Lepidium latifolium
This perennial invasive weed of European origin is an exploding problem in several U.S. Western states, e.g., Oregon, Nevada, California, Idaho, Utah, Wyoming, and Colorado. This plant, known in the U.S. as perennial pepperweed (PPW) or tall whitetop, is now the subject of intense interest by the public and by land management agencies in the affected areas. In response to this interest and to initiate some preliminary investigation into prospects for biological control, the European Biological Control Laboratory (EBCL) of the USDA's Agricultural Research Service developed a specific cooperative agreement with John Scott of CSIRO, totally funded by the Bureau of Land Management, U.S. Department of the Interior. The following are the objectives of this cooperative agreement:

- To search the literature, herbaria, and insect collections for information.
- To use—in collaboration with ARS and BLM—climate/soils/plant records to map promising sites for exploration.
- To conduct initial searches in France and Tunisia for candidate biological control agents; submit them for identification; and provide initial evaluation to plan for further research.

In the spring and early summer of 1999, ARS sponsored and CSIRO hosted William Volk, Soil Scientist, BLM-Montana, and Erin McConnell, Botanist, BLM-Oregon, as they joined the research team in France. Bill Volk worked on mapping likely sodic soils where PPW might be found, while John Scott developed climate maps for matching potential collection areas in Europe with sites in the U.S. where PPW is a problem. Erin McConnell examined European flora, U.S. flora, and the botanical literature to determine botanical relationships among Lepidium species in Europe and the U.S. Dr. Rachid Souissi, Research Associate-Entomologist, was hired by CSIRO as a short-term (9 month) appointment to find PPW within easy driving range of Montpellier and to make a preliminary analysis of potential candidate biocontrol agents (arthropods).

Plant distribution: John Scott reported that a search of the European Flora shows that PPW is distributed in two main clusters. One extends from the Iberian peninsula and proceeds north in Western Europe to about 60° N latitude. The second cluster extends from Crete northeastward through the Baltic area to the Caspian Sea (about 57° N lati-
tude). A large void occurs northeastward from the boot heel of Italy (40° N latitude, 8° E longitude) to the Ukraine (60° N latitude, 33° E longitude). This pattern suggests the existence of large genetic diversity. PPW was located at five sites along the Mediterranean coast (about 43 N latitude) in France from Cassis—east of Marseille—to Narbonne. In this area, the weed is in the early rosette stage in early January and is fruiting by mid-June.

**Natural enemies found on PPW in France:** Dr. Rachid Souissi found twenty four species of insects in 10 families and 4 orders on PPW. The greatest number of species was in Coleoptera (50%). Most of the species found were known polyphagous species. Two species of *Ceuthorynchus* deserve further testing for confirmation of identification and host specificity.

**Sodic soils:** Bill Volk reported on soils that should be associated with PPW in Europe and noted that soils in Central Spain (around Madrid or about 40° N latitude) should support PPW. This observation matches the plants’ distribution from the European Flora database. The climate around Madrid matches (about 70%) the climate of Central California (Sacramento). Thus, Central Spain should be the focus of future exploration.

**Determination of native plants related to PPW:** Erin McConnell reported on a literature search of cruciferous species native to the U.S. which are related to PPW. She emphasized those species which are threatened or endangered. This information is critical to future host-range testing. One species, *Lepidium barnebyanum*, is endangered (Utah) in the continental U.S. Another species, *L. papilliferum*, is threatened (Idaho), and 4 others are listed as sensitive in the continental U.S. More species of *Lepidium* are native (estimated 37) to North America than are native (estimated 11) to Eurasia. With respect to ploidy, *Lepidium latifolium* appears to be unique with 2n=24 chromosomes while all others tested to date have 16, 28, 32, or 48. Seven species of *Lepidium* other than PPW in the U.S. are reported to be of European origin and two of these are perennial (*L. heterophyllum* and *L. hirtum*). The status of these two species in the U.S. and Europe should be investigated for possible clues to the management of PPW in the U.S.

The following list of “research needs” was developed for *Lepidium latifolium*:

- Learn more about this species in North America.
- Survey for and identify insects and diseases associated with the weed in the U.S., e.g., Lars Baker can send representatives of the Wyoming Collection to EBCL
- Genetically characterize “biotypes” for targets in North America for comparison with collections of the plant in Eurasia.
- Develop a database on the ecology of *Lepidium latifolium* to assist in the basis of control via an integrated weed management system, e.g., determine seasonal changes in carbohydrate reserves in roots.

**Cardaria draba**

This exotic, noxious weed (hoary cress or heart-podded whitetop) is closely related to two other exotic weed species in the genus: *Cardaria chalapa* (lens-podded whitetop) and *Cardaria pubescens* (globe-podded whitetop). All three species belong to the Crucifereae and all are native to Eurasia. They are distinguished by the shape of their seed.

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1 Information on the biology, ecology, and control of this weed has been extracted from a chapter by Roger Sheley and Jack Stivers (pp. 401-407) *Biology and Management of Noxious Rangeland Weeds*, edited by Roger L. Sheley and Janet K. Petroff, Oregon State University Press, Corvallis, OR, 1999, 438 pp.
pods but are collectively referred to as “whitetop.” They all grow in open, unshaded areas under a variety of soil and range types. They are best adapted to moderately moist sites (30 to 40 cm rain annually) that are wet in late spring. Whitetop can invade open rangelands under such conditions. These weeds are sometimes a serious problem in irrigated crops such as alfalfa and sugar beets. Cardaria spp. contain glucosinolates which can be toxic to cattle. These weeds are herbaceous, long-lived rhizomatous perennials. Germinating from seed in autumn, they overwinter as rosettes and then initiate growth very early each spring. Seeds are spread by wind, water, machinery, and by contamination of hay and crop seed.

Control is very difficult as effective herbicides are limited and no herbicides are registered for control in alfalfa and sugar beets. Rotation is required into crops, e.g. cereal crops, where metsulfuron can be applied at 4.2 g a.i. / ha. Cardaria spp. cannot be controlled by picloram on rangelands although 2,4-D is somewhat effective. Preliminary evidence suggests that sheep will graze whitetop. No natural enemies are available for use as biological controls in the United States.

Cardaria seems to be a reasonable target for biological control because no native species exist in this genus. However, the genus is close to Lepidium which includes some species that are listed as threatened or endangered. Dr. Rouhollah Sobhian of the European Biological Control Laboratory, France, and Dr. Jeffrey Littlefield of Montana State University, Bozeman, Montana, have conducted initial studies in biological control of whitetop.

Dr. Sobhian’s report follows.

A root gall making weevil, Ceutorhynchus pleurostigma, has been reared from Cardaria draba in Greece and France. The taxonomists reported that the weevil is a pest on cabbage. However, for the following reasons I believe that this information, which was found in the old literature is not correct:

No galls could be found on cabbage plants grown in Montpellier in winter 1996-1997, while wild C. draba plants growing next to the cabbage plants were attacked by the weevil.

Rashid Souissi, a post Doc., made a survey on natural enemies of Lepidium latifolium. He reared out a similar weevil from the leaf petioles and the leaves of Lepidium without any gall formation on the plant. The weevil was identified by the taxonomists as C. pleurostigma. This seems to me and others as very unusual.

Therefore, three varieties of cabbage, C. draba and L. latifolium are being grown in the winter of 1999-2000 in a randomized complete block with 10 replicates of each plant species or variety. The study will show if the insect attacks cabbage or not. I am also planning to arrange for DNA analysis of the insects reared from Lepidium versus Cardaria.

A gall mite, Aceria draba (Acari : Eriophyidae), has a very wide range of distribution. It has been found in Iran, Turkey, Greece, and France (Sobhian) and in Poland. 2 This very promising agent has been under study by Jeff Littlefield at MSU, Bozeman, MT,

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2 This information is reported in the following: J.J. Lipa, et. al., Insects and Mites Associated with Cultivated and Weedy Cruciferous Plants (Cruciferae) in Poland and Central Europe. Polish Scientific Publishers, Warsaw, Poland, 1977, 354pp.
for several years. Dr. Littlefield reported that the mite reduces root biomass and prevents flowering. He is rearing the mite for on-going host specificity testing. He noted that the mite requires young leaf tissue to form galls. So far it looks host specific and seems to cause impressive damage to the weeds. In other words, it is quite promising. More material will be provided by EBCL to Dr. Littlefield so that he can complete the studies and apply for a release permit.

The following list of “research needs” was developed for Cardaria draba:
- Develop approved host test list to be used for weevil and mite.
- Expand EBCL program to include matching of climates/soils/genetics between the United States and Europe.
- Conduct North American surveys of insects/diseases associated with this species.
- Develop cooperation with CABI-Bioscience for survey in Northern Europe.

Isatis tinctoria

This plant, commonly known as Dyer’s Woad, is a native of southeastern Russia. It was introduced from Europe to the United States as a crop for producing dye during the Colonial Period. Although not troublesome east of the Missouri River, this species has become invasive in the alkaline soils of the arid intermountain West.  

Biology

Dyer’s Woad may be a winter annual, biennial, or short-lived perennial. The species thrives on dry, rocky sites because it produces a long taproot and a set of shallower lateral roots that can access deep soil and surface moisture. This weed is unusual in that it can invade well-vegetated undisturbed range sites. It is now reported as a weed in eight western states. The growth rate and seed production are phenomenal, e.g., one site in Montana increased from two acres to more than 100 acres in two years.

Individual plants have been observed to produce more than 10,000 seeds in one year. Seeds are dispersed by wind, water, animals, and man. Unlike other mustards, seeds of this species remain the fruit after dehiscence. The pericarp apparently imparts some dormancy factor to the seed; seeds removed from the fruits generally germinate.

Management

Grazing by sheep is not a viable alternative as they take dyer’s woad as a last resort. Hand pulling will work if managers can mobilize sufficient volunteer labor to do the job. Breaking or cutting off the tops only stimulates regrowth from the crown. Chemicals can be used where environmentally acceptable and economically viable. Metsulfuron plus 2,4-D is recommended for pastures and rangeland.

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Biological control

A rust pathogen, extant in the United States and tentatively identified as Puccinia thlaspeos, was discovered on dyer’s woad in 1978 in southern Idaho. The rust has spread on this weed species throughout Idaho and Utah. Although symptoms do not appear for three to nine months after infection, fruit and seed production are completely prevented on nearly all affected plants. Hand dissemination of spores to remote sites is being investigated.

If this rust is, in fact, Puccinia thlaspeos C. Schuls, it is an Eurasian rust fungus that develops on Arabis, Descurainia, Draba, Erysimum, Sisymbrium, Smelowskia, and Thlaspi, but this host range has not been confirmed for the United States isolate. Thus, additional biological agents, such as insects, could potentially be very useful.

The following information was extracted from a report and proposal by Enzo Colonnelli (Cooperating Scientist), Gaetano Campobasso (Research Entomologist), and Gianni Terragitti (Biological Technician) of the USDA-ARS European Biological Control Laboratory Substation in Rome Italy.

Dr. Colonnelli conducted a preliminary survey in Italy during 1998 for insects that are natural enemies of Isatis tinctoria.

Three weevils
Ceutorhynchus rusticus Gyllenhal, a root collar feeder
Ceutorhynchus peyerimhoffii Hustache, a flower feeder
Baris sp., a root feeder
A flea beetle— Coleoptera: chrysomelidae: Alticinae, a leaf feeder
A fly—Diptera: Agromyzidae, a leafminer

Support for the existence of good candidate biocontrol agents has been provided also by Gaetano Campobasso.

The Ceutorhynchus rusticus has been reared on dyer’s woad by Campobasso. This weevil has been reported as monophagous on Isatis tinctoria. Thus, this weevil appears to be a very promising candidate.

The weevil, Ceutorhynchus peyerimhoffii, seems to develop inside fruits on the seeds (Colonnelli, personal communication). It ranges from Western Europe to Kazakstan and Mongolia on Isatis spp.

Baris fallax H. Brisout is one species of the genus of Baris reported to occur exclusively on Isatis tinctoria in France; at least two other Baris spp. are known to feed on dyer’s woad.

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Thus, these researchers have already identified and conducted preliminary observations on several very promising candidate biocontrol agents against dyer’s woad.

Priority research objectives for the future

- Conduct preliminary host range tests on promising candidates from Italy and focus on cruciferous crops as test plants.

- Develop a host-test list to be approved by the TAG. The USDA-ARS, EBCL and their collaborator in Rome have already developed a tentative list.

- Genetically characterize dyer’s woad from the United States vs. European biotypes.

- Conduct climate/soil/vegetation matching for Europe vs. U.S. areas where dyer’s woad is invasive.

- Expand the search for candidate biocontrol agents as necessary.

Attendees (complete information listed in address list)

John L. (Lars) Baker  Darryl Jewett
Andre Gassmann  Anwar Rizvi
Harriet Hinz  Gaetano Campobasso
Erin McConnell  Jeff Littlefield
Bill Volk  David McLaren
Hank McNeel  Anthony Caesar
Rouhollah Sobhian  Mark Volkovitch
Alan Kirk  Barbra Mullin
Peter Rice  Dan Sharratt
Lincoln Smith  John Scott

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7 This information is reported in the following: A. Hoffman, Faune de France, 62, Coleopteres Curculionides (Troisieme partie). Lechevalier, Paris, 1958, pp. 1208-1839.
Wonderful meeting! Before, after and, of course, during. It’s really not the formal sessions, but the informal ones where bonds are formed and knowledge shared. Those that participated in the post-symposium tour also saw the real West (United States).