Ecology and Control of Perennial Pepperweed (*Lepidium latifolium* L.)

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Perennial pepperweed *(Lepidium latifolium* L.), native to southeastern Europe and western Asia, was accidentally introduced into North America early in the 19th century. Reportedly, it was first introduced in Yolo County, CA, as a contaminant of sugar beet seed imported from Europe. This creeping rooted perennial is currently found on both coasts of North America and in all western states except Arizona (Young et al. 1995). In California, perennial pepperweed infestations have been reported from all counties except Del Norte, Humboldt and Imperial.

Perennial pepperweed is adapted to sites that are at least seasonally moist in riparian and wetland areas. It is not adapted to upland soils with prolonged drought periods. We do not know what the ultimate range of this species will be. It is a ruderal species existing in extreme contrasting environments such as Donner Summit on Interstate 80 (2600 in elevation) and in the coastal salt marshes of the San Francisco Bay Area. This weed is particularly adapted, but not obligate, to salt affected soils.

Description

Perennial pepperweed is a member of the mustard family (Brassicaceae). Emerging seedlings have small (2 mm by 1.5 mm), bright green cotyledons typical of annual mustards. As such, they are extremely difficult to identify in ruderal communities. Seedlings are extremely rare in established stands. The plants form large spreading clones, with new stems arising from the creeping root system.

Plants annually die back to the soil surface in the Intermountain Area. We have not studied the phenology of perennial pepperweed infestations in cismontane and coastal California, so our comments on the growth of this weed apply to areas east of the Sierra Nevada.

Stems of perennial pepperweed are very woody at the base and persist for several years as dry material, forming nearly impenetrable thickets. Accumulations of old stems often completely obscure the initiation of foliar growth in the spring. Leaf emergence occurs in March, when rosettes of foliage spread on the soil surface. By late April, stem elongation begins. Stem growth is rapid, with canopies reaching 0.5 m by June 1 and 1.0 in by June 15 when flower stalk (panicles) appear. Under favorable growing conditions, canopies may reach 2.0 m or more.

Full flowering occurs from late June to early July with a dazzling display of individual small, cruciform white petaled flowers. They are packed in dense clusters on panicle branches.

The long petiolate, elliptical shaped leaves [2.5 by 8.0 cm, the 6-8 by 10 cm leaves described in the *Jepson Manual* (Hickman 1993) are large compared to Nevada material] become nonfunctional at the base of the stems as the stems elongate. By flowering time, the leaf canopy is composed of cauline leaves just below and on the branches of the inflorescence. The earlier developing bottom leaves have long petioles while the later developed upper leaves are nearly sessile.

Structurally, a stand consists of from 4 to 8 stems per 0.1 m^2 (roughly 1 sq. ft.), resulting in nearly complete foliar crown closure with only reduced light reaching the soil surface. Above ground green standing biomass of perennial pepperweed has been measured at 96,450 kg/ha while dry weight biomass has been measured at 21,307 kg/ha in Lassen County, California (unpublished research, D. Palmquist). These tall, dense stands, with the surface soil packed with creeping stems, become virtual mono-specific stands, free of other herbaceous plants.

Seed production is highly variable and has been measured to be as high as 1.6 X 10^{10} seeds/ha (unpublished research, D. Palmquist). In very dry years, flowering will be abundant, but seed production is limited. Seed set is low in years with prolonged spring and early summer precipitation, when infestations of the white leaf rust (Albugo) are rampant in perennial pepperweed stands. The seeds mature in August and September and are very

slow to dehisce from the single seeded fruits (silicles). Some seeds persist until the following spring. Germination is excellent from seeds collected in years of abundant seed production (Miller et al. 1986).

Nature of Competition

Several different approaches have been tried to test for allelopathic competition by perennial pepperweed and to identify the substances involved. Detailed analytical testing has failed to isolate or identify any such substances (unpublished research, R. Blank). Perennial pepperweed appears to successfully compete with other plant species for moisture, nutrients, and light.

Taxonomic Affiliations

Lepidium is well represented in western North America where the genus is represented by approximately 75 species. Many are annuals, but there are several perennial species. None of the native species have the aggressive, invasive behavior or form the dense, robust colonies associated with perennial pepperweed.

Farmers often refer to perennial pepperweed as tall whitetop. This is because of the similarity in colonizing ability and flower color with whitetop or hoary cress *(Cardaria draba* L.). Hoary cress is an invasive alien weed, widely distributed in hay fields and native meadows throughout the Intermountain Area. Hoary cress is much smaller in stature with gray, scruffy leaves compared to the robust, vivid green of perennial pepperweed.

Type Of Habitats Invaded

Perennial pepperweed has invaded riparian areas along the lower reaches of many river systems in the western United States. It is also found in coastal salt marshes in California. The riparian ecosystems where this weed has spread were often not in good ecological condition before the invasion. Often such areas consist of abusively grazed fields or abandoned crop land. In western Nevada, we have had difficulty finding high condition areas without perennial pepperweed to serve as experimental controls for determining the influence of invasion by this pest. The invaded riparian communities consist of cosmopolitan weeds and colonies of highly competitive alien perennial weeds such as quackgrass [*Elytrigia repens* (L.) Nevski].

On the lower reaches of the Susan River in California, and the Carson and Truckee Rivers in Nevada, perennial pepperweed has invaded soils that are highly influenced by soluble salts. In the Carson Desert of western Nevada, perennial pepperweed has become established on sites so affected by salts that there probably were no vascular plants previously growing on them. Perennial pepperweed is associated with wetlands, but has colonized areas that are, at least seasonally, very dry. In the case of salt affected soils, infested sites are seasonally extremely water deficient.

Once perennial pepperweed becomes established in riparian areas it follows irrigation canals and ditches to agricultural fields. In the Intermountain Area, it invades native hay meadows. Such meadows are the primary source of winter forage for the range livestock industry. The vegetation is a mixture of native sedges and rushes and a variety of introduced perennial grasses and various herbaceous broadleaf species. The irrigation system is primitive, wild flooding. During the late spring, these areas are often important nesting habitats for waterfowl and shore birds.

From sampling the nutrient content of hay produced on meadows infested with perennial pepperweed, we have determined that protein content and digestibility dramatically drops once the weed is established. Total forage production may actually increase.

Control of Perennial Pepperweed

Mechanical Control

In agricultural weed control, mechanical treatment is usually the first option for suppression of pests. The riparian-wetland areas where perennial pepperweed is becoming established are not suited by topography, rock

cover and/or woody vegetation for mechanical control. Most native hay meadows have never been plowed. The nature of perennial pepperweed's creeping root system negates most mechanical control measures. It is nearly impossible to cut the roots fine enough to prevent the sprouting of buds that form new plants (Wotring et al. 1995). Sprouts from root segments grow very rapidly, often resulting in flowering plants in the same year that the parent roots are cut in tillage operations. Mechanically cut roots are very resistant to drying. Roots exposed on the soil surface over winter will sprout the next spring. The crowns of established plants become enlarged and very woody.

Mowing

Some farmers believe repeated mowing can suppress perennial pepperweed. This form of control should not be dismissed without further trials, but mowing has to be very frequent with a very short stubble height for any chance of success in controlling this species. For most sites where it is established, such treatments are not practical. As we will expand upon later, mowing to remove the old accumulations of woody stems is a necessity before grazing or most herbicidal treatments can be applied.

Grazing

Once stem elongation begins, most herbivores will not consume the herbage of perennial pepperweed under any conditions. The only chance for herbivory is in the early spring when the leaves are just emerging. In order to obtain grazing utilization at this time, it is necessary to mechanically remove the previous years' accumulation of woody stems. In certain situations, such as extremely salt affected meadows, we have observed utilization of perennial pepperweed shoots by livestock.

There have been repeated, unverified reports that perennial pepperweed is poisonous to horses. The poisoning reportedly occurred with animals under confinement being fed hay contaminated with perennial pepperweed. Feeding trials are under way at the Poisonous Plant Laboratory, USDA, ARS, Logan, Utah, to determine if perennial pepperweed can be harmful to grazing animals.

Herbicidal Control

Applications of a wide variety of herbicides effectively kill the aerial portions of perennial pepperweed plants. Farmers have long used various formulations of 2,4-D [2,4-dichlorophenoxy acetic acid]. The biological effect of defoliation is lost by the next season with shoots arising from the root stocks. Essentially, the level of control the following spring from a previous herbicidal treatment has to be 100% or root sprouts will result in total aerial cover by the end of the growing season.

Farmers have traditionally applied 2,4-D at the prebloom growth stage. This happens to be at the time when elongating shoots appear above the previous year's accumulation of lodged and tangled stems. They are therefore available for the application of foliar active herbicides. We have established date of application trials with several herbicides, starting as early as April. Obviously, this requires removal of the old material so that rosettes can be exposed to the herbicides. From preliminary results, it appears that the pre-bloom applications are the most effective for control with the application of phenoxy herbicides. Partial control of the aerial portion of the plants occurs with applications at virtually any time during the growing season when there is soil moisture available for growth. This suggests the possibility of repeated treatments within and among years using the same or different herbicides. Such treatments would be aimed at reduction of the vegetative reproductive potential of the creeping roots.

The herbicide that has proven most effective for single application control of perennial pepperweed is chlorsulfuron {2- chloro-N-[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl] benzenesulfonamide}. This herbicide has both soil and foliar activity. The soil activity may be a problem in riparian areas where highly desirable perennial woody species may be harmed by root uptake of the herbicide.

All herbicide applications for perennial pepperweed control have to meet stringent requirements concerning pesticide use near open water. Wetlands and riparian areas are difficult environments in which to use herbicides.

Prolonged Suppression

The first and foremost basic principal of wildland weed control is never control a weed and leave the site open to re-invasion or invasion by another weed species. The controlled weed must be replaced with stable perennial vegetation capable of biologically suppressing the weed species. We have stressed that perennial pepperweed is an extremely competitive species that is capable of invading and replacing stands of quackgrass. Obviously, we are going to have to know the biology of perennial pepperweed in great detail in order to biologically suppress this pest.

Biological Control

Through 1990, no classical control program in the world using importation of a natural pest had been reported for weeds of the mustard family (C. Turner in Young et al. 1995). Safety considerations for host-specificity is one reason for the lack of development of biological control procedures for mustard weeds. There are too many valuable crop species in this family.

It has been determined that there are 11 perennial species of *Lepidium* native to the western United States (C. Turner). One of these species is presently listed as endangered, and 6 others are under review. This is bad news for potential biological control measures.

There may be potential for developing native pathogens for suppression of perennial pepperweed. White leaf rust - previously mentioned - may offer some possibilities.

Biological Impact of Perennial Pepperweed

Drastic actions are necessary to control perennial pepperweed and to sustain biological suppression. Before such actions are implemented, the impact of the biocontrol pest on specific environments must be accurately assessed. We must be certain that proposed cures for the invasive weed do not cause more injury to the environment than the pest itself.

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