United States Department of Agriculture

Weed Risk Assessment for *Bunias erucago* L. (Brassicaceae) – Southern warty cabbage

United States Department of Agriculture

Animal and Plant Health Inspection Service

December 6, 2016

Version 1

Left: Yellow flowers of *Bunias erucago*. Right: *Bunias erucago* seeds are contained in this very distinctive fruit. Photographs courtesy of Ferran Turmo i Gort (Turmo i Gort, 2014).

Agency Contact:

Plant Epidemiology and Risk Analysis Laboratory
Center for Plant Health Science and Technology

Plant Protection and Quarantine
Animal and Plant Health Inspection Service
United States Department of Agriculture
1730 Varsity Drive, Suite 300
Raleigh, NC 27606

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

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

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

	***Bunias erucago* L. – Southern warty cabbage**
Species	Family: Brassicaceae
Information	Synonyms: For a list of synonyms see The Plant List (The Plant List, 2013).
	Common names: Southern warty cabbage (NGRP, 2016; Weakley, 2015), corn rocket (Dave's Garden, 2016), crested warty cabbage (NRCS, 2016), crested bunias (Hanf, 1983; Williams, 1982; WSSA, 2016), toothed pod mustard (Massey, 1960).
	Botanical description: *Bunias erucago* is an annual or biennial herb that grows 20-60 cm high (Bojňanský and Fargašová, 2007). It has branched stems, some of which may be purplish, and has yellow, spatulate flowers (Massey, 1960).The fruits are 8-12 x 4-5 mm woody, ovoid, oblong achenes with four cristate wings and a glandulous surface. The seeds within the fruit are 2.5-3 x 2-2.6 mm in size, smooth, flattened, and suborbicular in shape (Bojňanský and Fargašová, 2007). A full botanical description is available in Massey (1960).
	Initiation: PPQ received a market access request for wheat seed for planting from the government of Italy (MPAAF, 2010). A commodity import risk analysis determined that *B. erucago* could be associated with this commodity as a seed contaminant. In this assessment, PERAL evaluated the risk potential of this species to the United States to help policy makers determine whether it should be regulated as a Federal Noxious Weed.
	Foreign distribution and status: *Bunias erucago* is native to parts of southern Europe (Ančev, 2007; Rollins, 1981; Verloove, 2006), Mediterranean Africa, and Turkey (NGRP, 2016). It is considered to be a casual escape in the United Kingdom (Wilson, 1852), Finland (Kurtto and Lahti, 1987), Belgium (Verloove, 2006), the Czech Republic (Pysek et al., 2002), and Hungary (Botond and Zoltan, 2004). In Europe, *B. erucago* is eaten in salads (Di Novella et al., 2013; Romano et al., 2013; Salisbury, 1961) and as a cooked vegetable (Dolina and Łuczaj, 2014; Luczaj and Dolina, 2015). *Bunias erucago* does not appear to be widely cultivated, but at least one European gardening database (PFAF, 2016) provides information about growing this species.
	U.S. distribution and status: *Bunias erucago* was collected in the United States from Philadelphia, PA, in 1877 and from a field in Prince Edward County, VA, in 1957 and 1959 (Massey, 1960). We did not find any additional occurrences of this species in the United States (e.g., GBIF, 2016; Kartesz, 2016; NGRP, 2016; NRCS, 2016). At least one U.S. gardening website (Dave's Garden, 2016) provides cultivation information for *B. erucago*, but this doesn't necessarily mean this species is actually being cultivated in the United States. We did not find any online nurseries selling this species.

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

1. *Bunias erucago* analysis

Establishment/Spread Potential

Bunias erucago is a casual escape in several European countries (Botond and Zoltan, 2004; Kurtto and Lahti, 1987; Pysek et al., 2002; Verloove, 2006; Wilson, 1852). It can be propagated from seed (Dave's Garden, 2016; PFAF, 2016), is self-fertile (Knuth and Müller, 1906), and is related to the weedy congener *B. orientalis* (CABI, 2016; Harvey and Gols, 2011). While *B. erucago* has few natural seed dispersal vectors (Benvenuti, 2007), its seed has been moved to new areas as a seed and grain contaminant (Clement and Foster, 2000; Massey, 1960; Verloove, 2006). We had an average level of uncertainty for this risk element.

Risk score = 6 Uncertainty index = 0.19

Impact Potential

Bunias erucago is listed as a weed of cereal crops, vineyards, cultivated fields, and fallows in Europe (Bojňanský and Fargašová, 2007; Massey, 1960; Saatkamp et al., 2014; Williams, 1982), but we did not find reports of it having any specific agricultural impacts. Additionally, we did not find any information about *B. erucago* having impacts in natural, urban, or suburban areas. We had an average level of uncertainty for this risk element.

Risk score = 1.2 Uncertainty index = 0.17

Geographic Potential

Based on three climatic variables, we estimate that about 82 percent of the United States is suitable for the establishment of *Bunias erucago* (Fig. 1). This predicted distribution is based on the species' known distribution elsewhere in the world and includes point-referenced localities and areas of occurrence. The map for *B. erucago* represents the joint distribution of Plant Hardiness Zones 4-11, areas with 0-100+ inches of annual precipitation, and the following Köppen-Geiger climate classes: steppe, Mediterranean, humid subtropical, marine west coast, humid continental warm summers, humid continental cool summers, subarctic, and tundra.

The area of the United States shown to be climatically suitable (Fig. 1) is likely overestimated since our analysis considered only three climatic variables. Other environmental variables, such as soil and habitat type, may further limit the areas in which this species is likely to establish. *Bunias erucago* mainly occurs in disturbed areas and waste ground in Europe (Rollins, 1981; Weakley, 2015).

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

Entry Potential *Bunias erucago* is valued as an ingredient in salads in Europe (Di Novella et al., 2013; Romano et al., 2013; Salisbury, 1961), but it does not appear to be widely cultivated. We did not find any online retailers selling this species. This species does move to new areas as a seed and grain contaminant (Clement and Foster, 2000; Massey, 1960; Verloove, 2006), and *B. erucago* plants have been found growing near ports (Salisbury, 1961).
Risk score = 0.3 Uncertainty index = 0.40

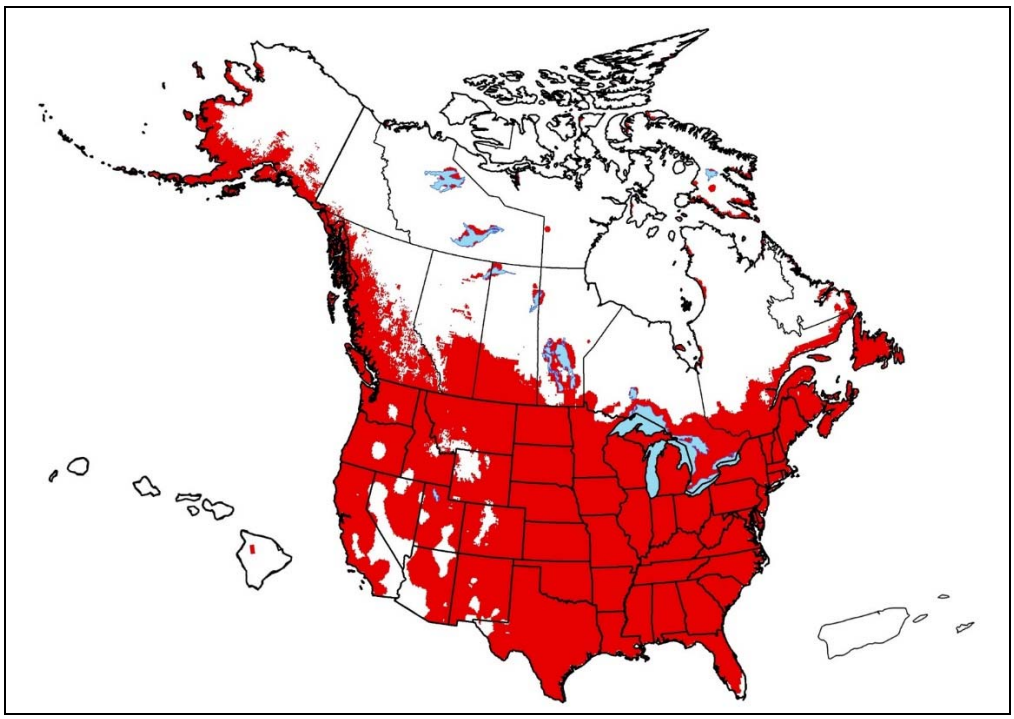

Figure 1. Potential geographic distribution of *Bunias erucago* in the United States and Canada. Map insets for Hawaii and Puerto Rico are not to scale.

2. Results

Model Probabilities: P(Major Invader) = 11.9%
P(Minor Invader) = 69.8%
P(Non-Invader) = 18.3%
Risk Result = Evaluate Further
Secondary Screening = Evaluate Further

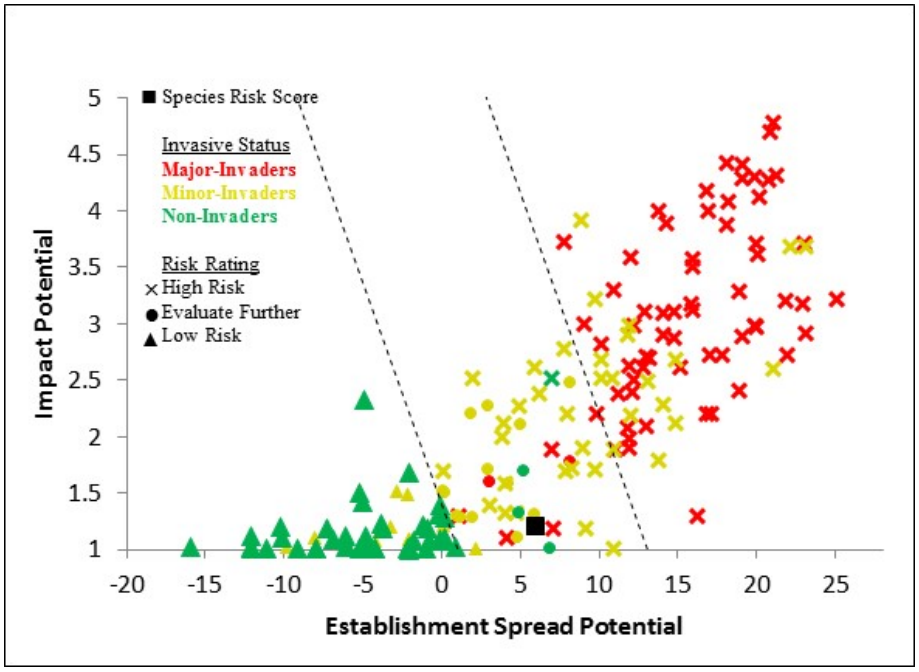

Figure 2. *Bunias erucago* risk score (black box) relative to the risk scores of species used to develop and validate the PPQ WRA model (other symbols). See Appendix A for the complete assessment.

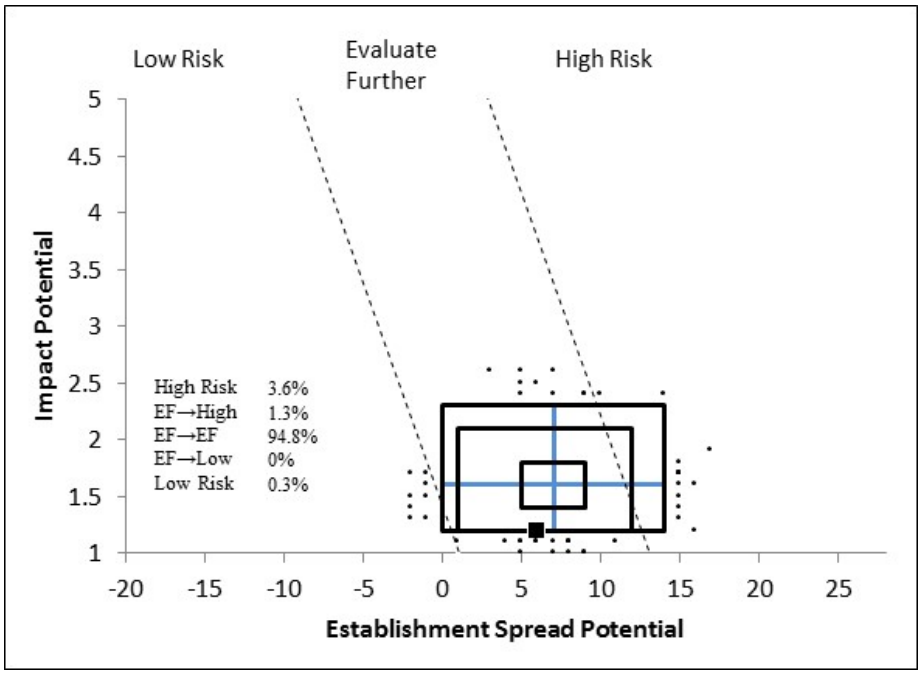

Figure 3. Model simulation results (N=5,000) for uncertainty around the risk score for *B. erucago*. The blue "+" symbol represents the medians of the simulated outcomes. The smallest box contains 50 percent of the outcomes, the second 95 percent, and the largest 99 percent.

3. Discussion

The result of the weed risk assessment for ***B. erucago*** is Evaluate Further, even after the secondary screening. The risk score for ***B. erucago*** is similar to the scores of the minor invaders that were used to develop and validate our weed risk assessment model (Figure 2). The result for the majority (94.3 percent) of our simulated risk scores was also Evaluate Further (Figure 3), which further suggests ***B. erucago*** would behave as a minor invader. ***Bunias erucago*** contaminates and spreads in seed and grain (Clement and Foster, 2000; Massey, 1960; Verloove, 2006), but its fruit is very distinctive (see photograph above) and different from the fruit of other ***Bunias*** species (Bojňanský and Fargašová, 2007). The seeds of ***B. erucago*** can also be distinguished from seeds of ***B. orientalis*** by differences in size (Bojňanský and Fargašová, 2007). The distinctive fruit of ***B. erucago*** may allow this species to be readily identified during seed and grain inspections.

4. Literature Cited

7 U.S.C. § 1581-1610. 1939. The Federal Seed Act, Title 7 United States Code § 1581-1610.

7 U.S.C. § 7701-7786. 2000. Plant Protection Act, Title 7 United States Code § 7701-7786.

Allaby, M. 2012. A Dictionary of Plant Sciences. Oxford University Press, Oxford, United Kingdom. 544 pp.

Ančev, M. 2007. Catalogue of the family Brassicaceae (Cruciferae) in the flora of Bulgaria. Phytologia Balcanica 13(2):153-178.

APHIS. 2016. Phytosanitary Certificate Issuance & Tracking System (PCIT). United States Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS). Last accessed October 24, 2016, https://pcit.aphis.usda.gov/pcit/faces/index.jsp.

Bailey, L. H., and E. Z. Bailey. 1976. Hortus Third: A Concise Dictionary of Plants Cultivated in the United States and Canada. Macmillan, London, United Kingdom. 1290 pp.

Benvenuti, S. 2007. Weed seed movement and dispersal strategies in the agricultural environment. Weed Biology and Management 7(3):141-157.

Birnbaum, C. 2006. NOBANIS – Invasive Alien Species Fact Sheet – *Bunias orientalis*. Online Database of the European Network on Invasive Alien Species – NOBANIS. Last accessed October 25, 2016, https://www.nobanis.org/.

Bocchieri, E. 1998. On the failure to find plants on some minor islands of Sardinia. Flora Mediterranea 8:197-212.

Bojňanský, V., and A. Fargašová. 2007. Atlas of Seeds and Fruits of Central and East-European flora: the Carpathian Mountains region. Springer, Dordrecht, The Netherlands. 1046 pp.

Botond, M., and B.-D. Zoltan (eds.). 2004. Biologiai Invaziok Magyarorszagon: Ozonnovenyek [Biological Invasions in Hungary: Invasive Plants]. TermészetBÚVÁR Alapítvány Kiadó, Budapest. 409 pp.

Burrows, G. E., and Tyrl. 2001. Toxic Plants of North America. Iowa State University Press, Ames, Iowa. 1342 pp.

CABI. 2016. Crop Protection Compendium. Commonwealth Agricultural Bureau International (CABI). http://www.cabi.org/cpc/.

Clement, E. J., and M. C. Foster (eds.). 2000. Alien Plants of the British Isles: A Provisional Catalogue of Vascular Plants (excluding grasses). Botanical Society of the British Isles, London, U.K. 590 pp.

Dave's Garden. 2016. PlantFiles. Dave's Garden. Last accessed October 24, 2016, from http://davesgarden.com/guides/pf/.

Di Novella, R., N. Di Novella, L. De Martino, E. Mancini, and V. De Feo. 2013. Traditional plant use in the National Park of Cilento and Vallo di Diano, Campania, Southern, Italy. Journal of Ethnopharmacology 145(1):328-342.

Dolina, K., and Ł. Łuczaj. 2014. Wild food plants used on the Dubrovnik coast (south-eastern Croatia). Acta Societatis Botanicorum Poloniae 83(3):175-181.

Dunn, S. T. 1903. A preliminary list of the alien flora of Britain. West, Newman & Company, London, United Kingdom. 30 pp.

Francois, L. 1929. Origin of seeds. Annales de la Science Agronomique 46(2):719-732.

Francois, L. 1941. Seeds and seedlings of plants indicative of the origin of cereals. Annales de Phytogénétique 7(Spec. No.):1-32.

GBIF. 2016. Data Portal. Global Biodiversity Information Facility (GBIF). Last accessed October 24, 2016, http://data.gbif.org/welcome.htm.

GreenPlantSwap. 2016. *Bunias erucago*. Corn rocket. GreenPlantSwap, Somerset, United Kingdom. Last accessed February 11, 2016, https://www.greenplantswap.co.uk/plants/3108-bunias-erucago.

Hanf, M. 1983. The Arable Weeds of Europe: With their Seedlings and Seeds. BASF, United Kingdom. 494 pp.

Harvey, J. A., and R. Gols. 2011. Development of *Mamestra brassicae* and its solitary endoparasitoid *Microplitis mediator* on two populations of the invasive weed *Bunias orientalis*. Population Ecology 53(4):587-596.

Heap, I. 2016. The International Survey of Herbicide Resistant Weeds. WeedScience.org. Last accessed October 24, 2016, http://www.weedscience.org.

Heide-Jørgensen, H. S. 2008. Parasitic Flowering Plants. Brill Publishers, Leiden, The Netherlands. 442 pp.

Hochkirch, A., T. Mertes, and J. Rautenberg. 2012. Conspecific flowers of *Sinapis arvensis* are stronger competitors for pollinators than those of the invasive weed *Bunias orientalis*. Naturwissenschaften 99(3):217-224.

Holm, L. G., J. V. Pancho, J. P. Herberger, and D. L. Plucknett. 1979. A Geographical Atlas of World Weeds. Krieger Publishing Company, Malabar, Florida, U.S.A. 391 pp.

IPPC. 2012. International Standards for Phytosanitary Measures No. 5: Glossary of Phytosanitary Terms. Food and Agriculture Organization of the United Nations, Secretariat of the International Plant Protection Convention (IPPC), Rome, Italy. 38 pp.

IPPC. 2015. International Standards for Phytosanitary Measures No. 2: Framework for Pest Risk Analysis. Food and Agriculture Organization of the United Nations, Secretariat of the International Plant Protection Convention (IPPC), Rome, Italy. 18 pp.

Kartesz, J. T. 2016. North American Plant Atlas [maps generated from Kartesz, J.T. 2010. Floristic Synthesis of North America, Version 1.0. Biota of North America Program (BONAP).]. The Biota of North America Program, Chapel Hill, N.C. Last accessed November 8, 2016, http://bonap.org/.

Knuth, P., and H. Müller. 1906. Handbook of Flower Pollination: Based upon Hermann Müller's Work 'The Fertilisation of Flowers by Insects', Volume 1. Clarendon Press, Oxford, United Kingdom. 382 pp.

Koop, A., L. Fowler, L. Newton, and B. Caton. 2012. Development and validation of a weed screening tool for the United States. Biological Invasions 14(2):273-294.

Kurtto, A., and T. Lahti. 1987. Suomen putkilokasvien luettelo (Checklist of the vascular plants of Finland). Pamphlet of Botanical Museum, University of Helsinki 11:1-163.

Lisci, M., and E. Pacini. 1993. Plants growing on the walls of Italian towns 2. Reproductive ecology. Giornale Botanico Italiano 127(6):1053-1078.

Luczaj, L., and K. Dolina. 2015. A hundred years of change in wild vegetable use in southern Herzegovina. Journal of Ethnopharmacology 166:297-304.

Mabberley, D. J. 2008. Mabberley's Plant-Book: A Portable Dictionary of Plants, their Classification and Uses (3rd edition). Cambridge University Press, New York, New York. 1021 pp.

Martin, P. G., and J. M. Dowd. 1990. A protein sequence study of the dicotyledons and its relevance to the evolution of the legumes and nitrogen fixation. Australian Systematic Botany 3:91-100.

Massey, A. B. 1960. *Bunias erucago* in Virginia. Rhodora 62(742):293.

MPAAF. 2010. § 319.5 Requirements for submitting requests to change the regulations in 7 CFR part 319. Ministero delle Politiche Agricole, Alimentari e Forestali (MPAAF), Rome. 29 pp.

NGRP. 2016. Germplasm Resources Information Network (GRIN). United States Department of Agriculture, Agricultural Research Service, National Genetic Resources Program (NGRP). Last accessed October 24, 2016, http://www.ars-grin.gov/.

Nickrent, D. 2009. Parasitic plant classification. Southern Illinois University Carbondale, Carbondale, IL, U.S.A. Last accessed June 12, 2009, http://www.parasiticplants.siu.edu/ListParasites.html.

NRCS. 2016. The PLANTS Database. United States Department of Agriculture, Natural Resources Conservation Service (NRCS), The National Plant Data Center. Last accessed October 24, 2016, http://plants.usda.gov.

PFAF. 2016. *Bunias erucago* - L. Plants For A Future (PFAF), England and Wales, United Kingdom. Last accessed November 2, 2016, http://www.pfaf.org/User/Plant.aspx?LatinName=Bunias+erucago.

PPQ. 2015. Guidelines for the USDA-APHIS-PPQ Weed Risk Assessment Process. United States Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS), Plant Protection and Quarantine (PPQ). 125 pp.

Pysek, P., J. Sadlo, and B. Mandak. 2002. Catalogue of alien plants of the Czech Republic. Preslia (Prague) 74(2):97-186.

Rollins, R. C. 1981. Weeds of the Cruciferae (Brassicaceae) in North America. Journal of the Arnold Arboretum 62:17-540.

Romano, D., A. Tribulato, S. Toscano, and D. Scuderi. 2013. Ethnobotanical uses of Brassicaceae in Sicily. Acta horticulturae 1005:197-204.

Saatkamp, A., L. Affre, P. Poschlod, P. Roche, U. Deil, and T. Dutoit. 2014. Decrease of plant alpha and beta-diversity with management intensity in vineyards and the influence of landscape context. Ecologia Mediterranea 40(2):17-28.

Salisbury, E. 1961. Weeds and aliens. Collins, London, United Kingdom. 384 pp.

Solida, L., A. Celant, L. Luiselli, D. A. Grasso, A. Mori, and A. Fanfani. 2011. Competition for foraging resources and coexistence of two syntopic species of *Messor* harvester ants in Mediterranean grassland. Ecological Entomology 36(4):409-416.

The Plant List. 2013. The Plant List. Version 1.1. United Nations Decade on Biodiversity, Kew Royal Botanic Gardens, and the Missouri Botanical Garden. Last accessed October 24, 2016, http://www.theplantlist.org/.

Turmo i Gort, F. 2014. *Bunias erucago* photographs. Used with permission from Ferran Turmo i Gort. Photographs published on Flickr.com. Last accessed November 2, 2016, https://www.flickr.com/photos/fturmog/.

Vaughan, J. G., and J. M. Whitehouse. 1971. Seed structure and the taxonomy of the Cruciferae. Botanical Journal of the Linnean Society 64(4):383-409.

Verloove, F. 2006. Catalogue of neophytes in Belgium (1800-2005). National Botanic Garden of Belgium, Meise, Belgium. 89 pp.

Weakley, A. S. 2015. Flora of the Southern and Mid-Atlantic States: Working Draft of 21 May 2015. University of North Carolina Herbarium, North Carolina Botanical Garden, University of North

Carolina at Chapel Hill, Chapel Hill, North Carolina, U.S.A. 1320 pp.

Williams, G. 1982. Elsevier's Dictionary of Weeds of Western Europe. Elsevier Scientific Publishing Company, Amsterdam. 320 pp.

Wilson, J. M. 1852. The Rural Cyclopedia: Or a General Dictionary of Agriculture, and of the Arts, Sciences, Instruments, and Practice, Necessary to the Farmer, Stockfarmer, Gardener, Forester, Landsteward, Farrier, & C. Fullarton and MacNab, Printers, London, United Kingdom. 778 pp.

WSSA. 2016. Composite List of Weeds. Weed Science Society of America (WSSA). Last accessed January 15, 2016, http://wssa.net/weed/composite-list-of-weeds/.

Zhengyi, W., P. H. Raven, and H. Deyuan. 2016. Flora of China. Missouri Botanical Garden Press, St. Louis, Missouri. Last accessed January 12, 2016, http://flora.huh.harvard.edu/china/.

Appendix A. Weed risk assessment for *Bunias erucago* L. (Brassicaceae). Below is all of the evidence and associated references used to evaluate the risk potential of this taxon. We also include the answer, uncertainty rating, and score for each question. The Excel file, where this assessment was conducted, is available upon request.

Question ID	Answer - Uncertainty	Score	Notes (and references)
ESTABLISHMENT/SPREAD POTENTIAL			
ES-1 [What is the taxon's establishment and spread status outside its native range? (a) Introduced elsewhere =>75 years ago but not escaped; (b) Introduced <75 years ago but not escaped; (c) Never moved beyond its native range; (d) Escaped/Casual; (e) Naturalized; (f) Invasive; (?) Unknown]	d - low	0	This species is native to parts of southern Europe (Ančev, 2007; Rollins, 1981; Verloove, 2006), northern Africa, and Turkey (NGRP, 2016). It was introduced to the United Kingdom from Austria in 1640 (Wilson, 1852). *Bunias erucago* is considered to be an alien species "growing spontaneously" in the United Kingdom (Dunn, 1903). It is considered a casual alien that has not escaped from cultivation in Finland (Kurtto and Lahti, 1987). It is listed as a casual alien species in the United Kingdom (Clement and Foster, 2000). Listed as a casual species in Belgium (Verloove, 2006), the Czech Republic (Pysek et al., 2002), and Hungary (Botond and Zoltan, 2004). Lisci and Pacini (1993) list *B. erucago* as an "accidental" species on Italian walls, which is defined as a rare species in a plant community present either by chance or as a relic from a previous community (Allaby, 2012). Bocchieri (1998) lists *B. erucago* as a species no longer found on minor islands of Sardinia. GRIN lists this species as "naturalized elsewhere" (NGRP, 2016). *Bunias erucago* was collected in the United States from Philadelphia, PA, in 1877 and from a field in Prince Edward County, VA, in 1957 and 1959 (Massey, 1960). However, it is unclear if *B. erucago* is still present in these locations. The alternate answers for the uncertainty simulation were both "e."
ES-2 (Is the species highly domesticated)	n - low	0	We found no evidence of breeding programs for *B. erucago*. Even though this plant is consumed in salads in Europe (Di Novella et al., 2013; Romano et al., 2013; Salisbury, 1961), this species is not usually cultivated (GreenPlantSwap, 2016).
ES-3 (Weedy congeners)	y - mod	1	Bailey and Bailey (1976) say there are about six species in the genus *Bunias*, while Mabberley (2008) says there are three. Holm et al. (1979) do not list any of these species as serious or principal weeds. The related species *Bunias orientalis* is native to Asia and has been introduced to Europe, where is has undergone an "explosion in abundance and rapidly became a dominant invasive part of the flora in many countries, including Germany, Czech Republic, Poland, Sweden, Norway, and elsewhere" (Harvey and Gols, 2011). *Bunias orientalis* is a problematic weed in vineyards. It can also invade natural grasslands and then form monotypic stands in this habitat (CABI, 2016). We used moderate uncertainty because *B. orientalis* is a more recent invader and its impacts are still being researched.
ES-4 (Shade tolerant at some stage of its life cycle)	n - low	0	"It cannot grow in the shade" (PFAF, 2016). A gardening website says *B. erucago* grows in full sun to partial shade (Dave's Garden, 2016). The related species *B. orientalis* "does not grow under shaded conditions" (Birnbaum,

Question ID	Answer - Uncertainty	Score	Notes (and references)
			2006). Based on this evidence, we answered no.
ES-5 (Plant a vine or scrambling plant, or forms tightly appressed basal rosettes)	n - negl	0	We found no evidence that *B. erucago* is a vine or has tightly appressed basal rosettes. This species has numerous, spreading branches that incline toward the ground (Wilson, 1852).
ES-6 (Forms dense thickets, patches, or populations)	n - mod	0	We found no information about *B. erucago* forming dense populations.
ES-7 (Aquatic)	n - negl	0	*Bunias erucago* is not an aquatic plant; it is a terrestrial plant in the family Brassicaceae (Massey, 1960).
ES-8 (Grass)	n - negl	0	*Bunias erucago* is not a grass; it is in the family Brassicaceae (formerly Cruciferae) (Massey, 1960).
ES-9 (Nitrogen-fixing woody plant)	n - negl	0	We found no evidence that it fixes nitrogen. *Bunias erucago* is not woody; it is an herbaceous plant (Wilson, 1852). Furthermore, it is not a member of a plant family known to contain nitrogen-fixing species (Martin and Dowd, 1990).
ES-10 (Does it produce viable seeds or spores)	y - negl	1	It can be propagated from seed (Dave's Garden, 2016; PFAF, 2016). Vaughan and Whitehouse (1971) provide illustrations of *B. erucago* seed.
ES-11 (Self-compatible or apomictic)	y - high	1	Knuth and Müller (1906) say *B. erucago* is "self-fertile" in the absence of insects. Based on this evidence, we answered yes, but used high uncertainty because very little information was available on this trait.
ES-12 (Requires specialist pollinators)	n - negl	0	This species is pollinated by bees, flies, and self-pollination (PFAF, 2016). Dave's Garden (2016) says *B. erucago* is "attractive to bees, butterflies and/or birds." *Bunias erucago* is self-fertile, and pollination does not seem to be affected by the absence of insects (Knuth and Müller, 1906). Hochkirch et al. (2012) studied pollinators visiting the related species *Bunias orientalis* and determined that the flowers of this related species were mainly visited by bees. Based on this evidence, we answered no.
ES-13 [What is the taxon's minimum generation time? (a) less than a year with multiple generations per year; (b) 1 year, usually annuals; (c) 2 or 3 years; (d) more than 3 years; or (?) unknown]	b - low	1	*Bunias erucago* is considered a therophyte (Lisci and Pacini, 1993), which is an annual plant that completes its life cycle during favorable conditions and whose seeds then survive harsh periods. It is an annual plant that flowers in June and July in the United Kingdom (Wilson, 1852). In Virginia, it is a biennial that flowers in early May (Massey, 1960). "Annual or biennial" (Bojňanský and Fargašová, 2007; Rollins, 1981). It flowers from February to July in Italy (Lisci and Pacini, 1993). Because some sources list this plant as a biennial, the alternate answers for the uncertainty simulation were both "c."
ES-14 (Prolific seed producer)	? - max	0	Unknown.
ES-15 (Propagules likely to be dispersed unintentionally by people)	? - max	1	While it seems likely that *B. erucago* could be spread by agricultural equipment, we found no direct evidence of this. Thus, we answered unknown.
ES-16 (Propagules likely to disperse in trade as contaminants or hitchhikers)	y - negl	2	Reported to contaminate seed of the forage legume *Onobrychis sativa* (sainfoil) in Europe (Massey, 1960). Spread in grain in the United Kingdom (Clement and Foster, 2000). *Bunias erucago* is thought to have been introduced into Belgium in grain (Verloove, 2006).

Question ID	Answer - Uncertainty	Score	Notes (and references)
			Bunias erucago plants have been found growing near ports, "perhaps introduced with packing material" (Salisbury, 1961). This species thought to have been accidentally introduced into Belgium (Verloove, 2006).
ES-17 (Number of natural dispersal vectors)	1	-2	Fruit and seed descriptions used to answer questions ES-17a through ES-17e: “fruit bur-like 0.8-1 cm long, indurate, indehiscent, 3-4 celled with indurate septa, slender pointed by firm persistent style, surface armed with 4 lines of broad thin teeth or ‘4 winged’” (Massey, 1960). "[D]umbell-shaped fruits that are four-seeded and four-angled with wavy ridges along the angles" (Salisbury, 1961). Seeds are 2 mm in length, smooth, oval in shape, and light brown to orange (Vaughan and Whitehouse, 1971).
ES-17a (Wind dispersal)	n - mod		We did not find any evidence of *B. erucago* being spread by wind. *Bunias erucago* is a barochorous species, which means seeds lack an apparent dispersal mechanism to move seeds away from the mother plant (Benvenuti, 2007). Lisci and Pacini (1993) list the seed dispersal method for *B. erucago* as unknown.
ES-17b (Water dispersal)	n - mod		We did not find any evidence of *B. erucago* being spread by water. *Bunias erucago* is a barochorous species and seeds do not have any apparent dispersal mechanism to move away from the mother plant (Benvenuti, 2007).
ES-17c (Bird dispersal)	n - mod		We did not find any evidence of *B. erucago* being spread by birds, and the fruit are not fleshy. Seeds do not have any apparent dispersal mechanism to move away from the mother plant (Benvenuti, 2007).
ES-17d (Animal external dispersal)	y - mod		*Bunias erucago* seeds are collected by *Messor minor* seed-harvester ants in Italy (Solida et al., 2011).
ES-17e (Animal internal dispersal)	n - mod		We did not find any evidence of *B. erucago* being spread internally by animals. Seeds do not have any apparent dispersal mechanism to move away from the mother plant (Benvenuti, 2007).
ES-18 (Evidence that a persistent (>1yr) propagule bank (seed bank) is formed)	? - max	0	*Bunias erucago* is a pseudo-serotinous species, which means seeds are retained on the plant for a prolonged period in a dormant state (Benvenuti, 2007). However, because we did not find any specific information about how long the seeds remain dormant, we answered unknown.
ES-19 (Tolerates/benefits from mutilation, cultivation or fire)	n - mod	-1	We did not find any evidence of *B. erucago* benefiting from mutilation or cultivation. Thus, we answered no.
ES-20 (Is resistant to some herbicides or has the potential to become resistant)	n - low	0	We found no evidence that *B. erucago* has developed weed resistance. It is not listed by Heap (2016).
ES-21 (Number of cold hardiness zones suitable for its survival)	8	0	
ES-22 (Number of climate types suitable for its survival)	8	2	
ES-23 (Number of precipitation bands suitable for its survival)	11	1	
IMPACT POTENTIAL			
General Impacts			

Question ID	Answer - Uncertainty	Score	Notes (and references)
Imp-G1 (Allelopathic)	? - max		Unknown.
Imp-G2 (Parasitic)	n - negl	0	We found no evidence that *B. erucago* is a parasitic plant; it is in the family Brassicaceae, which is not known to contain parasitic plants (Heide-Jørgensen, 2008; Nickrent, 2009).
Impacts to Natural Systems			
Imp-N1 (Changes ecosystem processes and parameters that affect other species)	n - low	0	We did not find any information about *B. erucago* impacting natural areas; this species mainly grows in disturbed areas (Weakley, 2015). Thus, we used low, rather than moderate, uncertainty for questions Imp-N1 through Imp-N6.
Imp-N2 (Changes habitat structure)	n - low	0	We did not find any information about *B. erucago* having this impact in natural areas.
Imp-N3 (Changes species diversity)	n - low	0	We did not find any information about *B. erucago* having this impact in natural areas.
Imp-N4 (Is it likely to affect federal Threatened and Endangered species?)	n - low	0	We did not find any information about *B. erucago* impacting natural areas; thus, it is unlikely that *B. erucago* would negatively impact Threatened or Endangered species.
Imp-N5 (Is it likely to affect any globally outstanding ecoregions?)	n - low	0	We did not find any information about *B. erucago* impacting natural areas; thus, it is unlikely that *B. erucago* would negatively impact globally outstanding ecoregions.
Imp-N6 [What is the taxon's weed status in natural systems? (a) Taxon not a weed; (b) taxon a weed but no evidence of control; (c) taxon a weed and evidence of control efforts]	a - low	0	Because we did not find any information about *B. erucago* having impacts in natural areas, we answered "a" with low uncertainty. The alternate answers for the uncertainty simulation were both "b."
Impact to Anthropogenic Systems (cities, suburbs, roadways)			
Imp-A1 (Negatively impacts personal property, human safety, or public infrastructure)	n - low	0	We did not find any information about *B. erucago* having any impacts in urban and suburban areas. We used low uncertainty because it is an herbaceous plant (Wilson, 1852) that is unlikely to have these impacts.
Imp-A2 (Changes or limits recreational use of an area)	n - low	0	We did not find any information about *B. erucago* having any impacts in urban and suburban areas. We used low uncertainty because it is an herbaceous plant (Wilson, 1852) that is unlikely to have these impacts.
Imp-A3 (Affects desirable and ornamental plants, and vegetation)	n - mod	0	We did not find any information about *B. erucago* having any impacts in urban and suburban areas.
Imp-A4 [What is the taxon's weed status in anthropogenic systems? (a) Taxon not a weed; (b) Taxon a weed but no evidence of control; (c) Taxon a weed and evidence of control efforts]	a - low	0	*Bunias erucago* is found growing on the walls of Italian towns (Lisci and Pacini, 1993) and occurs in "human-made habitats" in the Czech Republic (Pysek et al., 2002), but we did not find any evidence that it has any negative impacts at these locations. Thus, we answered "a" with low uncertainty. The alternate answers for the uncertainty simulation were both "b."
Impact to Production Systems (agriculture, nurseries, forest plantations, orchards, etc.)			
Imp-P1 (Reduces crop/product yield)	n - high	0	Even though *B. erucago* is considered to be a weed of crops in Europe (Massey, 1960), we did not find any specific information about reductions in crop yield. Thus, we answered no but used high uncertainty.
Imp-P2 (Lowers commodity value)	n - high	0	We did not find any specific information about *B. erucago* lowering commodity value.

Question ID	Answer - Uncertainty	Score	Notes (and references)
Imp-P3 (Is it likely to impact trade?)	? - max		*Bunias erucago* is a seed and grain contaminant (Clement and Foster, 2000; Massey, 1960; Verloove, 2006). The related species *B. orientalis* is listed as a harmful organism by China (APHIS, 2016). It is unclear if our trading partners would take action against *B. erucago*. Thus, we answered unknown.
Imp-P4 (Reduces the quality or availability of irrigation, or strongly competes with plants for water)	n - mod	0	We did not find any information about *B. erucago* having this impact.
Imp-P5 (Toxic to animals, including livestock/range animals and poultry)	n - mod	0	We did not find any information about *B. erucago* being toxic to animals. It is not listed by Burrows and Tyrl (2001). *Bunias erucago* is consumed by humans in parts of Europe (Di Novella et al., 2013; Dolina and Łuczaj, 2014; Luczaj and Dolina, 2015; Romano et al., 2013; Salisbury, 1961).
Imp-P6 [What is the taxon's weed status in production systems? (a) Taxon not a weed; (b) Taxon a weed but no evidence of control; (c) Taxon a weed and evidence of control efforts]	b - low	0.2	It is considered a weed of crops in central Europe (Massey, 1960). It is a weed of fields, fallows, and vineyards in Poland and Romania (Bojňanský and Fargašová, 2007). *Bunias erucago* is a weed "only of minor importance" in parts of Europe (Williams, 1982). It is a weed of cereal crops and vineyards in France (Saatkamp et al., 2014), and is common in cultivated fields in France (Francois, 1929; Francois, 1941). We found no evidence of this plant being controlled in production systems. Based on this information, we answered "b" with low uncertainty. The alternate answers for the uncertainty simulation were both "c."
GEOGRAPHIC POTENTIAL			Unless otherwise indicated, the following evidence represents geographically referenced points obtained from the Global Biodiversity Information Facility (GBIF, 2016).
Plant hardiness zones			
Geo-Z1 (Zone 1)	n - low	N/A	We did not find any evidence of *B. erucago* occurring in this plant hardiness zone.
Geo-Z2 (Zone 2)	n - mod	N/A	We did not find any evidence of *B. erucago* occurring in this plant hardiness zone.
Geo-Z3 (Zone 3)	n - high	N/A	We did not find any evidence of *B. erucago* occurring in this plant hardiness zone.
Geo-Z4 (Zone 4)	y - low	N/A	A couple of points in Austria and France.
Geo-Z5 (Zone 5)	y - low	N/A	A couple of points in France and Germany.
Geo-Z6 (Zone 6)	y - negl	N/A	Multiple points in Germany and Austria. A gardening website reports *B. erucago* is hardy from to this zone (Dave's Garden, 2016).
Geo-Z7 (Zone 7)	y - negl	N/A	Numerous points in Greece, Germany, and France. A gardening website reports *B. erucago* is hardy to this zone (Dave's Garden, 2016).
Geo-Z8 (Zone 8)	y - negl	N/A	Numerous points in Greece, France, and Spain. A gardening website reports *B. erucago* is hardy to this zone (Dave's Garden, 2016).
Geo-Z9 (Zone 9)	y - negl	N/A	Numerous points in Greece, France, and Spain. A gardening website reports *B. erucago* is hardy to this zone (Dave's Garden, 2016).

Question ID	Answer - Uncertainty	Score	Notes (and references)
Geo-Z10 (Zone 10)	y - negl	N/A	Numerous points in France and a few points in Portugal. A gardening website reports *B. erucago* is hardy to this zone (Dave's Garden, 2016).
Geo-Z11 (Zone 11)	y - negl	N/A	Multiple points in Greece.
Geo-Z12 (Zone 12)	n - high	N/A	We did not find any evidence of *B. erucago* occurring in this plant hardiness zone.
Geo-Z13 (Zone 13)	n - mod	N/A	We did not find any evidence of *B. erucago* occurring in this plant hardiness zone.
Köppen -Geiger climate classes			
Geo-C1 (Tropical rainforest)	n - mod	N/A	We did not find any evidence of *B. erucago* occurring in this climate class.
Geo-C2 (Tropical savanna)	n - mod	N/A	We did not find any evidence of *B. erucago* occurring in this climate class.
Geo-C3 (Steppe)	y - negl	N/A	Multiple points in Greece.
Geo-C4 (Desert)	n - mod	N/A	We did not find any evidence of *B. erucago* occurring in this climate class.
Geo-C5 (Mediterranean)	y - negl	N/A	Numerous points in France.
Geo-C6 (Humid subtropical)	y - negl	N/A	Multiple points in Greece, Croatia, and Italy.
Geo-C7 (Marine west coast)	y - negl	N/A	Numerous points in France.
Geo-C8 (Humid cont. warm sum.)	y - low	N/A	A few points in Greece.
Geo-C9 (Humid cont. cool sum.)	y - negl	N/A	Multiple points in Greece, Germany, and Austria.
Geo-C10 (Subarctic)	y - negl	N/A	Numerous points in France.
Geo-C11 (Tundra)	y - negl	N/A	Multiple points in Switzerland and France.
Geo-C12 (Icecap)	n - high	N/A	We did not find any evidence of *B. erucago* occurring in this climate class.
10-inch precipitation bands			
Geo-R1 (0-10 inches; 0-25 cm)	y - mod	N/A	A couple of points in Spain.
Geo-R2 (10-20 inches; 25-51 cm)	y - negl	N/A	Numerous points in Spain.
Geo-R3 (20-30 inches; 51-76 cm)	y - negl	N/A	Numerous points in France and Spain.
Geo-R4 (30-40 inches; 76-102 cm)	y - negl	N/A	Numerous points in France.
Geo-R5 (40-50 inches; 102-127 cm)	y - negl	N/A	Numerous points in France.
Geo-R6 (50-60 inches; 127-152 cm)	y - negl	N/A	Multiple points in Greece and Germany.
Geo-R7 (60-70 inches; 152-178 cm)	y - negl	N/A	Multiple points in France, Germany, and Austria.
Geo-R8 (70-80 inches; 178-203 cm)	y - low	N/A	A couple of points in Germany and one in Austria.
Geo-R9 (80-90 inches; 203-229 cm)	y - mod	N/A	One point in Germany and one in Austria.
Geo-R10 (90-100 inches; 229-254 cm)	y - high	N/A	One point in Switzerland.
Geo-R11 (100+ inches; 254+ cm)	y - high	N/A	One point in Switzerland.
ENTRY POTENTIAL			
Ent-1 (Plant already here)	n - high	0	The only records of *Bunias erucago* in North America are specimens collected from Philadelphia, PA, in 1877 and from a field in Prince Edward County, VA, in 1957 and 1959 (Massey, 1960). However, it is unclear if *B. erucago* is still present in these locations. However, it is unclear if *B. erucago* is still present in these locations. We answered no to this question so we could further examine pathways

Question ID	Answer - Uncertainty	Score	Notes (and references)
			of entry for *B. erucago*.
Ent-2 (Plant proposed for entry, or entry is imminent)	n - mod	0	We found no evidence that *B. erucago*'s entry is imminent.
Ent-3 (Human value & cultivation/trade status)	c - high	0.25	In Europe, *B. erucago* is eaten in salads (Di Novella et al., 2013; Romano et al., 2013; Salisbury, 1961) and as a cooked vegetable (Dolina and Łuczaj, 2014; Luczaj and Dolina, 2015). The Plants For A Future database provides cultivation information for this species (PFAF, 2016). However, we did not find any retailers selling this species. Based on this limited evidence, we answered "c," but used high uncertainty because we only found very limited evidence of cultivation. The alternate answers for our uncertainty simulation were both "b."
Ent-4 (Entry as a contaminant)			
Ent-4a (Plant present in Canada, Mexico, Central America, the Caribbean or China)	n - mod		We checked several databases (e.g., GBIF, 2016; NGRP, 2016; NRCS, 2016; Zhengyi et al., 2016) and found no evidence that *B. erucago* is present in these areas.
Ent-4b (Contaminant of plant propagative material (except seeds))	? - max		Unknown.
Ent-4c (Contaminant of seeds for planting)	y - low	0.04	Reported to contaminate seed of the forage legume *Onobrychis sativa* (sainfoil) in Europe (Massey, 1960).
Ent-4d (Contaminant of ballast water)	n - mod	0	We found no evidence of *B. erucago* contaminating this pathway.
Ent-4e (Contaminant of aquarium plants or other aquarium products)	n - low	0	We found no evidence of *B. erucago* contaminating aquarium products.
Ent-4f (Contaminant of landscape products)	? - max		Unknown.
Ent-4g (Contaminant of containers, packing materials, trade goods, equipment or conveyances)	? - max		*Bunias erucago* plants have been found growing near ports, "perhaps introduced with packing material" (Salisbury, 1961). However, because the author of this quote is speculating, we answered unknown.
Ent-4h (Contaminants of fruit, vegetables, or other products for consumption or processing)	y - low	0.01	It has spread in grain in the United Kingdom (Clement and Foster, 2000). *Bunias erucago* is thought to have been introduced into Belgium in grain (Verloove, 2006).
Ent-4i (Contaminant of some other pathway)	a - mod	0	We did not find any information about additional pathways for *B. erucago*.
Ent-5 (Likely to enter through natural dispersal)	n - mod	0	Because the seeds do not have any apparent dispersal mechanism to move away from the mother plant (Benvenuti, 2007), *B. erucago* is unlikely to enter the United States through natural dispersal.