely these hosts are affected by this parasitic plant.
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 - high	0	Several ornamental plants are hosts for *P. aegyptiaca* (Jafar, 1978; Qasem, 2009), although it is not clear whether the impacts from *P. aegyptiaca* were in in production systems or in other anthropogenic systems, such as gardens. We found no evidence that this species is controlled in non-production anthropogenic systems. Both alternate answer for this questions were 'b'.

Question ID	Answer - Uncertainty	Score	Notes (and references)
Impact to Production Systems (agriculture, nurseries, forest plantations, orchards, etc.)			
Imp-P1 (Reduces crop/product yield)	y - negl	0.4	We found reports of extensive and increasing infestation of musk melon and watermelon in the Xinjiang province of China in 1994, with 20 to 70 percent yield loss (Parker, 2009). Heavy infestations of *P. aegyptiaca* in carrot can cause total yield loss (Bernhard et al., 1998; Cochavi et al., 2015). In Turkey, yield loss in tomato is 25-40 tons per hectare, and the overall loss in Turkish tomato production is estimated at €200 million ($244.6 million) (Hershenhorn et al., 2009). This species also causes yield loss in tomato in Iran (Babaei et al., 2010).
Imp-P2 (Lowers commodity value)	y - low	0.2	Growers in Israel, Ethiopia, and Sudan have abandoned infested fertile fields for less profitable fields or have switched to less profitable non-host crops in infested fields (Hershenhorn et al., 2009). Broomrapes adversely affect crop quality (Sadidi et al., 2011).
Imp-P3 (Is it likely to impact trade?)	y - low	0.2	*Orobanche* spp. (synonyms of *Phelipanche aegyptica* occur in this genus) are listed as prohibited, or subject to quarantine in at least 16 countries, including several important trading partners, such as Canada and Mexico (APHIS, 2018). This species is also found as a contaminant in trade (see ES-16).
Imp-P4 (Reduces the quality or availability of irrigation, or strongly competes with plants for water)	? - max		As a parasitic plant, *P. aegyptiaca* draws all of its nutrients, minerals, and water from the host plant root (Cochavi et al., 2015). Plants under salt stress may accumulate more salt in their leaves when also parasitized by *P. aegyptiaca* (Cochavi et al., 2018). Several sources indicate wilting as a symptom in host plants that are infected by *Orobanche* spp. (Bernhard et al., 1998) or *P. aegyptiaca* (CABI, 2014), which may indicate that the species strongly competes with the host plant for water. It is unclear, however, if the wilting caused by *P. aegyptiaca* is in fact the result of strong competition for water or results from increased respiration (Singh and Singh, 1971).

Question ID	Answer - Uncertainty	Score	Notes (and references)
Imp-P5 (Toxic to animals, including livestock/range animals and poultry)	n - low	0	We found no evidence that this parasitic weed is toxic to animals. Additionally, it is not on the ASPCA list of poisonous plants (ASPCA, 2018) or on the Cornell University list of plants toxic to livestock (Brown, 2015).
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	*Phelipanche aegyptiaca* is recorded by Holm et al. (1979) as a serious or principal weed in Afghanistan, Iran, Jordan, Italy, Saudi Arabia. Considerable efforts are made to control this weed using fumigation (Miyao, 2017), crop rotation (Babaei et al., 2010), crop substitution (Bernhard et al., 1998), biological control (CABI, 2014), soil solarization (Robson et al., 1991), host plant resistance (Goldwasser et al., 1997), herbicides (Cochavi et al., 2015; Cochavi et al., 2016; Eizenberg et al., 2012; Haidar and Shdeed, 2015), and trap crops (Jervekani et al., 2016). Controls, however, often fail to provide adequate management of the weed (Hershenhorn et al., 2009; Sadidi et al., 2011). Both alternate answers for this question were 'b'.
GEOGRAPHIC POTENTIAL			Unless otherwise indicated, the following evidence represents geographically referenced locations obtained from the Global Biodiversity Information Facility (GBIF, 2017).
Plant hardiness zones			
Geo-Z1 (Zone 1)	n - negl	N/A	We found no reports of this species in this Zone.
Geo-Z2 (Zone 2)	n - negl	N/A	We found no reports of this species in this Zone.
Geo-Z3 (Zone 3)	n - negl	N/A	We found no reports of this species in this Zone.
Geo-Z4 (Zone 4)	n - negl	N/A	We found no reports of this species in this Zone.
Geo-Z5 (Zone 5)	? - max	N/A	Several reports from Afghanistan and Pakistan. Since these reports are in mountainous areas, it is not clear if they have been reported from micro-climates that may represent warmer areas. Therefore answering unknown.
Geo-Z6 (Zone 6)	? - max	N/A	We found no reports of this species in this Zone, it is reported from warmer and cooler Zones. This suggests the it may be able to survive in this Zone.

Question ID	Answer - Uncertainty	Score	Notes (and references)
Geo-Z7 (Zone 7)	y - mod	N/A	We found at least six reports of this species in this Zone, from China, Afghanistan, Georgia, and Turkey.
Geo-Z8 (Zone 8)	y - low	N/A	We found no reports of this species in this Zone, it is reported from warmer and cooler zones. This suggests it may be able to survive in this Zone.
Geo-Z9 (Zone 9)	y - negl	N/A	We found at least one report of this species from this Zone in California.
Geo-Z10 (Zone 10)	y - negl	N/A	We found numerous reports of this species within this zone in Israel. we also found a report from Nepal.
Geo-Z11 (Zone 11)	y - negl	N/A	We found numerous reports of this species within this Zone in Israel.
Geo-Z12 (Zone 12)	y - negl	N/A	We found numerous reports of this species within this Zone in Israel.
Geo-Z13 (Zone 13)	? - max	N/A	We found no reports of this species in this Zone. We did, however, find numerous reports of this organism in Zone 12, suggesting that it is adapted to warmer temperatures. It is not clear if the taxon has ever been exposed to Zone 13, since this Plant Hardiness Zone is not with within the native range of the species.
Köppen -Geiger climate classes			
Geo-C1 (Tropical rainforest)	n - low	N/A	We found no evidence of this species in this climate class.
Geo-C2 (Tropical savanna)	n - low	N/A	We found no evidence of this species in this climate class.
Geo-C3 (Steppe)	y - negl	N/A	We found at least 15 reports of this species in this climate class, from Israel, Cyprus, Afghanistan, Pakistan, and Iran.
Geo-C4 (Desert)	y - negl	N/A	We found at least 13 reports of this species in this climate class, from Israel, Algeria, Afghanistan, Pakistan, China, Egypt, and Jordan.
Geo-C5 (Mediterranean)	y - negl	N/A	We found numerous reports of this species in this climate class within Israel alone. It is widespread in Mediterranean climate areas (Hershenhorn et al., 2009).
Geo-C6 (Humid subtropical)	y - low	N/A	We found at least six reports of this species in this climate class, from Pakistan and Nepal.
Geo-C7 (Marine west coast)	y - high	N/A	We found one report of this species in this climate class from China.
Geo-C8 (Humid cont. warm sum.)	y - high	N/A	We found one report of this species in this climate class from Turkey.
Geo-C9 (Humid cont. cool sum.)	y - high	N/A	We found two reports of this species in this climate class, from Greece and China.

Question ID	Answer - Uncertainty	Score	Notes (and references)
Geo-C10 (Subarctic)	n - low	N/A	We found no evidence of this species in this climate class.
Geo-C11 (Tundra)	n - low	N/A	We found no evidence of this species in this climate class.
Geo-C12 (Icecap)	n - low	N/A	We found no evidence of this species in this climate class.
10-inch precipitation bands			
Geo-R1 (0-10 inches; 0-25 cm)	y - negl	N/A	We found numerous reports of this species in this precipitation band in Israel and several reports from Pakistan and Afghanistan.
Geo-R2 (10-20 inches; 25-51 cm)	y - negl	N/A	We found numerous reports of this species in this precipitation band in Israel.
Geo-R3 (20-30 inches; 51-76 cm)	y - negl	N/A	We found numerous reports of this species in this precipitation band in Israel and several reports from Pakistan and Afghanistan.
Geo-R4 (30-40 inches; 76-102 cm)	y - low	N/A	We found at least one report of this species in this precipitation band in Turkey.
Geo-R5 (40-50 inches; 102-127 cm)	y - mod	N/A	We found at least three reports of this species in this precipitation band, from Georgia, China, and Nepal.
Geo-R6 (50-60 inches; 127-152 cm)	y - high	N/A	We found at least one report of this species in this precipitation band in China.
Geo-R7 (60-70 inches; 152-178 cm)	n - low	N/A	We found no evidence of this species in this precipitation band.
Geo-R8 (70-80 inches; 178-203 cm)	n - negl	N/A	We found no evidence of this species in this precipitation band.
Geo-R9 (80-90 inches; 203-229 cm)	n - negl	N/A	We found no evidence of this species in this precipitation band.
Geo-R10 (90-100 inches; 229-254 cm)	n - negl	N/A	We found no evidence of this species in this precipitation band.
Geo-R11 (100+ inches; 254+ cm)	n - negl	N/A	We found no evidence of this species in this precipitation band.
ENTRY POTENTIAL			
Ent-1 (Plant already here)	n - mod	0	*Phelipanche aegyptiaca* is not considered to be established in the United States. It was detected in a tomato field in California in 2014; an eradication program was instituted and after two years was considered successful (Condos and Wright, 2016; Miyao, 2017). It was detected in an adjacent tomato field in 2016 and eradication was immediately begun (Mullaly, 2016).
Ent-2 (Plant proposed for entry, or entry is imminent)	n - low	0	This species has not been proposed for import.

Question ID	Answer - Uncertainty	Score	Notes (and references)
Ent-3 [Human value & cultivation/trade status: (a) Neither cultivated or positively valued; (b) Not cultivated, but positively valued or potentially beneficial; (c) Cultivated, but no evidence of trade or resale; (d) Commercially cultivated or other evidence of trade or resale]	a - negl	0	We found no evidence that this parasitic species is cultivated, used, or positively valued. Our literature review indicates that this species is consistently considered weedy and undesirable (Joel et al., 2007; Rubiales and Heide-Jorgensen, 2011).
Ent-4 (Entry as a contaminant)			
Ent-4a (Plant present in Canada, Mexico, Central America, the Caribbean or China)	y - low		It is present in China (Xinjiang Province) (Parker 2009). It has been reported fom Cuba (Oviedo et al., 2012), but this report may be referencing a different species.
Ent-4b (Contaminant of plant propagative material (except seeds))	n - high	0	We found no evidence of contamination of propagative material, although this is a possibility.
Ent-4c (Contaminant of seeds for planting)	y - negl	0.08	The minute seeds may easily be transferred from one field to another by cultivation practices and in contaminated crop seeds (Joel, 2013; Rubiales et al., 2009).
Ent-4d (Contaminant of ballast water)	n - low	0	We found no evidence.
Ent-4e (Contaminant of aquarium plants or other aquarium products)	n - low	0	This is not a pest of aquatic systems, nor is it found near aquatic systems. It is a pest of field crops in the Mediterranean.
Ent-4f (Contaminant of landscape products)	? - max		We have no record of *P.aegyptiaca* having been intercepted at U.S. ports of entry since 1985; however, the genus *Orobanche* (synonyms of *Phelipanche aegyptiaca* occur in this genus) has been intercepted numerous times on a variety of imported goods (seeds, roots, flowers, and plants) (PPQ, 2018; queried 8/14/2018).
Ent-4g (Contaminant of containers, packing materials, trade goods, equipment or conveyances)	y - low	0.04	The minute seeds may be easily transferred by vehicles and farming machines (Rubiales et al., 2009).
Ent-4h (Contaminants of fruit, vegetables, or other products for consumption or processing)	? - max	0.02	We have no evidence to suggest this, and it is unlikely that seeds from this species would contaminate most plant parts for consumption. The seeds are very small, however, and could go unnoticed on leafy commodities, such as lettuce or cabbage.

Question ID	Answer - Uncertainty	Score	Notes (and references)
Ent-4i (Contaminant of some other pathway)	b - mod	0	The seeds may be easily transferred from one field to another in contaminated crop seeds; accidentally harvesting plant shoots in lentil straw and forage crops may also disperse the seeds (Rubiales et al., 2009).
Ent-5 (Likely to enter through natural dispersal)	n - high	0	This parasitic plant is not known to be established in Canada or Mexico and is unlikely to blow on wind currents from its native range. Its method of entry into California is unknown. It is not clear if the records of this taxon from Cuba (Oviedo et al., 2012) actually represent *O. ramosa*.