

**SPECIES: *Cardaria* spp.**

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**INTRODUCTORY**

**SPECIES:** *Cardaria* spp.

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Heart-podded hoary cress  
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Heart-podded hoary cress  
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**AUTHORSHIP AND CITATION:**

Zouhar, Kris. 2004. *Cardaria* spp. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: <http://www.fs.fed.us/database/feis/> [2007, September 24].

**FEIS ABBREVIATION:**

CARSPP  
CARCHA  
CARDRA  
CARPUB

**SYNONYMS:**

*Lepidium draba* L. (= *Cardaria draba* L. (Desv.)) [46]

**NRCS PLANT CODE [98]:**

CARDA2

CACH10  
CADR  
CAPU6

**COMMON NAMES:**

hoary cress  
globe-pod hoarycress  
hairy whitetop  
heart-pod hoarycress  
lens-pod hoarycress  
lenspod whitetop  
whitetop

**TAXONOMY:**

The currently accepted genus name for hoary cress is *Cardaria* Desv. (Brassicaceae) [44]. This review summarizes available information on the following hoary cress species:

*Cardaria chalapensis* (L.) Hand.-Maz. [30,33,41,44,44] lens-podded hoary cress  
*Cardaria draba* L. (Desv.) [30,33,43,44,44,45,53,58,101] heart-podded hoary cress  
*Cardaria pubescens* (C.A. Mey.) Jarm. [30,33,44,44,45,53,101] globe-podded hoary cress

For the purpose of this review, "hoary cress" refers to all 3 species, while individual species will be referred to by the common names given above.

Hybridization between heart-podded and lens-podded hoary cress occurs where the 2 species grow together in southern Alberta. There are no known natural hybrids between globe-podded hoary cress and either heart-podded or lens-podded hoary cress [66,67].

**LIFE FORM:**

Forb

**FEDERAL LEGAL STATUS:**

No special status

**OTHER STATUS:**

As of this writing (2004), hoary cress is listed as a noxious weed or weed seed in 17 U.S. states and 3 Canadian provinces [44,99]. See the [Plants](#), [Invaders](#), or [APHIS](#) databases or individual state and provincial noxious weed lists for more information.

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## DISTRIBUTION AND OCCURRENCE

**SPECIES:** *Cardaria* spp.

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#### GENERAL DISTRIBUTION:

Hoary cress is native to southwestern Asia and has been introduced to every continent except Antarctica [66]. There is evidence that all 3 species were introduced to many locations in North America as contaminants in alfalfa (*Medicago sativa*) seed from Turkestan in the early 1900s up until around 1922 [35,67]. Turkestan alfalfa and its associated weeds are more common in the West because this type of alfalfa did not grow well in the more humid regions of the east [35]. [Plants database](#) provides a distributional map of hoary cress and the 3 individual species.

Lens-podded hoary cress is native to Kazakhstan, Uzbekistan, and Turkmenistan, and also occurs (but is likely not native) in Pakistan, northern India, Afghanistan, Iran, Iraq, Syria, and Israel. It has been introduced to England, Argentina, and North America. Lens-podded hoary cress was 1st collected in the U.S. in California, in 1918 and in Alberta, Canada, in 1926 [67]. It is a common field weed in central and western Canada and the U.S., but is rare in eastern North America [67,98]. Lens-podded hoary cress is most invasive of the 3 hoary cress species in Canada, particularly in irrigated areas of Saskatchewan, Alberta, and British Columbia [66].

The 1900s was not the earliest introduction of heart-podded hoary cress to North America. It was probably initially introduced by early American settlers from Europe, possibly as an ornamental or garden plant. It was collected in 1862 on Long Island, New York, and in 1878 in Ontario [35]. It was likely introduced multiple times and from other places since then [67]. Heart-podded hoary cress is native to the Balkan Peninsula, Georgia, Armenia, Azerbaijan, Turkmenistan, Kazakhstan, southern Russia, Turkey, Israel, Syria, Iraq, and Iran. Heart-podded hoary cress is the least abundant of the hoary cresses in Canada, where it occurs primarily in southern Manitoba and southern Alberta [66]. It occurs throughout the U.S. except in southern portions of California (Mojave and Colorado deserts) and the south-central states [20,60]. It appears to be most invasive in big sagebrush (*Artemisia tridentata*) ecosystems in eastern Oregon, where it occupies >100,000 ha ([64] and references therein).

Globe-podded hoary cress is native to Kazakhstan, Uzbekistan, Turkmenistan, northern Iran, and Afghanistan, and can be found in Argentina and North America. It is a common weed in central and western Canada and the U. S., but is rare in eastern North America. It was 1st collected in the U.S. in Michigan in 1919, and in Alberta, Canada in 1926 [67]. Globe-podded hoary cress occurs in the same areas as lens-podded hoary cress and is frequently associated with it in Canada and the U.S. [66].

Hoary cress is primarily a weed of agricultural lands and disturbed sites such as roadsides and railways. Reports of its occurrence in wildlands or rangelands are rare. The following biogeographic classification systems are presented to demonstrate where hoary cress might be present or invasive, based on reported occurrence and biological tolerance to factors likely to limit its distribution. Precise distribution information is unavailable. Therefore, these lists are speculative and not exhaustive, and hoary cress may be present and possibly invasive in other vegetation types.

#### ECOSYSTEMS [29]:

FRES15 Oak-hickory  
 FRES17 Elm-ash-cottonwood  
 FRES19 Aspen-birch  
 FRES20 Douglas-fir  
 FRES21 Ponderosa pine  
 FRES28 Western hardwoods  
 FRES29 Sagebrush  
 FRES32 Texas savanna  
 FRES33 Southwestern shrubsteppe  
 FRES34 Chaparral-mountain shrub  
 FRES35 Pinyon-juniper

FRES36 Mountain grasslands  
 FRES37 Mountain meadows  
 FRES38 Plains grasslands  
 FRES39 Prairie  
 FRES41 Wet grasslands  
 FRES42 Annual grasslands

STATES/PROVINCES: ([key to state/province abbreviations](#))

lens-podded hoary cress:

**UNITED STATES**

CA	CO	ID	IN	IA	KS	MO	MT	NE	NV
NM	ND	OR	SD	UT	WA	WY			

**CANADA**

AB	BC	MB	ON	SK
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heart-podded hoary cress:

**UNITED STATES**

AZ	CA	CO	CT	DE	ID	IL	IN	IA	KS
KY	ME	MD	MA	MI	MN	MO	MT	NE	NV
NJ	NM	NY	ND	OH	OK	OR	PA	RI	SD
TX	UT	VT	VA	WA	WV	WI	WY		

**CANADA**

AB	BC	MB	NS	ON	PQ	SK
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globe-podded hoary cress:

**UNITED STATES**

AZ	CA	CO	ID	KS	MI	MO	MT	NE	NV
ND	OR	PA	UT	WA	WI	WY			

**CANADA**

AB	BC	MB	SK
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BLM PHYSIOGRAPHIC REGIONS [[10](#)]:

- 1 Northern Pacific Border
- 2 Cascade Mountains
- 3 Southern Pacific Border
- 4 Sierra Mountains
- 5 Columbia Plateau
- 6 Upper Basin and Range
- 8 Northern Rocky Mountains
- 9 Middle Rocky Mountains
- 10 Wyoming Basin
- 11 Southern Rocky Mountains
- 12 Colorado Plateau
- 13 Rocky Mountain Piedmont
- 14 Great Plains

15 Black Hills Uplift

16 Upper Missouri Basin and Broken Lands

KUCHLER [51] PLANT ASSOCIATIONS:

K010 Ponderosa shrub forest

K011 Western ponderosa forest

K016 Eastern ponderosa forest

K017 Black Hills pine forest

K018 Pine-Douglas-fir forest

K019 Arizona pine forest

K023 Juniper-pinyon woodland

K024 Juniper steppe woodland

K025 Alder-ash forest

K026 Oregon oakwoods

K028 Mosaic of K002 and K026

K030 California oakwoods

K031 Oak-juniper woodland

K032 Transition between K031 and K037

K034 Montane chaparral

K036 Mosaic of K030 and K035

K037 Mountain-mahogany-oak scrub

K038 Great Basin sagebrush

K047 Fescue-oatgrass

K048 California steppe

K049 Tule marshes

K050 Fescue-wheatgrass

K051 Wheatgrass-bluegrass

K052 Alpine meadows and barren

K055 Sagebrush steppe

K056 Wheatgrass-needlegrass shrubsteppe

K063 Foothills prairie

K064 Grama-needlegrass-wheatgrass

K065 Grama-buffalo grass

K066 Wheatgrass-needlegrass

K067 Wheatgrass-bluestem-needlegrass

K068 Wheatgrass-grama-buffalo grass

K069 Bluestem-grama prairie

K070 Sandsage-bluestem prairie

K074 Bluestem prairie

K075 Nebraska Sandhills prairie

K079 Palmetto prairie

K081 Oak savanna

K098 Northern floodplain forest

K101 Elm-ash forest

SAF COVER TYPES [26]:

14 Northern pin oak

16 Aspen

39 Black ash-American elm-red maple

42 Bur oak

62 Silver maple-American elm

63 Cottonwood

95 Black willow

- 109 Hawthorn
- 210 Interior Douglas-fir
- 211 White fir
- 217 Aspen
- 220 Rocky Mountain juniper
- 222 Black cottonwood-willow
- 233 Oregon white oak
- 235 Cottonwood-willow
- 236 Bur oak
- 237 Interior ponderosa pine
- 238 Western juniper
- 239 Pinyon-juniper
- 240 Arizona cypress
- 246 California black oak
- 249 Canyon live oak
- 250 Blue oak-foothills pine
- 255 California coast live oak

SRM (RANGELAND) COVER TYPES [\[89\]](#):

- 101 Bluebunch wheatgrass
- 102 Idaho fescue
- 103 Green fescue
- 104 Antelope bitterbrush-bluebunch wheatgrass
- 105 Antelope bitterbrush-Idaho fescue
- 107 Western juniper/big sagebrush/bluebunch wheatgrass
- 109 Ponderosa pine shrubland
- 110 Ponderosa pine-grassland
- 201 Blue oak woodland
- 202 Coast live oak woodland
- 203 Riparian woodland
- 209 Montane shrubland
- 210 Bitterbrush
- 214 Coastal prairie
- 215 Valley grassland
- 217 Wetlands
- 301 Bluebunch wheatgrass-blue grama
- 302 Bluebunch wheatgrass-Sandberg bluegrass
- 303 Bluebunch wheatgrass-western wheatgrass
- 304 Idaho fescue-bluebunch wheatgrass
- 305 Idaho fescue-Richardson needlegrass
- 306 Idaho fescue-slender wheatgrass
- 307 Idaho fescue-threadleaf sedge
- 309 Idaho fescue-western wheatgrass
- 310 Needle-and-thread-blue grama
- 311 Rough fescue-bluebunch wheatgrass
- 312 Rough fescue-Idaho fescue
- 314 Big sagebrush-bluebunch wheatgrass
- 315 Big sagebrush-Idaho fescue
- 316 Big sagebrush-rough fescue
- 317 Bitterbrush-bluebunch wheatgrass
- 318 Bitterbrush-Idaho fescue
- 319 Bitterbrush-rough fescue
- 320 Black sagebrush-bluebunch wheatgrass

321 Black sagebrush-Idaho fescue  
322 Curlleaf mountain-mahogany-bluebunch wheatgrass  
323 Shrubby cinquefoil-rough fescue  
324 Threetip sagebrush-Idaho fescue  
401 Basin big sagebrush  
402 Mountain big sagebrush  
403 Wyoming big sagebrush  
404 Threetip sagebrush  
405 Black sagebrush  
406 Low sagebrush  
407 Stiff sagebrush  
408 Other sagebrush types  
409 Tall forb  
411 Aspen woodland  
412 Juniper-pinyon woodland  
413 Gambel oak  
415 Curlleaf mountain-mahogany  
416 True mountain-mahogany  
417 Littleleaf mountain-mahogany  
418 Bigtooth maple  
419 Bittercherry  
420 Snowbrush  
421 Chokecherry-serviceberry-rose  
422 Riparian  
509 Transition between K031 and K037  
601 Bluestem prairie  
604 Bluestem-grama prairie  
605 Sandsage prairie  
606 Wheatgrass-bluestem-needlegrass  
607 Wheatgrass-needlegrass  
608 Wheatgrass-grama-needlegrass  
609 Wheatgrass-grama  
610 Wheatgrass  
611 Blue grama-buffalo grass  
612 Sagebrush-grass  
613 Fescue grassland  
614 Crested wheatgrass  
615 Wheatgrass-saltgrass-grama  
710 Bluestem prairie  
714 Grama-bluestem  
801 Savanna  
802 Missouri prairie  
803 Missouri glades  
804 Tall fescue  
805 Riparian

#### HABITAT TYPES AND PLANT COMMUNITIES:

In North America, hoary cress is most commonly found in grainfields, hayfields, and on roadsides. In many areas where alfalfa is or has been grown, especially in western North America, any of the 3 hoary cress species may occur with Russian knapweed (*Acroptilon repens*) and other nonnative species that were imported as contaminants of Turkestan alfalfa seed in the early 1900s [35]. Movement of hoary cress from cultivated fields to adjacent rangelands is a concern and is apparently becoming more common [60].

In Saskatchewan, lens-podded and globe-podded hoary cress are found in brome (*Bromus* spp.) and alfalfa fields and in other areas of disturbance such as gardens, feed lots, and along watercourses. These 2 species have also been found on native grassland sites dominated by western wheatgrass (*Pascopyrum smithii*). Silver sagebrush (*A. cana*), black greasewood (*Sarcobatus vermiculatus*), Nuttall's saltbush (*Atriplex nuttallii*), rose (*Rosa* spp.), and western snowberry (*Symphoricarpos occidentalis*) may also be present [85,86].

According to Miller and others [64], heart-podded hoary cress migrates from cultivated fields to adjacent semiarid upland sites dominated by big sagebrush communities in eastern Oregon, where it may be found in many seral stages. It is apparently well-adapted to sites with relatively dry, shallow soil that are dominated by Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) and crested wheatgrass (*Agropyron cristatum*). Bluebunch wheatgrass (*Pseudoroegneria spicata*) and Thurber needlegrass (*Achnatherum thurberianum*) may also occur. Heart-podded hoary cress is also found on sites dominated by basin big sagebrush (*Artemisia tridentata* ssp. *tridentata*) and crested wheatgrass, where basin wildrye (*Leymus cinereus*) may also occur. Heart-podded hoary cress is found in communities seeded to desert wheatgrass (*Agropyron desertorum*) and crested wheatgrass [64].

Heart-podded hoary cress was common on study sites in southwestern Montana that were dominated by antelope bitterbrush (*Purshia tridentata*), rough fescue (*Festuca altaica*) and/or bluebunch wheatgrass, and spotted knapweed (*Centaurea maculosa*) [37].

Along the middle Snake River in Idaho, heart-podded hoary cress is found in transitional grass-shrub communities with species such as saltgrass (*Distichlis spicata*), cheatgrass (*B. tectorum*), beardless wildrye (*L. triticoides*), Wood's rose (*Rosa woodsii*), western poison-ivy (*Toxicodendron rydbergii*), fragrant sumac (*Rhus aromatica*), and weedy forbs such as summer-cypress (*Kochia scoparia*) and Russian-thistle (*Salsola kali*) [23].

Near Utah Lake, heart-podded hoary cress is found in 6- to 9.6-year-old saltcedar (*Tamarix ramosissima*) communities with saltgrass, summer-cypress, povertyweed (*Iva axillaris*), rabbitfoot-grass (*Polypogon monspeliensis*), and spear saltbush (*Atriplex patula*) [13,14].

Pyke [76] lists globe-podded hoary cress among those nonnative plants that are highly invasive and competitive in sagebrush (*Artemisia* spp.) ecosystems in the Intermountain West. In Nevada, globe-podded hoary cress also occurs in communities dominated by willow (*Salix* spp.), sagebrush, and pinyon-juniper (*Pinus-Juniperus* spp.) [45].

Along the Bighorn River in Wyoming, nonnative, invasive plants such as globe-podded hoary cress, Russian knapweed, and Canada thistle (*Cirsium arvense*) often dominate herbaceous cover in shrublands associated with saltcedar (*T. chinensis*), but are generally rare in native shrublands. In open portions of native woodland that have been disturbed by fire and/or grazed by livestock, globe-podded hoary cress, halogeton (*Halogeton glomeratus*), and Russian-thistle are sometimes locally abundant. These native shrublands are dominated by species such as sandbar willow (*S. exigua*), skunkbush sumac (*Rhus trilobata*), rubber rabbitbrush (*Chrysothamnus nauseosus*), big sagebrush, black greasewood, western snowberry, and Wood's rose [1].

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## BOTANICAL AND ECOLOGICAL CHARACTERISTICS

**SPECIES:** *Cardaria* spp.

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- [RAUNKIAER LIFE FORM](#)
- [REGENERATION PROCESSES](#)
- [SITE CHARACTERISTICS](#)
- [SUCCESSIONAL STATUS](#)
- [SEASONAL DEVELOPMENT](#)

## GENERAL BOTANICAL CHARACTERISTICS:

The following description of hoary cress provides characteristics that may be relevant to fire ecology, and is not meant for identification. Keys for identification are available (e.g. [33,41,44,53]). Correct identification of hoary cress is important if control strategies are planned. Plants that may be mistaken for hoary cress include field pennycress (*Thlapsi arvense*) and western yarrow (*Achillea millefolium*) [60].

The following general description of hoary cress is based on several sources [20,41,44,67], unless otherwise cited. Characteristics may vary between species, and observations in Alberta suggest some variation within species, especially among strains of lens-podded hoary cress, in leaf size and shape, spreading ability, and stand density [87]. Similarly, in California, Bellue [9] noted variation in leaf shape in heart-podded hoary cress and lens-podded hoary cress, but not in globe-podded hoary cress.

## Morphology:

Hoary cress is a perennial forb with a spreading root system from which many aerial shoots, 6 to 24 inches tall (15-60 cm), are produced. Stems are variously described as anywhere from "sprawling" to erect [20,34,44,67], and 2 sources indicate that heart-podded hoary cress plants lodge as they age [9,52]. Hoary cress stems are described as "stoutish," and may be sparsely to densely pubescent [67].

Hoary cress leaves are about 0.5 to 4 inches long (1-10 cm), and 0.1 to 1.4 inches (0.3-3.5 cm) wide. Basal leaves form a rosette, tend to be more slender but larger than stem leaves, and narrow into a short petiole. Upper leaves clasp the stem. Hoary cress inflorescence is composed of numerous small flowers with petals about 0.1 inch (3 mm) long. Inflorescences are generally elongate with spreading to shortened corymbs on 1 to several flowering branches.

The fruits are silicles. The primary difference between hoary cress species is in the shape of the silicle or seed pod, as indicated by the descriptive common names: lens-podded, heart-podded, and globe-podded. Mature fruits of lens-podded hoary cress are glabrous, indehiscent, and about 2 to 6 mm long and 4 to 6 mm wide with 1 to 4 seeds. Mature fruits of heart-podded hoary cress are about 2 mm long and 1.5 mm wide, with 1 to 2 seeds in each half. Heart-podded hoary cress seeds are mucilaginous when wet, which helps them stick to the soil surface and aids germination under low moisture conditions. Fruits of globe-podded hoary cress are indehiscent, 3 to 4.5 mm long and 2.5 to 4.5 mm wide, and frequently seedless or with 1 to 2 (rarely 3-4) seeds [48,60].

Root systems of all 3 hoary cress species consist of deeply penetrating vertical and lateral roots with thick, corky bark, large food reserves, and numerous underground buds from which rhizomes and aboveground shoots arise [28,66,84,91]. Established plants appear to readily sequester resources via these extensive root systems, and thus have low rates of shoot mortality [54].

A study in northeastern Oregon in big sagebrush communities found the majority of heart-podded hoary cress biomass is below ground (76%). The large proportion of biomass allocation to roots (44%) and rhizomes (56%) gives heart-podded hoary cress a highly competitive root system with a large pool of stored carbon, large numbers of belowground meristems, and access to deep soil water [64].

Selleck [86] studied root systems of the 3 hoary cress species under controlled conditions. Heart-podded hoary cress roots commonly penetrated 29 to 32 inches (74-81 cm) into the soil and were occasionally as deep as 5 feet (1.6 m). Along the South Saskatchewan River, globe-podded hoary cress roots were traced vertically to a depth of 18.5 feet (5.6 m), at which depth the rootlets became too delicate to follow [85]. According to Sterling [91] hoary cress roots can penetrate to depths of 12 to 30 feet (4-9 m). Frazier [28] describes vertical roots of heart-podded hoary cress that reached a depth of 10 to 12 feet (3-4 m) by the end of the 2nd growing season. Miller and others [64] observed roots and rhizomes of heart-podded hoary cress at a depth of 4 feet (120 cm), although the majority of the root biomass was located in the upper 8 inches (20 cm). Rhizomes were more evenly distributed throughout the upper 24 inches (60 cm) of the soil profile.

Permanent lateral roots of hoary cress occur most commonly in the upper 7 inches (18 cm) of soil, but can occur at any depth. Stem buds can develop on any part of the permanent root system and give rise to leafy shoots (if at

the ground line) or to rhizomes (if below ground), which in turn give rise to leafy shoots [28,84,91].

Hoary cress has no known mycorrhizal associations [66,73].

### Stand structure:

Populations of all 3 hoary cress species tend to spread by vegetative reproduction more than by seed, resulting in scattered, sometimes dense patches [20,54,84,85]. In Saskatchewan, infestations of lens-podded and globe-podded hoary cress, growing in competition with western wheatgrass and shrubs, were characterized by scattered, dense patches with densities exceeding 100 shoots per m<sup>2</sup> only once, and rarely exceeding 50 shoots per m<sup>2</sup> [86].

Without competition heart-podded hoary cress produced larger, denser stands than either lens-podded or globe-podded hoary cress in Alberta [87]. In Wyoming big sagebrush communities in northeastern Oregon, shoot densities of established heart-podded hoary cress populations varied annually. Densities increased with early-season cool, dry periods followed by warmer, wetter conditions; and decreased with frost or drought damage. Measured changes in shoot density did not indicate an expansion or contraction of heart-podded hoary cress populations [54]. McInnis and others [60] observed an average of 45 shoots per ft<sup>2</sup> (484 shoots/m<sup>2</sup>) on a site fully occupied by heart-podded hoary cress in eastern Oregon.

### Life span:

Heart-podded hoary cress plants sampled in lower Michigan and near Eureka, Illinois, had clearly demarcated growth rings in root sections that were used to determine the age of the plants. Most individuals were relatively young (2-4 years old), but individuals up to 8 years old were occasionally found [22].

### Allelopathy:

Heart-podded hoary cress plants contain phytotoxic chemicals that may inhibit germination and initial seedling growth of other plants in natural environments. Water extracts of dried heart-podded hoary cress roots reduced germination rate of winter wheat (*Triticum aestivum*), alfalfa, crested wheatgrass, bluebunch wheatgrass, and heart-podded hoary cress seeds when compared with distilled water. Winter wheat and heart-podded hoary cress were more tolerant to the extract than the other species. Root length of all tested species was reduced by the extract when compared with distilled water [47].

RAUNKIAER [78] LIFE FORM:

[Hemicryptophyte](#)

[Geophyte](#)

REGENERATION PROCESSES:

Hoary cress reproduces both sexually (by seed) and asexually (by extensive, persistent roots and rhizomes). Local spread is primarily asexual [28,60,66].

**Breeding system:** According to Mulligan and Findlay [66], all 3 species of hoary cress are self-incompatible and are outcrossed by insects. This may be why silicles of lens-podded and globe-podded hoary cress are often seedless [66]. Both lens-podded hoary cress and heart-podded hoary cress have a tendency for partial sterility, although there is considerable intercolony variation [34,84]. Scurfield [84] suggests heart-podded hoary cress is "capable of automatic self-pollination."

### Seed production:

Reproduction by seed is less important than vegetative reproduction in local spread of hoary cress [20,54,84,85]. The little information that is available regarding the number of seeds produced by individual plants suggests that large numbers of hoary cress seeds may be produced under good conditions [60,66]. Seed production may vary with individual species, site characteristics, and weather conditions.

Several studies have compared regeneration traits among the 3 hoary cress species. In Alberta, lens-podded and heart-podded hoary cress produced as many as 850 mature fruits per flowering stem. Nearly all the fruits on heart-podded hoary cress contained 2 seeds. Lens-podded hoary cress fruits had 2 to 4 seeds, 2 or 3 being the most common. The authors stated that globe-podded hoary cress produced far fewer seeds than the other 2 species, although no numbers were given [21]. In Saskatchewan, percentage of flowering shoots of lens-podded and globe-podded hoary cress was highest under irrigation and in years with above-average precipitation. Globe-podded hoary cress grown in field plots produced an average of 300 fruits per plant, ranging from 30 to 560 per plant [86].

According to a review by Mulligan and Findlay [66], a single heart-podded hoary cress plant may produce 1,200-4,800 seeds, at 1.8 g/1,000 seeds. In samples from North Dakota heart-podded hoary cress produced 2,300 viable seeds per stem plus many infertile seeds, at 2.15 g/1,000 seeds, and globe-podded hoary cress produced 20 seeds per stem at 1.0 g/1,000 seeds [92]. Near Keating, Oregon, McInnis and others [60] measured nearly 17,000 viable heart-podded hoary cress seeds/ft<sup>2</sup>, produced in a single year.

### Seed dispersal:

Once mature, hoary cress seeds are released singly through ruptures in silicle walls, as individual silicles, or as silicle clusters that break away from the parent plant [60].

Seeds can be distributed to new sites in many ways including [20,21,35,60,80,81,84]:

- by sowing contaminated crop seed
- in surface runoff, irrigation, and running water
- by wind, especially along highways
- in seedheads attached to vehicles and equipment
- in plant material cut for hay or livestock bedding
- by road building and maintenance activities
- in topsoil, gravel, and other quarried materials, and
- in soil during the transport of root crops along roads and railways.

Hoary cress seeds are about the same size as alfalfa and clover (*Trifolium* spp.) seeds and are often carried as an impurity in commercial seeds. Many hoary cress infestations were started by sowing alfalfa or clover seed contaminated with hoary cress seed, or by using hay contaminated with mature hoary cress plants [21,35]. In the Pacific Northwest, hoary cress ripens before the 1st cutting of alfalfa hay [70].

Little is known about the role of animals in distributing hoary cress seed, although seed could be distributed by birds, small mammals, ungulates, and other grazing animals in the following ways [75]:

- in small mammal caches
- in plant material used for nests and burrows
- in soil trapped in ungulate hooves, and
- in ingested seeds which pass through the digestive tract.

According to Chipping and Bossard [20], heart-podded hoary cress seed survives in uncomposted cattle dung. Lowry [57] found germination of heart-podded hoary cress seeds may be diminished by ruminant digestion, but

remains high enough for managers to be concerned with spread of viable seeds in manure. Seed mortality can be increased by increasing fiber in the ruminant diet to slow passage rates. Alternatively, animals can be dry-lotted after grazing in contaminated areas to help restrict spread of heart-podded hoary cress [57].

### Seed banking:

Several reviews suggest that buried hoary cress seeds remain viable in the soil for about 3 to 4 years [20,21,54,88].

Brown and Porter [15] found that hoary cress seed viability declined rapidly in 3 years. Deeply buried seeds showed greater viability than shallow seed:

	% viability at time of collection	% viability after 1 year		% viability after 3 years	
		4-6"	16-18"	4-6"	16-18"
lens-podded hoary cress	98	86	78	18	52
heart-podded hoary cress	54	37	52	0	0
globe-podded hoary cress	15	15	13	2.5	9

According to Bruns and Rasmussen [16], germination rate varied from 66% to 72.5% in lens-podded hoary cress seeds tested at intervals during 22 months of dry storage. After 5 years of dry storage, germination rate was 17% [17].

Water-dispersed hoary cress seed may rapidly lose viability. Total germination of lens-podded hoary cress seeds stored in running water dropped from 72.5% to 11.8% after only 1 month of storage in running water and was less than 2% after 6 months of water storage [16]. In another experiment, only 9% of lens-podded hoary cress seeds remained viable after 2 months in running water, and after 19 months all lens-podded hoary cress seeds had disintegrated [17].

### Germination:

Laboratory studies on seed viability in the 3 hoary cress species suggest relatively high germination rates of mature, fresh lens-podded hoary cress (66-98%) seeds, moderate rates for heart-podded hoary cress (54%), and low rates for globe-podded hoary cress (15%) [15,17,84]. Germination rates decline over time when seed is buried [15] or held in dry storage [16] or running water [16,17]. Germination of hoary cress under field conditions is affected by temperature, available moisture, and depth of burial [15,48].

Germination of heart-podded hoary cress can take place at temperatures between 33 °F (0.5 °C) and 104 °F (40 °C), but optimum temperature is between 68 and 86 °F (20-30 °C). Concentrations of oxygen below 10% and above 56% are unfavorable to germination [15].

Heart-podded hoary cress germination is limited by dry conditions [48]. Laboratory trials in environmental chambers suggest heart-podded hoary cress seeds require approximately 4 days of "near-optimum" moisture and temperature conditions to germinate, showing lower germination rates and poor root development when available moisture is below field capacity (-0.03 MPa) [48,60]. Kiemnec and Larson [48] report heart-podded hoary cress germination rates of 82%, 55%, 11%, and 0% at osmotic potentials of 0, -0.5, -1.0, and -1.5 MPa, respectively. In big sagebrush ecosystems in northeastern Oregon, seed reproduction of heart-podded hoary cress occurred 2 out of 8 years and was associated with warm, moist weather in May. Heart-podded hoary cress germination in buried seed packets was restricted to the time period between 1 February and 15 March, and was affected by topographic position and burial depth. Germination of heart-podded hoary cress seeds was favored on toe slopes with minimal soil coverage where soil moisture remained near field capacity in the spring. Germination rate was low on ridgetops and north slopes, and lowest on south slopes. Germination at the other topographic positions improved with some seed burial [54].

Germination and root growth of heart-podded hoary cress was not diminished in saline conditions in a laboratory experiment. Salinity increases up to an electrical conductivity of 12 dS/m had no effect on either germination or root growth [48].

### Seedling establishment/growth:

Established hoary cress populations spread primarily by vegetative means [20,54]. Growth and spread of hoary cress plants depends on site conditions such as soil disturbance, vegetation, and moisture availability.

According to a review by McInnis and others [60], heart-podded hoary cress seedlings have a better chance of establishing on disturbed sites such as ditch banks, roadsides, haystack yards, and pocket gopher mounds than on sites fully occupied by vegetation. On semiarid Wyoming big sagebrush/bluebunch wheatgrass rangeland in northeastern Oregon, heart-podded hoary cress seedling emergence occurred on tilled plots and on disturbed soils adjacent to American badger holes and pocket gopher mounds [54,64]. Seedling emergence was greater on sites dominated by annual grasses than sites dominated by shrubs. None of the heart-podded hoary cress seedlings that emerged during the study period survived beyond May. This was likely due to a lack of available soil moisture [54].

Studies in Saskatchewan indicate that perimeter extension or recession of lens-podded and globe-podded hoary cress stands frequently coincides with the presence or absence of competing species. Globe-podded hoary cress spread most frequently in denuded areas or where western wheatgrass was the major competitor. Extensions of globe-podded hoary cress were less frequent, and some recession occurred, in competition with smooth brome (*Bromus inermis*) and Russian knapweed. Recessions of globe-podded hoary cress also occurred where rose (*Rosa* spp.) or western snowberry (*Symphoricarpos occidentalis*) were prevalent. Under dry conditions shrubs were the most effective competitors with both lens-podded and globe-podded hoary cress [86].

Vegetative spread of hoary cress is dependent on available moisture. During a period of above-average precipitation in Saskatchewan, globe-podded hoary cress plants increased in radius 2.5 feet (0.8 m) at 1 site (Glen Kerr) and 5.7 feet (1.7 m) at another (Leader). Lens-podded hoary cress was less vigorous, receding 1.8 feet (0.5 m) at Leader during the same period. During a period when rainfall was 15% below average, globe-podded hoary cress increased 1 foot (0.3 m) in radius at Glen Kerr. At Leader, both globe-podded hoary cress and lens-podded hoary cress receded during this period. Both species increased in an area that was irrigated twice annually [86].

### Asexual regeneration:

Vigorous vegetative reproduction is of prime importance in the survival and spread of hoary cress. Hoary cress is capable of vegetative reproduction by sprouting from adventitious buds on vertical and lateral roots [54,66]; sprouting from root fragments [60,84]; and forming new shoots from adventitious buds following removal of top-growth and/or the root crown [84,90]. Heart-podded hoary cress shoots can be produced every year from adventitious buds on the creeping root system, but density of shoots varies by year [60].

Frazier [28] observed growth of a heart-podded hoary cress plant under controlled conditions without competition. Twenty-six weeks after the plant emerged as a seedling, the primary vertical root had penetrated 37 inches (97 cm) vertically and had given rise to 9 horizontal roots that were arranged radially around the primary vertical root. Horizontal roots had developed secondary vertical roots. There were 17 regions of shoot development on the 9 permanent horizontal roots. Shoot growth of these 17 regions came from 41 rhizomes, each of which arose from a root-borne stem bud. The plant spread radially over 6 feet (2 m) the 1st growing season and over 11 feet (3.4 m) by the end of the 2nd season [28]. Spreading of the permanent lateral roots in this manner leads to horizontal spreading of the plant [28,91].

Spread of heart-podded hoary cress occurs at a relatively slow rate in semiarid rangeland of northeastern Oregon. Results presented by Larson and others [54] suggest that rapid April growth of heart-podded hoary cress shoots from lateral roots leaves plants susceptible to frost or drought damage in May. In contrast, cool, dry weather in April followed by moist conditions in early May (with maximum temperatures near 64 °F (18 °C) and lows above 34 °F (1 °C)) were associated with 31% and 41% increases in shoot density. Factors such as irrigation,

disking established populations, foraging by pocket gophers, and other influences that increase soil moisture or fragmentation of existing root systems may increase hoary cress rate of spread [54].

### Hoary cress

root fragments may develop into new plants. Size and depth of burial affect viability of root fragments. Root fragments 0.5 inch long (1 cm) had 50% viability, while fragments 1 to 2 inches long (2.5-5 cm) had higher viability, more shoots per cutting, and shorter times to shoot emergence. Increasing the depth of planting from 1.5 to 3 inches (4-8 cm) decreased viability of cuttings, decreased slightly the number of shoots per fragment, and increased slightly the time taken for 50% emergence of shoots. In general, root fragments produced a shoot at one end and a root at the other. Cultivation and irrigation facilitate spread of hoary cress by spreading roots [84]. Pocket gophers and other small mammals may also spread hoary cress root fragments [60].

Parent roots of hoary cress are capable of budding and regrowth after winter freezing or cutting, unless severed 12 to 18 inches (30-46 cm) below the soil surface [84,90].

### SITE CHARACTERISTICS:

**General climate:** Hoary cress readily establishes and thrives in irrigated cropland in western North America. Globe-podded hoary cress and lens-podded hoary cress are especially suited to moist sites, and are not abundant in semiarid environments. In the Pacific Northwest heart-podded hoary cress has expanded its distribution from irrigated hayfields onto adjacent semiarid rangelands [64]. It is the most common species on North American rangelands [60]. According to a review by Chipping and Bossard [20], heart-podded hoary cress survives heavy frosts and snowfall in California.

Judging from its distribution in Europe, heart-podded hoary cress withstands prolonged cold [84]. At its northernmost limit in Finland, average July temperature is 59 to 63 °F (15-17 °C). The number of days with a temperature greater than 39 °F (4 °C) is 120 to 140. The number of days with coherent snow cover is about 160, and the average rainfall lies between 24 and 39 inches (600-1,000 mm) per year (Hulten 1950, as cited by [84]).

**Soil characteristics, soil moisture, precipitation:** Hoary cress occurs on a variety of soil types, but occurs most commonly on soils with neutral to alkaline pH. It is often found on saline soils where moisture is in at least moderate supply, and is especially abundant under irrigation [20,21,41,44,45,53,84,85,86,91].

According to a review by Chipping and Bossard [20], heart-podded hoary cress in California occurs in wet and dry grasslands, scrubs, and arid areas with alkali soils; lens-podded hoary cress is particularly common in the northern part of the state on red-brown soils and disturbed, generally saline soils and fields. In Alberta all 3 species may be abundant on alkaline soils, with globe-podded hoary cress appearing to prefer them. The fact that such soils stay wet late in the spring may favor hoary cress, especially under cultivation [21]. In eastern Oregon, heart-podded hoary cress is most abundant on "potentially arable" sites, although it also appears well-adapted to sites with relatively dry, shallow soil [64].

Heart-podded hoary cress occurs on soil textures varying from light, sandy, and friable to gravelly, stony, or clayey (clay fraction over 50%). It occurs on sites in Kansas and Australia where lime fragments occur in the lower soil profile ([84] and references therein).

Hoary cress populations tend to expand in wet years or on moist sites. According to Parsons [71], heart-podded hoary cress occurs in areas where annual rainfall exceeds 16 inches (400 mm). Infestations of lens-podded hoary cress and globe-podded hoary cress in Saskatchewan thrived and expanded when rainfall was 20% above average (12-13 inches (310-330 mm)), but decreased when rainfall was 15% below average. Prolonged dry conditions resulted in reduced vigor, decreased densities, inflorescence inhibition, suppressed growth, and recession of the infested area for both species. Globe-podded hoary cress was hardier than lens-podded hoary cress under drought conditions [85,86]. Under irrigation in Alberta, heart-podded hoary cress was the most vigorous and globe-podded hoary cress the least vigorous of the 3 species [87].

### Aspect, elevation, latitude/longitude:

Abroad, hoary cress is found up to 6,890 feet (2,100 m) in Switzerland and up to 5,250 feet (1,600 m) in southwestern Iran ([84] and references therein). Elevation ranges reported for hoary cress in North America are as follows:

Species	State	Elevation range	References
lens-podded hoary cress	CA	<4,900 ft (<1,500 m)	[41]
	UT	4,200-6,200 ft (1,280-1,890 m)	[103]
heart-podded hoary cress	CA	<4,900 feet (<1,500 m)	[41]
	CO	3,500-8,500 ft (1,070-2,590 m)	[40]
	NV	4,500-7,500 ft (1,400-2,300 m)	[45]
	NM	4,000-8,000 ft (1,200-2,400 m)	[58]
	UT	4,200-8,800 ft (1,280-2,680 m)	[103]
globe-podded hoary cress	CA	<6,600 ft (<2,000 m)	[41]
	CO	5,000-7,500 ft (1,500-2,300 m)	[40]
	NV	3,600-6,000 ft (1,100-1,800 m)	[45]
	UT	5,400-7,400 ft (1,650-2,260 m)	[103]

According to a review by Chipping and Bossard [20], heart-podded hoary cress is generally found below 4,000 feet (1,200 m), but it is also known from elevations of over 6,000 feet (1,800 m) in Montana and over 8,000 feet (2,400 m) in Utah.

Heart-podded hoary cress reaches its northernmost limit in Finland at approximately 65° N (Hulten 1950, as cited by [84]).

### Evidence of disturbance:

Throughout its North American distribution hoary cress is described as occurring in disturbed areas such as "waste ground," "waste places," roadsides, railways, ditch banks, along field margins, hedgerows, pastures, drained wetlands, heavily grazed areas, open and abandoned fields, and abandoned gardens [30,41,44,45,58,80,81,84]. It is most invasive in cultivated and sown arable and pasture land, especially under irrigation [44,45,58,80,81,84].

### SUCCESSIONAL STATUS:

Hoary cress' affinity for disturbed, open sites (e.g. [20,84]) implies that it is an early successional species. It is most often found in unshaded areas, but can withstand the moderate shade of hedgerows [84]. It is unclear how long hoary cress populations persist in an area. Population persistence is probably dependent on a combination of factors including associated vegetation, site conditions, climate, and land management practices.

### SEASONAL DEVELOPMENT:

Seasonal development of hoary cress varies somewhat among species and among geographic locations.

According to a review by Chipping and Bossard [20], heart-podded and lens-podded hoary cress seeds can germinate 35 to 42 days after they are released from the fruit. In California they generally germinate after the 1st rains, typically in autumn. Basal rosettes of heart-podded hoary cress are formed 3 to 4 weeks after germination, and plants overwinter as a rosette. Heart-podded hoary cress also germinates in autumn in Australia [71]. Plants may germinate in spring or early summer and overwinter as a rosette, flowering the following spring [20]. This is typically the case in the Pacific Northwest, where heart-podded hoary cress seeds mature in late July or early August but are not likely to germinate until the following February or April [60].

Heart-podded hoary cress root buds initiate new leaf growth in late March in northeastern Oregon [64]. Similarly,

hoary cress species begin growth from seed, root buds, or rhizomes in "early spring" in Alberta [21] and in early May in Saskatchewan. Emergence occurred at approximately the same time as emergence of other perennial weeds such as absinth wormwood (*Artemisia absinthium*) and yellow toadflax (*Linaria vulgaris*) in Saskatchewan, but was 13 days later than leafy spurge (*Euphorbia esula*) emergence [86].

Hoary cress seedlings usually do not flower their 1st year [20,71]. In Saskatchewan, globe-podded hoary cress grown from seed planted in October 1957 did not produce inflorescences until 1959 [86].

Several studies document phenological development of hoary cress in the West. In **California**, heart-podded hoary cress is the earliest of the 3 species to complete flowering and form seed. According to Chipping and Bossard [20] heart-podded hoary cress generally flowers from March to June, but can flower as early as December in mild coastal climates. Bellue [9] observed seasonal development of hoary cress in California as follows: Heart-podded hoary cress plants were in full bloom by late March, and silicles formed by mid-April. By the end of May, heart-podded hoary cress plants had few to no flowers remaining, and plants began lodging from the weight of maturing silicles. Lens-podded hoary cress came into blossom later than heart-podded hoary cress and remained in bloom for a considerably longer period. It was in full bloom with some silicles just beginning to form by mid-April, and still in profuse bloom in May. By the 1st of June many lens-podded hoary cress plants had mature silicles, while other plants were still in full flower. On July 18, silicles were fully matured and by the 1st of August had all dried. Globe-podded hoary cress began blooming about the same time as lens-podded hoary cress, but remained in bloom well into winter. In March, globe-podded hoary cress plants were in early bud stage and had attained full bloom by late April. At the end of May globe-podded hoary cress seed began to form while a large percentage of the stand was still in bud and early bloom stages. In early June some silicles were mature. By September, many plants were still in early bud and full bloom, and blooms were observed into December [9].

Globe-podded hoary cress blooms later than the other 2 species in **Nevada** [82].

In northeastern **Oregon**, Miller and others [64] studied the seasonal pattern of development of heart-podded hoary cress on big sagebrush semiarid rangeland. Reproductive stems began to develop by late April, became fully elongated by early May, and flowered by mid-May. Seeds were in milk to dough stage by early June. Phenology was similar between upland and stream terrace sites, with leaf development on the upland site more advanced than on the terrace site only during the early part of the growing season. Considerable phenological variability occurred within sites. When the majority of the stand was flowering, some plants were still in the rosette stage [64].

#### In **Alberta**,

hoary cress commonly blooms in May. Globe-podded hoary cress consistently flowers about 10 to 14 days later than either heart-podded or lens-podded hoary cress. The other 2 are in late flower and early pod stages during the last week in June, while globe-podded hoary cress is still in early bud to flowering stage under comparable conditions [21,91].

In **Saskatchewan**, on 18 May 1959, plants of globe-podded hoary cress were 2 to 5 inches (5.1-12.7 cm) tall and bore 5 to 7 leaves. On 3 June plants 5 to 7 inches (12.7-17.8 cm) tall had 12 leaves and were initiating buds. Some flowers were open on 7 July. By 14 July, flowers were replaced by silicles, with some almost fully developed. On 20 July, seeds were fully developed, but immature. Leaves were usually shed at seed maturity [86].

Other flowering dates of hoary cress are as follows:

Species	Flowering time	Location	Reference
lens-podded hoary cress	April-August	Great Plains	
	April-August	Great Plains	[33]

	April-June	Illinois	[65]
	March-August	New Mexico	[58]
	May-August	Nevada	[45]
	late May-July	Ottawa	[34]
globe-podded hoary cress	May-August	Great Plains	[33]
	May-July	Nevada	[45]
lens-podded, heart-podded, & globe-podded hoary cress	May-July	northeastern U.S.	[30]

According to Chipping and Bossard [20], large stands of heart-podded hoary cress that are close to the water table may flower year-round. Under stressful conditions flowers may develop on stems 4 to 6 inches (10-15 cm) high with just 1 branch. In well-watered conditions flowering may start when the plant is as small but continue until many flowering branches have developed and plant height approaches 20 inches (50 cm) ([20] and references therein).

Under experimental conditions, cotyledons of sown heart-podded hoary cress seeds appeared above ground 5 to 6 weeks after planting and expanded to maximum size (about 5 times the dimension of seed) in about 3 weeks. During this period the 1st leaves emerged and continued to enlarge for 5 or 6 weeks, forming a loose rosette. The radicle developed into a prominent taproot, from which lateral roots developed in 2 to 3 weeks. Lateral stem shoots appeared after about 13 to 14 weeks, often arising from the upper regions of the hypocotyl and from the cotyledonary axils of older plants. After this stage the plant began to assume more mature vegetative characteristics [90]. Simonds [90] provides a detailed description of development of heart-podded hoary cress.

A single heart-podded hoary cress plant growing under controlled conditions without competition developed several shoots, taproots to a depth of 10 inches (25 cm), and 5 or 6 horizontal roots with numerous vegetative buds in 25 days. During the 1st year of development, it spread over an area 12 feet (3.7 m) in diameter and produced 455 shoots. Subsequent radial increases ranged from 2 to 2.5 feet (0.6-0.8 m) annually (Kirk and others (1943) as cited by [66,86]).

Hoary cress roots have ample food reserves to overwinter and produce new shoots in spring [60,66]. According to Miller and others [64] the greatest allocation of carbon to heart-podded hoary cress roots occurs during the flowering stage in northeastern Oregon. A seasonal trend in carbohydrate accumulation in lens-podded hoary cress roots was observed under both cultivated and noncultivated conditions in Colorado [8]. According to Barr [8], maximum accumulation of carbohydrates occurred around 1 August, while the lowest carbohydrate content was found around 25 April, when sampling was started. Until about the middle of September, total sugar content was higher in roots more than 12 inches (30 cm) deep than in those in the top 12 inches (30 cm) of soil [8,66].

## FIRE ECOLOGY

**SPECIES:** *Cardaria* spp.

- [FIRE ECOLOGY OR ADAPTATIONS](#)
- [POSTFIRE REGENERATION STRATEGY](#)

**FIRE ECOLOGY OR ADAPTATIONS:**

### **Fire adaptations:**

Because of its extensive perennial root system with numerous underground buds and rhizomes, hoary cress is likely to survive even severe fire, depending on site conditions. Hoary cress may establish by seed after fire. In Australia, heart-podded hoary cress sometimes initially appears after a grass fire. According to Parsons [71], the

heat presumably breaks the dormancy of heart-podded hoary cress seeds lying in or on the soil. However, this remains untested. Tolerance of hoary cress seeds to heating is unknown. Hoary cress seeds may also be dispersed onto burned sites from off-site sources following fire. Research in this area is needed.

### Fire regimes:

Hoary cress occurs primarily on agricultural land in western North America, where historic fire regimes have been dramatically altered. Historic fire regimes in sagebrush ecosystems in the Pacific Northwest, where heart-podded hoary cress may be invasive, had fire return intervals of 10 to 70 years [72,83,100,108]. Fire size, frequency, and seasonality in these ecosystems have been altered in recent decades, primarily by invasion of [cheatgrass](#) (*Bromus tectorum*). Hoary cress did not occur in these communities at the time in which historic fire regimes were functioning. It is unclear how historic fire regimes might affect hoary cress populations. It is also unclear how the presence of hoary cress might affect these fire regimes. Research in this area is needed.

The following table provides fire return intervals for plant communities and ecosystems where hoary cress may occur. If you are interested in the fire regime of a plant community that is not listed here, please consult the complete [FEIS fire regime table](#).

Community or Ecosystem	Dominant Species	Fire Return Interval Range (years)
bluestem prairie	<i>Andropogon gerardii</i> var. <i>gerardii</i> - <i>Schizachyrium scoparium</i>	< 10 [50,72]
sagebrush steppe	<i>Artemisia tridentata</i> / <i>Pseudoroegneria spicata</i>	20-70 [72]
basin big sagebrush	<i>A. tridentata</i> var. <i>tridentata</i>	12-43 [83]
Wyoming big sagebrush	<i>A. tridentata</i> var. <i>wyomingensis</i>	10-70 (40**) [100,108]
plains grasslands	<i>Bouteloua</i> spp.	< 35 [72,107]
cheatgrass	<i>Bromus tectorum</i>	< 10 [74,104]
California steppe	<i>Festuca-Danthonia</i> spp.	< 35 [72,94]
juniper-oak savanna	<i>Juniperus ashei</i> - <i>Quercus virginiana</i>	< 35 [72]
wheatgrass plains grasslands	<i>Pascopyrum smithii</i>	< 5-47+ [72,77,107]
pinyon-juniper	<i>Pinus-Juniperus</i> spp.	< 35 [72]
interior ponderosa pine*	<i>P. ponderosa</i> var. <i>scopulorum</i>	2-30 [3,7,55]
eastern cottonwood	<i>Populus deltoides</i>	< 35 to 200 [72]
quaking aspen (west of the Great Plains)	<i>P. tremuloides</i>	7-120 [3,36,63]
mountain grasslands	<i>Pseudoroegneria spicata</i>	3-40 (10**) [2,3]
Rocky Mountain Douglas-fir*	<i>Pseudotsuga menziesii</i> var. <i>glauca</i>	25-100 [3,4,5]
California oakwoods	<i>Quercus</i> spp.	< 35 [3]
oak-hickory	<i>Quercus-Carya</i> spp.	< 35 [102]
oak-juniper woodland (Southwest)	<i>Quercus-Juniperus</i> spp.	< 35 to < 200 [72]
white oak-black oak-northern red oak	<i>Q. alba</i> - <i>Q. velutina</i> - <i>Q. rubra</i>	< 35 [102]
blue oak-foothills pine	<i>Q. douglasii</i> - <i>P. sabiniana</i>	<35
Oregon white oak	<i>Q. garryana</i>	< 35 [3]
California black oak	<i>Q. kelloggii</i>	5-30 [72]

oak savanna	<i>Q. macrocarpa/Andropogon gerardii-Schizachyrium scoparium</i>	2-14 [72,102]
elm-ash-cottonwood	<i>Ulmus-Fraxinus-Populus</i> spp.	< 35 to 200 [25,102]

\*fire return interval varies widely; trends in variation are noted in the species summary

\*\*mean

#### POSTFIRE REGENERATION STRATEGY [93]:

Rhizomatous herb, rhizome in soil

Caudex/herbaceous root crown, growing points in soil

Geophyte, growing points deep in soil

Ground residual colonizer (on-site, initial community)

Secondary colonizer (on-site or off-site seed sources)

## FIRE EFFECTS

**SPECIES:** *Cardaria* spp.

- [IMMEDIATE FIRE EFFECT ON PLANT](#)
- [DISCUSSION AND QUALIFICATION OF FIRE EFFECT](#)
- [PLANT RESPONSE TO FIRE](#)
- [DISCUSSION AND QUALIFICATION OF PLANT RESPONSE](#)
- [FIRE MANAGEMENT CONSIDERATIONS](#)

#### IMMEDIATE FIRE EFFECT ON PLANT:

Fire may kill aboveground portions of hoary cress plants [82], but is unlikely to damage all perennating tissues, which can occur throughout the upper 24 inches (60 cm) of the soil profile. Rhizomes have been observed as deep as 4 feet (120 cm) below ground [64], and roots extend to even greater depths (see [General Botanical Characteristics](#)). Passage of a flame quickly over the tops of hoary cress plants, such that the foliage is heated enough to cause it to wilt within a few minutes, may cause some deterioration of the root for several inches below the crown. However, plants are still able to sprout from root buds following this treatment [82].

In Australia, heart-podded hoary cress seedlings sometimes initially appear after a grass fire. According to Parsons [71], the heat breaks the dormancy of heart-podded hoary cress seeds lying in or on the soil. However, this remains untested, and tolerance of hoary cress seeds to heating is unknown.

#### DISCUSSION AND QUALIFICATION OF FIRE EFFECT:

No additional information is available on this topic.

#### PLANT RESPONSE TO FIRE:

Information regarding hoary cress response to fire is not available in the literature. Asher and others [6] make a reference to postfire spread of hoary cress, stating, "recent examples of severe postfire weed spread and impacts include...hoary cress near Worland, Wyoming", but no additional information is given.

Hoary cress is likely to sprout following removal of top-growth by fire. This is the case with mowed hoary cress plants, which sprout even after repeated cutting [9,21,60,84]. Corns and Frankton [21] cite evidence that the roots of hoary cress may successfully resist complete inhibition (method not given) of top-growth for an entire season without noticeable loss in vigor.

More research is needed in this area.

#### DISCUSSION AND QUALIFICATION OF PLANT RESPONSE:

No additional information is available on this topic.

#### FIRE MANAGEMENT CONSIDERATIONS:

##### **Postfire colonization potential:**

It has been suggested that hoary cress may initially appear following fire [71], although no specific cases are documented. Information regarding hoary cress seed longevity, heat tolerance, location of populations in the proximity of the burn area, fire suppression activities, and potential for seed dispersal into the burned area is needed to predict postfire colonization potential [12].

**Fire as a control agent:** Rosenfels and Headley [82] report that hoary cress was successfully controlled in many areas by searing plants with a hand-held burner. They say that in several cases, searing caused a deterioration of the root several inches below the crown. In field trials using a commercial, coil-type burner at intervals of 2, 3, 4, and 8 weeks, hoary cress plants were eradicated in about 2.5 seasons at every interval except 8 weeks. It appeared that plants seared every 8 weeks or more would live indefinitely. They conclude that under the conditions of these tests, searing can be regarded as an acceptable substitute for hoeing, but not as a method giving quick results [82].

Land managers should always be cautious when using fire to control invasives because it may promote the establishment of other fire-tolerant invasive species [12].

**Preventing postfire establishment and spread:** The USDA Forest Service's "Guide to Noxious Weed Prevention Practices" [97] provides several fire management considerations for weed prevention in general that apply to hoary cress.

When planning a prescribed burn, preinventory the project area to evaluate cover and phenology of any hoary cress or other invasive plants present on or adjacent to the site, and avoid ignition and burning in areas at high risk for hoary cress establishment or spread due to fire effects. Avoid creating soil conditions that promote weed germination and establishment. Areas of soil disturbance (e.g. those brought about by fire suppression activities) are especially susceptible to invasive plant establishment. Weed status and risks must be discussed in burn rehabilitation plans. Also, wildfire managers might consider including weed prevention education and providing weed identification aids during fire training; avoiding known weed infestations when locating fire lines; monitoring camps, staging areas, helibases, etc., to be sure they are kept weed free; taking care that equipment is weed free; incorporating weed prevention into fire rehabilitation plans; and acquiring restoration funding. Additional guidelines and specific recommendations and requirements are available [32,97].

Preventing invasive plants from establishing in weed-free burned areas is the most effective and least costly management method. This can be accomplished through early detection and eradication, careful monitoring, and by limiting invasive plant seed dispersal into burned areas by [6,32,97]:

- re-establishing vegetation on bare ground as soon as possible
- using only certified weed-free seed mixes when revegetation is necessary
- cleaning equipment and vehicles prior to entering burned areas
- regulating or preventing human and livestock entry into burned areas until desirable site vegetation has recovered sufficiently to resist invasion by undesirable vegetation
- detecting weeds early and eradicating before vegetative spread and/or seed dispersal
- eradicating small patches and containing or controlling large infestations within or adjacent to the burned area

In general, early detection is critical for preventing establishment of large populations of invasive plants.

Monitoring in spring, summer, and fall is imperative. Eradicate established hoary cress plants and small patches adjacent to burned areas to prevent or limit seed dispersal into the site [[6,32,97](#)].

The need for revegetation after fire can be assessed on the basis of the degree of desirable vegetation displaced by invasive plants prior to burning, and on postfire survival of desirable vegetation. Revegetation necessity can also be related to invasive plant survival as viable seeds, root crowns, or rhizomes capable of reproduction. In general, postfire revegetation should be considered when desirable vegetation cover is less than about 30% [[32](#)].

Goodwin and others [[31,32](#)] provide guidelines for determining burn severity, revegetation necessity, and establishing and managing competitive plants. The following paragraphs provide some general guidelines for invasive species management after fire. See [Integrated Noxious Weed Management after Wildfires](#) for a more detailed source of this information. More research is needed specific to fire tolerance and response of hoary cress in specific sites and ecosystems in which it occurs.

When prefire cover of hoary cress is absent to low, and prefire cover of desirable vegetation is high, revegetation is probably not necessary after low- and medium-severity burns. After a high-severity burn on a site in this condition, revegetation may be necessary (depending on postfire survival of desirable species), and intensive monitoring for invasive plant establishment is necessary to detect and eradicate newly established invasives before they spread [[32](#)].

When prefire cover of hoary cress is moderate (20-79%) to high (80-100%), revegetation may be necessary after fire of any severity if cover of desired vegetation is less than about 30%. Intensive weed management is also recommended, especially after fires of moderate to high severity [[32](#)].

Fall dormant broadcast seeding into ash will cover and retain seeds. If there is insufficient ash, seedbed preparation may be necessary. A seed mix should contain quick-establishing grasses and forbs (exclude forbs if broadleaf herbicides are anticipated) that can effectively occupy available niches. Managers can enhance the success of revegetation (natural or artificial) by excluding livestock until vegetation is well established (at least 2 growing seasons) [[32](#)].

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## MANAGEMENT CONSIDERATIONS

**SPECIES:** *Cardaria* spp.

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- [IMPORTANCE TO LIVESTOCK AND WILDLIFE](#)
- [OTHER USES](#)
- [IMPACTS AND CONTROL](#)

### IMPORTANCE TO LIVESTOCK AND WILDLIFE:

There is little information available regarding the use of hoary cress by livestock. According to reviews and agricultural extension literature, livestock seldom eat hoary cress. Domestic sheep, goats, and cattle may eat it, especially during early growth stages of the plant [[20,70,84](#)]. Cattle may also eat large quantities of seedheads in late summer, when more palatable forage is no longer available [[60,61](#)]. Viable seeds may be passed in the feces of livestock [[20,57](#)] (see [Seed dispersal](#)).

No information is available regarding the use of hoary cress by wildlife.

### Palatability/nutritional value:

Both palatability and nutritional value of hoary cress decrease as plants mature. During its early growth stages, nutritional levels of hoary cress are adequate to meet the requirements of most livestock. As plants mature, the foliage becomes coarse and bitter, and nutritive value decreases [[20,61](#)].

McInnis and others [61] conducted chemical analysis of heart-podded hoary cress from 8 sites in Baker County, Oregon, during each of 5 growth stages: rosette, bolting, early bloom, full bloom, and hard seed. Collections of whole plants from rosette to hard seed, respectively, indicated the following trends: crude protein (29 to 8%), organic matter digestibility (77 to 49%), and digestible energy (2.9 to 1.8 Mcal/kg). Levels of 11 micro- and macro- elements were typical of other rangeland plants [61].

Heart-podded hoary cress and other wild members of the mustard family were tested for their nutritional composition, and it was concluded that they could be used for human dietary purposes due to the amount and diversity of nutrients that they contain. Nutrient composition of fresh heart-podded hoary cress leaves was [38,39]:

moisture*	protein*	carbohydrates*	fiber*	lipids*	ashes*	vitamin C**	carotenoids**	energy (kJ)
85.58	3.43	3.60	2.97	0.31	3.14	134	4.5	126

\*g/100 g fresh biomass

\*\*mg/100 g fresh biomass

Mineral elements in fresh heart-podded hoary cress leaves in mg/100 g of fresh biomass [39]:

Na	K	Ca	Mg	P	Fe	Cu	Zn	Mn
55	721	200	121	118	3.2	0.13	0.91	0.99

It is often suggested that hoary cress is at least mildly toxic to livestock [20,70,85]. Hoary cress contains glucosinolates, which are sulfur-containing compounds that can form toxic compounds in the digestive tracts of animals. Sulfur content in fresh heart-podded hoary cress leaves varied from 0.7% to 2.7% in 1 study. The reported maximum tolerable level for most grazing animals is 0.4% ([61], and references cited therein). Therefore, while hoary cress has some forage value, McInnis and others [61] suggest managers use caution when allowing animals to graze hoary cress-infested rangelands.

Analysis of components in heart-podded hoary cress that could be toxic to humans suggests that consumption of tender, young heart-podded hoary cress leaves by humans is probably not risky. Antinutrient composition of fresh heart-podded hoary cress leaves was [38,39]:

oxalic acid (mg/100 g fresh biomass)	nitrate (mg/100 g fresh biomass)	erucic acid (%)
trace	346 ± 60	1.23

**Cover value:** No information is available on this topic.

#### OTHER USES:

Flowers of hoary cress are frequently visited by insects and provide nectar for honeybees. Seeds of heart-podded hoary cress may be utilized as a substitute for pepper [66].

#### IMPACTS AND CONTROL:

##### **Impacts:** *Cardaria*

species occur as crop weeds throughout the Middle East, Europe, Australia, and New Zealand. Heart-podded hoary cress has been considered England's most serious weed pest since 1949, and the most serious weed pest for the Wimmera region of Australia ([20] and references therein). Heart-podded hoary cress is the least invasive of the 3 hoary cresses in Canada, and is probably the most invasive of the hoary cresses in the U.S. [66].

Lens-podded hoary cress is more widespread and troublesome than either of the other 2 species in California [9].

Globe-podded hoary cress is generally not as aggressive as lens-podded hoary cress [66].

Hoary cress' reputation for forming dense monocultures and competing aggressively for soil moisture under some conditions on rangeland and pastures has led some authors to conclude that hoary cress, in turn, excludes most or all other herbaceous vegetation. Thus hoary cress is reputed to reduce crop yields, displace native plants, and reduce biodiversity, wildlife habitat, and forage production, causing "a serious threat to the cattle industry." There is insufficient information available to determine the conditions under which these monocultures might occur in wildlands, but there is abundant evidence that they occur in croplands, "waste lands," roadsides, and lands that are otherwise heavily impacted ([\[20,60,88\]](#), and references therein).

Preserve managers of The Nature Conservancy consider hoary cress a "moderate to serious" threat to native plant species in riparian and wetland settings, and a "minor" threat in native grasslands. Hoary cress is most likely to infest disturbed sites such as those caused by grazing, irrigation, drainage, and cultivation [\[80,81\]](#).

Results presented by McInnis and others [\[47,60\]](#) demonstrate the presence of phytotoxic compounds in heart-podded hoary cress root extracts. According to the authors, glucosinolates in the plant may inhibit germination and initial seedling growth of other plants. Hoary cress is considered by many to be at least mildly toxic to livestock [\[20,61,70,85\]](#). When eaten by cattle it is said to taint dairy products [\[71,84\]](#).

### **Control:**

Effective management of hoary cress requires an integrated approach that includes 1) containment of known infestations; 2) prevention to assure new sites are not invaded; and 3) control to reduce or eliminate known infestations [\[60\]](#).

Containment of existing infestations of hoary cress on agricultural lands can help prevent spread to wildlands, and can be achieved by reducing movement of seeds onto new sites and by treating the boundaries of infestations to prevent spread of lateral roots. Because initial establishment of hoary cress is frequently by seed, proactive management to reduce seed dispersal is one of the most effective and least expensive measures to reduce establishment of new populations [\[60,88\]](#).

A single treatment to remove aboveground portions of hoary cress plants is insufficient to control hoary cress. Hoary cress roots have remained alive for a year even when aboveground growth has been controlled [\[91\]](#). Eradicating hoary cress infestations requires a persistent, long-term, integrated approach, and may not be justifiable unless hoary cress plants are also eradicated from adjoining ditch banks, fencerows, roads, trails, and other disturbed areas. Small infestations of hoary cress may be eradicated from these areas by several methods (e.g. repeated hoeing, burning, hand-pulling, herbicide application) [\[82\]](#).

Studies by McInnis and others [\[60\]](#) in Oregon suggest 8 steps for land managers and others who frequent wildlands and rangelands to control heart-podded hoary cress: 1) learn to identify hoary cress and look for it whenever you are in the field; 2) take measures to prevent dispersing seeds to noninfested areas; 3) treat infestations when they are small and easy to control; 4) apply control techniques known to be effective; 5) apply translocated herbicides to heart-podded hoary cress when it is flowering; 6) always read and follow herbicide labels; 7) monitor treated infestations and follow up with additional treatment if necessary; and 8) manage rangelands for an abundance of vigorous and diverse vegetation [\[60\]](#).

In all cases where invasive species are targeted for control, no matter what method is employed, the potential for other invasive species to fill the void left by their removal must be considered [\[12\]](#).

### **Prevention:**

The most cost-effective method for managing hoary cress is to prevent its establishment and spread. Seed and root dispersal can be limited by careful management in the following ways [\[60,84,86,88\]](#):

- Manage rangelands for plant communities in which all niches are occupied by vigorous plants. Grazing management plans consisting of moderate forage utilization and seasonal rotation of livestock can help desirable perennial plants maintain vigor and competitive ability and minimize hoary cress establishment and spread.

- Livestock should not graze weed-infested areas during flowering and seedset. When animals do graze infested areas during and after seed production, they should be transported to a holding area for 10 to 14 days, to allow time to digest and excrete seeds, before moving to uninfested areas.
- Driving vehicles and machinery through infested areas during the seeding period should be avoided. Undercarriages of vehicles and equipment should be checked for seedheads and cleaned when leaving infested areas.
- Remove hoary cress plants from along waterways to prevent movement of seeds and root fragments in running water. Screen irrigation water before applying it to fields.
- Circumvent hoary cress patches during cultivation and harvest to prevent spreading their roots and seeds throughout fields.
- Do not transport hay from fields infested with hoary cress to uninfested areas. Only certified weed-seed-free feed should be used in wildlands. Seeds in unprocessed hay consumed by livestock before entering National Forests may spread more exotic species than seed in feed pellets [19].
- Recreationists should be careful to brush and clean their equipment and animals and destroy seeds in a hot fire before leaving an area.
- Monitor for new or satellite infestations especially along roadways, railways, and waterways, and eradicate early. The eradication plan should include delimiting the infestation boundaries, applying control treatments, setting a control schedule, revegetating, planning follow-up monitoring, and estimating costs.

#### Integrated management:

No single treatment provides effective, long-term control of hoary cress. Managing hoary cress requires an integrated strategy. Integrated management includes early detection, assessment, and containment of infestations before they spread. Factors to be addressed before a management decision is made also include assessment of nontarget vegetation, soil types, climatic conditions and important water resources; and an evaluation of the benefits and limitations of control methods [68]. Hobbs and Humphries [42] advocate an integrated approach to the management of plant invasions that includes "a focus on the invaded system and its management, rather than on the invader" and "identification of the causal factors enhancing ecosystem invasibility" as an effective approach to controlling invasive species. This type of "ecological control" puts an emphasis on removing the ecological stressors that may be underlying the causes of invasion, rather than on direct control of invasive species [42].

Not many studies explore integrated management of hoary cress except in agricultural settings. Once hoary cress establishes, integrating various combinations of competitive plantings, crop rotations, careful grazing management, and herbicides (e.g. [82,91]) can reduce hoary cress to manageable levels. While these approaches may not be appropriate in wildland management, control of hoary cress in agricultural lands can help prevent its spread to wildlands.

A key component of any integrated weed management program is sustained effort, constant evaluation, and the adoption of improved strategies [88].

#### Physical/mechanical:

Various mechanical control methods have been employed to control hoary cress in agricultural settings. Hoary cress has a massive root system (76% of total plant biomass) that provides it with a large pool of stored carbohydrates for regrowth, and numerous belowground buds that can develop into new shoots [60]. Hoary cress roots have remained alive even when aboveground growth has been inhibited for 1 year [91]. Therefore, methods that remove only the aboveground portion of hoary cress have minimal impact unless repeated over several years in order to starve roots.

Several authors provide details on eradication or control of hoary cress by clean cultivation (e.g. [8,20,66,70,82,84,88,91]). Important considerations include timing initiation of and intervals between cultivations, number of cultivations, depth of tillage, considerations for avoiding spread of root fragments, proper implements to be used, soil moisture considerations, and planting of competitive crops. Authors suggest that 2 to 4 years of cultivation are required to control hoary cress.

Where physical conditions permit, hoeing at intervals of 3 to 4 weeks (depending on rate of regrowth) may be as effective as cultivation for eradication of hoary cress. Stands of globe-podded hoary cress were eradicated in 1.5 to 2 seasons by hoeing at intervals of 4 weeks. Soils must remain moist between hoeing so that plants can regrow and deplete their root reserves [82]. Similarly, Sheley and Stivers [88] suggest that digging can be a useful method for controlling hoary cress, especially small patches. Plants must be completely removed within 10 days after emergence throughout the growing season for 2 to 4 years [88].

Mowing alone will not provide effective long-term control of hoary cress [59,60]. Some authors suggest that hoary cress plants can survive repeated removal of top-growth for at least 1 season without noticeable loss in vigor [21,84,91]. Two consecutive years of mowing may have a more noticeable effect; however, hoary cress plants often preserve some of their vitality even after 3 years of mowing ([21] and references therein). Bellue [9] observed that lens-podded hoary cress and globe-podded hoary cress quickly recovered after mowing by producing new lateral growth and flowerheads. Recovery of heart-podded hoary cress was less vigorous [9]. Additionally, mowing may adversely affect desirable plant species. In Saskatchewan, densities of competing forbs remained relatively constant in unmowed plots, but ultimately decreased in mowed plots [86].

Other observations of mowed hoary cress stands suggest mowing reduces biomass and seed production in hoary cress and may result in stands with fewer shoots [59,86]. The date of mowing influences subsequent reproductive effort in heart-podded hoary cress. Plants mowed during flowering produced fewer viable seeds than plants mowed during bolting [59,60]. Phenology of subsequent regrowth of defoliated plants was more uniform at any given date than that of unclipped plants. The authors suggest that while defoliation alone is not expected to be an effective long-term control of heart-podded hoary cress, properly-timed grazing followed by herbicide application may increase mortality [59].

Heart-podded hoary cress survived mulching treatments with straw or tar paper [84].

#### Flooding:

For control of heart-podded hoary cress, flooding to a depth of 6 to 10 inches (15-25 cm) for about 3 months can produce 90% control of the plant. However, short-term submergence lasting a week has no effect on the plant ([20] and references therein).

Rosenfels and Headly [82] discuss flooding as means of eradicating hoary cress from fields where the soil is clayey enough to hold water without excessive seepage, and where there is no great loss of soil fertility following prolonged submersion. They did not conduct experiments, but discussed the method with farmers who had tried it in a region with fine-textured soils around Stillwater, Nevada. Applying water in May or June and maintaining a depth of several inches until early September met with success. Hoary cress plants must be completely submerged. Flooding has limited application, because many areas are not suited to its use [82].

Fire: See the [Fire Management Considerations](#) section of this summary.

#### Biological:

Biological control of invasive species has a long history, and there are many important considerations to be made before the implementation of a biological control program. The reader is referred to other sources (e.g. [79,106]) and the [Weed Control Methods Handbook](#) [96] for background information on biological control. Additionally, [Cornell University](#), [Texas A & M University](#), and [NAPIS](#) websites offer information on biological control.

As of this writing, no insects or fungi for use as biological control agents are available for use on hoary cress in

the U.S. Insects have not been developed as biological controls of hoary cress for 2 reasons. First, while hoary cress is listed among the noxious weeds of many states, it is of lower priority than other widely distributed and economically important weeds. Second, hoary cress is a member of the mustard family that contains numerous important agronomic plants such as canola, turnip, radish, and commercial mustards. Identifying insects that feed specifically on hoary cress and not on closely related mustards is difficult [11,60].

**Grazing:** Hoary cress has some forage value for grazing animals [61] and is sometimes grazed by cattle [20,61] and domestic sheep [20,61,69,88]. However, hoary cress may be at least mildly toxic to livestock ([61], and references therein). McInnis and others [61] suggest managers use caution when allowing animals to graze infested rangelands by providing supplemental iodine, utilizing mature and nonlactating animals, and reducing opportunities for animals to consume hoary cress [61]. Grazing animals can also serve as vectors for hoary cress seed and plant dispersal [20,57].

McInnis and others [59] demonstrated that defoliation of heart-podded hoary cress during its early growth stages could reduce its reproductive effort, and speculated that properly timed grazing combined with subsequent herbicide application could be a practical control measure.

A complete grazing management program has not been developed for hoary cress [88]. According to Olson [69], the dominance of rangeland ecosystems by nonnative, invasive plants such as yellow starthistle (*Centaurea solstitialis*), spotted knapweed, leafy spurge, and hoary cress may represent "steady states" [56], especially if these rangeland systems continue to be grazed only by cattle and horses, which tend to avoid these plants. A potential solution is to introduce or reintroduce small ruminants to these disturbed systems, restoring a balance by using grazers that prefer nonnative forbs [69].

#### Chemical:

Herbicides are effective in gaining initial control of new or severe infestations, but are rarely a complete or long-term solution to invasive species management [18]. Herbicides are more effective on large infestations when incorporated into long-term management plans that include replacement of weeds with desirable species, careful land use management, and prevention of new infestations. Control with herbicides is temporary, as it does not change conditions that allow infestations to occur (e.g. [109]). See the [Weed Control Methods Handbook](#) [96] for considerations on the use of herbicides in natural areas and detailed information on specific chemicals.

Most research on chemical control of hoary cress has focused on cropland - usually alfalfa, clover, or wheat fields. Experiments commonly include combinations of herbicides and other nonchemical methods [20]. Sodium chlorate and 2,4-D were the most commonly used herbicides for hoary cress in agricultural settings in the early 1900s (e.g. [21,82]).

Chemicals tested with limited success at controlling hoary cress include 2,4-D [20,24,49,88], metsulfuron [24,49,105], dicamba [20], chlorsulfuron [20,24,27,105], and glyphosate [20]. High application rates of imazethapyr in alfalfa-orchardgrass (*Dactylis glomerata*) pastures in western Montana provided greater than 90% control during the year of application. However, single applications provided no control the year following application, regardless of application rate. Yields of alfalfa and orchardgrass either decreased or were unaffected [95]. Chemicals that are ineffective at controlling hoary cress include picloram [88], bromoxynil, and fluroxypyr [24]. Managers are encouraged to refer to individual herbicide studies, as timing and rate of application, mixtures, and use of adjuvants are important considerations in chemical control and are beyond the scope of this review.

Heart-podded hoary cress is difficult to control chemically due to the short period of maximum carbon allocation to belowground tissue, the large proportion of belowground dormant buds, and the wide variation in phenology among plants at any give time. According to Miller and others [64], chemical control of heart-podded hoary cress is most effective during flowering, when herbicides are translocated with carbon into roots and rhizomes. Herbicides applied prior to flowering may not be as effective because the flow of carbon is mainly to aboveground tissues; therefore, herbicides applied prior to flowering may damage shoots but will not enter the

root system in high enough concentrations to kill the plant. Herbicides applied after flowering will not be effective because low soil moisture causes leaves to senesce, thus reducing photosynthesis and translocation within the plant. Effective chemical control is often variable because phenological stage of individual heart-podded hoary cress stems may not be uniform at any given calendar date, with some stems in the flowering stage while others are still in the rosette stage [64].

Because the effectiveness of chemical control for hoary cress is highly variable and unpredictable, chemical treatments must usually be repeated several times or combined with mechanical treatments to be successful [49,64,85,86,87,88,95]. Thus, chemical treatments are often prohibitively expensive on rangelands or natural areas [64].

**Cultural:** In agricultural settings, hoary cress can be controlled by tilling and planting competitive crops [82,85,86]. Alfalfa is an effective competitor where moisture is abundant, while perennial grasses and shrubs are more effective under dryland conditions and in years of lower than average precipitation [85,86].

The concentration of heart-podded hoary cress roots in the upper 20 cm of the soil profile is similar to the root distribution of many cool-season perennial grasses. The overlap in root distribution may increase the intensity of interspecific competition between heart-podded hoary cress and other herbaceous species [64].

Preliminary results presented by Mealor [62] suggest that native grasses growing among long-lived infestations of nonnative invasive species such as hoary cress and Russian knapweed may be better adapted to compete with invasive populations. More research is needed to understand the "implications of using exotic-selected native genotypes to restore native communities that are more resistant to invasion" [62].

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