Growth, Plant Water Relations and Carbon Allocation of Heart-Podded Hoary Cress (*Cardaria draba* (L.) Desv.)[1]

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SUMMARY: The noxious weed heart-podded hoary cress, also known as whitetop, has been expanding from cultivated fields to adjacent sagebrush steppe communities. Control measures are often not effective in prohibiting the expansion of this species. Plant water status, carbon allocation, and growth were measured on two sites to attain more information on the biology of heart-podded hoary cress. Leaves developed in the fall but did not survive winter. However, terminal buds just below the surface did survive winter, initiating new leaves in the spring. Below-ground biomass in the upper 24 inches was 3 times greater than above-ground biomass. Maximum translocation of carbon to below-ground tissue occurred during full flowering. Although production of heart-podded hoary cress was greater on the potential arable terrace site, this species also appeared to be adapted to the more arid, shallow soil, upland site.

Heart-podded hoary cress (*Cardaria draba* (L.) Desv.), also commonly know as whitetop, is a noxious, introduced weed. It is a deep rooted perennial, capable of reproducing by both seed and vegetative shoots originating from underground stems. Since its introduction from Europe in 1862, this species has invaded cropland and rangeland in British Columbia, Alberta, Saskatchewan, Washington, Oregon, Idaho, northern California, and Nevada. One of three species of hoary cress, heart-podded hoary cress is the most abundant species in Oregon and has the widest distribution in the United States. It grows in open areas and is adapted to alkali soils.

Heart-podded hoary cress can produce large numbers of viable seed and vegetative shoots, allowing it to rapidly invade cultivated and disturbed areas. It can gradually dominate stands of alfalfa and can have a major economic impact on agronomic crops. Movement of heart-podded hoary cress from cultivated fields to adjacent semi-arid upland big sagebrush (*Artemisia tridentata* Nutt.) communities is also common. Its recent movement into the big sagebrush ecosystem in the northwestern United States on a rather large scale is cause for concern. In eastern Oregon, heart-podded hoary cress occupies over 250,000 acres. It grows in big sagebrush communities in different seral stages and in communities seeded to crested wheatgrass (*Agropyron desertorum* Schult.). Shrubs are the most effective competitors with heart-podded hoary cress whereas grasses are less effective competitors.

Chemical and biological control of hoary cress species has been studied. Chemical treatments usually have to be repeated several times, or combined with farming practices for successful control. Thus, treatments are often prohibitively expensive on rangelands. The effectiveness of chemical control also has been highly variable and unpredictable. To date, biological control methods have not been effective.

Variability of effectiveness among control treatments indicates that more information on the basic biology of this species is needed. Thus, the goal of this study was to measure plant water relations, carbon allocation, and growth of heart-podded hoary cress. We also compared phenology and plant water relations of this species growing on an arable deep soil site with an adjacent big sagebrush upland site.

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MATERIALS AND METHODS

The study site is on the south slope of the Wallowa Mountains, approximately 3 miles north of Keating, Oregon, which is situated 15 miles northeast of Baker City in northeastern Oregon. Soils are of granitic origin. Climate throughout this area is maritime with cold wet winters and hot dry summers. The growing season typically begins in early March and ends about mid-June. The nearest weather station with a similar geographic position is 22 miles east in Richland, Oregon. Although weather varies across short distances in this area, precipitation throughout this region was below normal during the 1987-1988 crop year (Sept-June), and near normal during the 1988-1989 crop year. In Richland, Oregon, crop year precipitation for 1987-1988 and 1988-1989 was 46 percent and 82 percent of the mean, respectively. Temperatures in the region were 7 percent warmer during the 1988 than 1989 growing seasons.

Two sites were sampled consisting of an upland and an adjacent terrace site. The upland site was located approximately 30 feet above the terrace site, on a 15 percent west facing slope with a sandy loam soil averaging 20 inches in depth. The plant community was dominated by Wyoming big sagebrush (*Artemisia tridentata ssp. wyomingensis* Beetle) and crested wheatgrass. A few remnant plants of bluebunch wheatgrass (*Agropyron spicatum* Rybd.) and Thurber needlegrass (*Stipa thurberiana* Piper) were present. The level terrace contained soils deeper than 48 inches. The plant community was dominated by basin big sagebrush (*Artemisia tridentata ssp tridentata* Nutt.) and crested wheatgrass. A few giant wildrye (*Elymus cinereus* Scribn. and Merrill) plants were present in the understory. The experiment was repeated during the 1988 and 1989 growing seasons.

Soil water content was measured to bedrock on the upland site, and to 48 inches on the terrace site throughout both growing seasons. Plant measurements recorded were phenology, above-ground and below-ground biomass, plant water status, and carbohydrate allocation to above and below-ground plant parts.

RESULTS AND DISCUSSION

Although heart-podded hoary cress did not develop the density or biomass of shoots on the upland site compared with the terrace site, it appeared to be adapted to the Wyoming big sagebrush site. In both years, plant water status decreased earlier in the growing season on the upland site than the terrace site. Although plant water status was lower (more stressed) on the upland site during the later half of the growing season, phenology was similar between sites. In 1988, heart-podded hoary cress flowered in mid-May and developed seeds in early June, although soil water content was very limited on the upland site. The ability of plants to complete growth through seed development on the upland site may partially be attributed to greater growth activity early in the season than on the terrace site, based on leaf development and water use. The ability of heart-podded hoary cress to adjust to limited soil water conditions also allows this plant to complete growth and seed production.

Leaves began to grow during the fall on the terrace site. These leaves did not survive winter. However, the upturned buds on which these leaves were attached survived the winter directly beneath the soil surface producing leaves and above-ground shoots the following spring. Early development of leaves in the spring from rhizomes directly beneath the soil surface probably contributes to the competitiveness of heart-podded hoary cress.

Growth of heart-podded hoary cress on both sites was primarily from underground shoots. Although, heart-podded hoary cress can produce large amounts of viable seed, no seedlings were observed in the permanent plots. However, we did observe heart-podded hoary cress seedlings growing on disturbed soils adjacent to badger holes and gopher mounds on both sites in 1988 and 1989. A recent study indicated that heart-podded hoary cress seedling establishment was greatest in annual communities and on disturbed soil surfaces. Few if any seedlings established on undisturbed soils.

Approximately 76 percent of heart-podded hoary cress biomass was located below-ground (Table 1). Similar values have been reported for a number of rhizomatous forbs. The high degree of biomass allocation to roots and rhizomes provides heart-podded hoary cress a competitive root system, a large food storage capacity, and extensive below-ground buds, capable of developing above-ground shoots. Root biomass was concentrated in the upper 8 inches of the soil profile. Similarly, perennial grasses usually have the largest proportion of their root biomass in the upper 8 to 12 inches. This overlap in root distribution probably increases the intensity of interspecific competition between heart-podded hoary cress and other herbaceous species. Food storage (sugar) was greater in roots located in the 12 to 24 inch soil layer compared with roots in the upper 12 inch layer. Root distribution and sugar content may indicate a difference in root function. The upper roots may be primarily feeding roots, whereas roots at 12 to 24 inches may be for both feeding and food storage. Based on root distribution, heart-podded hoary cress probably has a greater capacity than perennial grasses, to extract soil water and nutrients at greater soil depths. Fall growth and plant water status indicated that roots were able to effectively acquire deep soil moisture. In another study the roots of globe-podded hoary cress (*Cardaria pubescens* [Mey.] Jarm.) were traced to the water table, 21 feet below the surface. On the upland site, rooting depth was restricted by shallow soils (20 inches), precluding acquisition of deep soil moisture.

Carbon uptake, assimilation, and translocation to roots and rhizomes occurs in less than 24 hours. In both years the greatest degree of carbon uptake and retention of newly assimilated carbon in aboveground plant tissue occurred during the rosette stage. The rapid uptake of carbon during the rosette stage may result from: 1) favorable microclimate during that labeling period, and/or 2) high carbon demand during this rapid growth phase. The comparatively low enrichment during the seed stage probably is a result of reduced physiological activity as plants approach dormancy, and soil content becomes depleted. Plant water status and water uptake were relatively low during seed set in mid-June.

Respiration can account for a large fraction of carbon translocated to roots. However, in the present study there was relatively little decline in newly assimilated carbohydrates in the roots and rhizomes after the peak at 24-h. The greatest decline of newly assimilated carbon occurred during the rosette stage when root and rhizome growth was probably at its peak, and growth respiration rates may also have been relatively high. In the present study, the patterns of carbon allocation clearly depended on phenological stage.

The greatest absolute enrichment of newly assimilated carbon in the roots and rhizomes, and the greatest proportional flow of carbon to roots and rhizomes occurred during the flower stage. Enrichment of carbon in the roots and rhizomes is considerably less at both the previous and subsequent stages of phenology. Prior to flowering, carbon demand by above-ground organs may be greater due to rapid shoot elongation and leaf development. During flowering, leaves and shoots are fully developed, possibly decreasing the demand for carbon in aboveground parts. Following flowering, leaves begin to senesce and soil water content becomes limited, reducing carbon assimilation. The period of maximum carbon allocation to below-ground structures was not associated with maximum plant growth. Not surprisingly, past work has shown that chemical control of heart-podded hoary cress was most successful during the flower stage. The narrow window of maximum carbon allocation to roots and rhizomes, and variation of phenology within a given area may account for the difficulty associated with chemical control of this species.

MANAGEMENT IMPLICATIONS

Heart-podded hoary cress is an effective colonizer, invading open, disturbed ground by seed, and then colonizing adjacent undisturbed sites by vegetative reproduction. When unimpeded by competition, this species has the capacity to rapidly spread and occupy a site. This emphasizes the importance of reestablishing desirable plant species

	Aboveground	Belowground	Above: Belowground Biomass
Biomass (lbs/ac)	3,390	11,034	0.31
		Soil Depth (mm)	
	0-200	200-400	400-600
Root:Rhizome	1.41	0.33	0.40
% Biomass[1]			
Roots	0.73	0.16	0.11
Rhizomes	0.40	0.38	0.22

[1]Values are percentage of total root or rhizome biomass occurring at the various depths.

immediately following heart-podded hoary cress control. However, control of this species is difficult. Inconsistent chemical control can probably be attributed to variable phenology, short time period of maximum carbon flow to below-ground organs, and a large reserve of below-ground dormant buds. Application of foliar herbicides should be applied during maximum translocation of carbohydrates to belowground parts. The large proportion of biomass located below-ground, and deeply established rhizomes also makes this species both difficult and economically prohibitive to control with cultivation on rangelands. Past work indicated three consecutive years of cultivation were required to attain effective control of all three hoary cress species. Although heart-podded hoary cress is most abundant on potentially arable sites, this species appeared to be adapted to the drier shallow soil on the Wyoming big sagebrush site.