Cheatgrass in the Columbia Basin Shrub-Steppe

Laura Johnson
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The Columbia River Basin is located mostly in central Washington State. The environment in this area is described as a "shrub-steppe" because of its location in the rain shadow of the northern Cascades, and its domination by big sagebrush (*Artemisia tridentata*) and perennial grasses like blue-bunch wheatgrass (*Agropyron spicatum*). These grasses give the terrain a bumpy look, rather than the smooth appearance of, for example, a field of wheat. European influence began to have a major effect on the shrub-steppe only in the 1880's. This is when heavy cattle grazing was introduced, a force that had never been a factor in the area (O'Connor and Wieda 27).

Bromus tectorum (cheatgrass) is an annual, monocot "true grass" native to Europe, Asia and parts of northern Africa. It evolved with large herbivores, so it can survive repeated trampling and heavy grazing. This means it can be used for cattle fodder, although it loses most of nutritional value as it dries, which is early in the summer (Zouhar, Management Considerations). Cheatgrass is a highly invasive species, which has become established on every continent by both purposeful and accidental transplant. Once established cheatgrass is nearly impossible to eliminate and extremely difficult to contain. Cheatgrass is highly competitive for water and nutrients, and has a synergistic relationship with fire, where cheatgrass spread and fire frequency feed each other.

Over the past 500 years it has closely followed European immigration patterns. In the inter-mountain west, cheatgrass was most likely introduced through contaminated grain seed, discarded cattle bedding and livestock movement (Novak and Mack 115). Cheatgrass was first reported in the Pacific Northwest in 1889 in British Columbia, though by 1900 it was present at several, widely distributed sites in the intermountain west. To Novak and Mack (116) this suggests that cheatgrass was introduced almost simultaneously at several sites in the intermountain west. Cheatgrass now ranges over 100 million acres of rangeland and in the shrub-steppe of the Columbia Basin where it has successfully competed with the native perennial grasses (O'Connor and Wieda, 27).

Cheatgrass now dominates most of the shrub-steppe region, and some areas have been converted to a near monoculture of this invasive weed. Cheatgrass is an ecological problem for two major reasons. First, *Bromus tectorum* can decrease the species diversity of an invaded area, making it less hospitable to native wildlife. Second, cheatgrass has the potential to alter the disturbance cycle of an area by increasing the occurrence of wildfire; all while harnessing the destruction of the fire to invade and exploit the nutrients in newly freed areas. According to Paschke (2003, 4), removing cheatgrass from public lands, such as military installations, will reduce soil erosion, create more sustainable ecosystems, preserve forage for livestock, benefit native species and reduce the frequency of fire. Native grasses in the Columbia shrub-steppe are more nutritious for livestock, make more efficient use of sun and water, and produce less continuous fuel for fire (Pellant, 4 and 7).

Despite the problems that result from cheatgrass invasion, and the desirability of a diverse native plant community, it is extremely difficult to rehabilitate an area that is dominated by cheatgrass. These difficulties are due to the life history of cheatgrass, its self-sustaining relationship with fire, and its competitive advantage after fire.

Cheatgrass germinates primarily in autumn, while the perennial species on the shrub-steppe germinate in the spring. However, if fall conditions were unfavorable cheatgrass can germinate in the spring instead. Flexibility of germination ensures that at least one batch of cheatgrass will grow every year. Fall germination gives cheatgrass a major advantage over spring germinating perennials by having primary access to nutrients in the soil (Pellant, 3). Early germination also shifts *Bromus tectorum's* growth period such that it dies earlier in the year.

Cheatgrass is also a prolific seed producer, although production varies with plant population density and environmental conditions. In an individual plant, seed production can range from 25 to 5000 seeds, which fall close to the parent or are carried short distances by wind. Cheatgrass seeds can also stay dormant in soil for about three years, which gives it the potential to bank more seeds than there are plants in an area (Zuohar, Botanical and Ecological Characteristics). This is an advantage, because even if cheatgrass already dominates an area, after an ecological disturbance seed banks that have been waiting for an opportunity can germinate quickly to reclaim the area. Seed banking may also help cheatgrass continue to dominate a site, even in years when it could not produce seeds.

Wildfire on the shrub steppe destroys perennial plants until the next growing season and kills sagebrush (Melgoza, Nowak and Tausch, 8). This leaves a void in the ecosystem that needs to be filled, and in the past 100 years cheatgrass has aggressively filled that void. As no analogous plant exists in the shrub-steppe ecosystem, the invasion of cheatgrass has drastically changed the ecological community and disturbance regime to suit its needs.

Cheatgrass is well adapted to frequent wildfires; its seeds can survive and germinate after fire season, when nutrients released by the fire are most plentiful. In fact, cheatgrass' life cycle and structure tend to promote more frequent fire. In addition to drying early, it has a fine structure and grows in the space that naturally separates patches of native grasses and sagebrush. Cheatgrass also produces a lot of ground litter that acts as insulation for its seeds, and this ground litter can also act as horizontal fuel for fire (Evans & Young 1978, 185). When fire strikes a cheatgrass dominated area it will often spread to native plant communities as well, where it removes fire-intolerant plants, which do not naturally reestablish until after cheatgrass seeds have germinated in the fall.

Laylock (427) states that conversion of shrub-steppe plant communities to a cheatgrass monoculture can become a "self-enhancing stable-state domain" if the interval between fires is less than five years. This means that cheatgrass can effect changes to dominate indefinitely over large areas as well as invade adjacent areas. Cheatgrass competes successfully with native species for water and nutrients and can alter soil morphology. These, in conjunction with the fire cycle, make it very difficult to reintroduce native species.

Cheatgrass makes very efficient use of soil water. In their 1990 paper, Melgoza, Nowak and Tausch examined cheatgrass' success after fire in the context of water use. They wanted to know if the plant's growth and spread was due only to the exploitation of resources freed by the removal of fire intolerant plants, or if cheatgrass competed successfully with individual plants that survived the fire. On their site in Nevada, the researchers chose *Stipa comata* (needle-and-thread grass) and *Chrysothamnus viscidiflorus* (yellow rabbitbrush) to examine because they have a high rate of fire survival.

The researchers found that cheatgrass does compete with the surviving plants. In instances where cheatgrass was growing nearby, the soil water content around native plants was significantly lower than around native plants without competition from cheatgrass. Native plants growing near cheatgrass also had less above-ground biomass. Neither the fire nor cheatgrass competition affected the efficiency of water use in the surviving plants.

Climate or cheatgrass' growth response to the fire disturbance may have played a role in cheatgrass' competitive success at the Nevada test site. In 1977 Cline, Uresk and Rickard found that undisturbed communities of cheatgrass and bluebunch wheatgrass in south central Washington used similar amounts of soil water down to 0.5 meters. However, between the depths of 0.5 and 1.4 meters, bluebunch wheatgrass utilized 15 cm of soil water in the growing season, while cheatgrass in its own (nearby) community used only 8 cm of soil water. Thus, deep soil moisture favors the success of established perennials.

Yellow rabbitbrush is native to central Washington, and with an established root structure it would be expected to fare well in competition for water. One possible explanation is that there was not enough rainfall on the Nevada site to make deep soil roots an advantage. Melgoza (1990) noted that water is often a limiting growth factor in arid environments. Another possibility is that cheatgrass' root growth outcompeted the native plants for nutrients and water after the fire.

In 1991, Melgoza and Nowak found that cheatgrass occupies root space quickly after a fire, and that it inhibits the growth of native plant roots. This study took place on one of the same sites used in the 1990 study of soil water competition. The researchers found that total root length densities were statistically equal on native only and mixed cheatgrass/native sites. If native plant root growth were unimpeded the root length densities on the mixed site would be greater than on the native-only site.

Another reason for cheatgrass dominance after fire is its ability to exploit nutrients in the soil over the long term. Norton et al. (445) found greater microbial decomposition in the surface horizons of soil on cheatgrass-dominated sites, diminishing the quality of soil organic matter. Nutrients in a shrub-steppe normally cycle “tightly” throughout the year and over large amounts of space.

Cheatgrass infestation changes the timing, distribution and composition of organic matter and nutrients in the soil. Cheatgrass allocates more nutrients to producing above-ground biomass, which leads the soil under cheatgrass to have “shallow, rapidly cycling soil organic matter pools.” This depletion of the soil has an effect similar to annual crop cultivation. This change in soil morphology makes it difficult to reintroduce native perennial species, which need nutrients to cycle longer during the year.

A final reason cheatgrass performs so well after fire is its response to biologically available nitrogen. In 2003, Lowe, Lauenroth and Burke found that cheatgrass responds in linear increments to increases in soil nitrogen, while shortgrass steppe vegetation reaches an asymptote at higher levels (247). This explains in part why cheatgrass flourishes after fire; the first plants to invade the area are able to devote as much nitrogen as needed to above-ground biomass and copious seed production. This adds empirical support to Paschke, McLedon and Redente, who found that by reducing nitrogen availability over four years they were able to change an old field with depleted soil into a plant community where plants dry later in the season, a trait of native perennial plants (144). The researchers reduced nitrogen availability by adding sucrose to the soil. In another field, fertilizing with nitrogen increased the amount of annual grasses compared to perennial plants. Limitation of bio-available nitrogen in the natural environment could potentially be a mechanism to control cheatgrass growth and invasion.

Lowe, Lauenroth and Burke also found that cheatgrass responds more quickly to nutrient enrichment than native species (249). However, at very low levels of nitrogen availability neither cheatgrass nor the native perennial was affected by nutrient competition. Their experiments showed that cheatgrass grows more successfully when competing against North American perennial plants than it does against other *Bromus tectorum.* This was the opposite pattern from the native perennials, which grew better among themselves. Success was measured in biomass, height and nitrogen concentrations in plant tissue. These results show how cheatgrass can compete so fiercely with native perennial species while forming a stable community once it dominates the landscape.

Cheatgrass management has been a problem since early in the 20th century, but conquering the management difficulties has become more of a priority since with social movement toward conservation (Young and Clements, 3). There are a variety of techniques that have been used to try to prevent cheatgrass invasion or eliminate it on intermountain range sites. These include biological control through grazing, physical or mechanical removal, chemical management or cultural techniques to seed more desirable species into cheatgrass infested areas. Cheatgrass needs to be controlled on a site for at least two growing seasons for native species to become established. Because of the difficulty in doing this cheatgrass management techniques must be combined to some extent for plant community recovery to have any success. Physical, chemical and burning are recommended only for seedbed preparation before using cultural techniques (Zuohar, Management Considerations).

Cutting and pulling cheatgrass by hand is inefficient, while tilling or "disking" cheatgrass dominated areas can damage desirable species and destabilize the soil. There are no biological methods that selectively harm cheatgrass without hurting desirable species. Some research is being done into using certain fungi, mold, and bacteria for this purpose (Zuohar, Management Considerations). Grazing has been used historically as a biological control for cheatgrass, although it has to be very carefully managed. In late spring cattle may selectively avoid eating cheatgrass in favor of greener native species, and thinned stands of cheatgrass have been shown to produce more seeds to fill the area to capacity. If grazing has been improperly managed, post-fire seeding may fail and cheatgrass may return in even stronger numbers (Evans and Young, 1978, 185).

Chemical and cultural controls of cheatgrass have the potential to be the least harmful or risky cheatgrass control mechanisms. Herbicides can be selected for their biological inactivity or sensitivity to specific conditions (Young and Clements, 4). Seeding allows one to choose the most desirable native or most resilient analogue plants to secure establishment in the area.

One of the most widely cited systems for cheatgrass removal is the "Atrazine-Fallow" technique. In this system, a layer of the herbicide Atrazine is applied the in the fall after a wildfire or controlled burn in a cheatgrass dominated area. Atrazine is a cheap and common herbicide. It is very insoluble and stays close to the soil surface, near the cheatgrass seedbank, where it limits the seeds potential for germination and inhibits photosynthesis in grown plants. Atrazine controls weeds and acts as a "chemical fallow" to keep nutrients and moisture in the soil (Young and Clements, 5). Perennial wheatgrass seeded the year after a chemical fallow have high "seedling vigor" and high second year yields

(Evans and Young, 1977, 333). Evans and Young (1977) had the best second year stands of perennial grasses when they used the herbicide 2, 4-D to kill sagebrush, which may protect cheatgrass seeds from Atrazine sprayed from a plane or helicopter (334). Using 2, 4-D to improve native plant establishment in a sagebrush-steppe rather than rangeland is clearly counterproductive. While perennial grasses can begin to recover a site even where some cheatgrass remained, it is extremely important to protect the site from grazing for at least a year after seeds have germinated (Evans and Young, 1978, 188 and West and Hassan, 131).

Research is continuing on management and seedbed preparation techniques. According to Young and Clements, interest in the use of herbicides in conjunction with seeding has been growing in recent years (3). Hopefully, chemicals that are more selective and biologically inert will be found by research scientists working today. Better yet, if a cost effective strategy can be devised, nitrogen immobilization may be an excellent strategy to inhibit the spread of many types of fast growing exotic grasses in addition to cheatgrass. Paschke found that native grasses were able to withstand diminished nitrogen availability (145). Seeding with native species after fire and limiting nitrogen to control may allow us to limit the spread of cheatgrass through environmental manipulations rather than with man-made chemicals and disruptive machinery.

Future research in chemical cheatgrass control could examine the effect of sagebrush shading on survival of cheatgrass seeds during application of an Atrazine-fallow. A cost/benefit analysis of aerial spraying versus ground-rig application could help determine the best way to fully prepare a chemically fallowed site for seeding. Nitrogen limitation is currently done by adding sucrose to the soil. It is essential that cost effective techniques be found if this technique is to be utilized over large areas.

Bibliography:

Beyers, Jan L. *Postfire Seeding for Erosion Control: Effectiveness and Impacts on Native Plant Communities.* Conservation Biology 18 (2004): 947 – 956

Cline, J. F.; D. W. Uresk; and W. H. Rickard. *Comparison of Soil Water Used by a Sagebrush – Bunchgrass and a Cheatgrass Community.* Journal of Range Management 30 (1977): 199 – 201

Evans, Raymond A. & James A. Young. *Effectiveness of Rehabilitation Practices Following Wildfire in a Degraded Big Sagebrush – Downy Brome Community.* Journal of Range Management 31 (1978): 185 – 188

Evans, Raymond A. & James A. Young. *Weed Control – Revegetation Systems for Big Sagebrush – Downy Brome Rangelends.* Journal of Range Management 30 (1977): 331 - 336

Laycock, W. A. 1991. Stable states and thresholds of range condition on North American rangelands: a viewpoint. Journal of Range Management. 44: 427-433.

Lowe, Petra N.; William K Lauenroth; Ingrid C. Burke. *Effects of nitrogen availability on competition between* Bromus tectorum *and* Bouteloua gracilis. Plant Ecology. 167 (2003): 247 – 254

Melgoza, Graciela and Robert S. Nowack. *Competition between cheatgrass and two native species after fire: Implications from observations and measurements of root distribution.* Journal of Range Management 44 (1991): 27 – 33

Melgoza, Graciela; Robert S. Nowack; and Robin J. Tausch. *Soil water exploitation after fire: competition between* Bromus tectorum *(cheatgrass) and two native species.* Oceologia 83 (1990): 7 – 13

Norton, Jay B., et al. *Soil morphology and organic matter dynamics under cheatgrass and sagebrush-steppe plant communities*. Journal of Arid Environments 57 (2004): 445 – 466

Novak, Stephen J. and Richard N. Mack. *Tracing Plant Introduction and Spread: Genetic Evidence from* Bromus tectorum *(Cheatgrass).* BioScience. 51 (2001): 114 – 122.

O'Connor, Geoganne and Karen Wieda. Northwest Arid Lands: An Introduction to the Columbia Basin Shrub-Steppe. Columbus, OH: Battelle Press, 2001.

Paschke, Mark W. Integrated control and assessment of knapweed and cheatgrass on Department of Defense installations. 2003 annual report. SERDP CS1145. SERDP Support Office, HydroGeoLogic Inc., 1155 Herndon Parkway Suite 900, Herndon, VA 20170. 67p.

Paschke, Mark W.; Terry McLendon; and Edward F. Redente. *Nitrogen Availability and Old-Field Succession in a Shortgrass Steppe.* Ecosystems 3 (2000): 144 – 158

Pellant, Mike. Cheatgrass: The Invader that Won the West. Interior Columbia Basin Ecosystem Management Project. 1996. Available: http://www.icbemp.gov/science/pellant.pdf. [November 22 2005]

West, Neil E. and M.A. Hassan. *Recovery of Sagebrush – Grass Vegetation Following Wildfire.* Journal of Range Management 38 (1985): 131 – 134

Young, James A. & Charlie D. Clements. *Cheatgrass Control and Seeding.* Rangelands 22.4 (2000): 3 – 7

Zouhar, Kris. "Bromus tectorum." Fire Effects Information System. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory. 2003, January. Accessed, November 15, 2005 http://www.fs.fed.us/database/feis//plants/graminoid/brotec/index.html